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Creating an Online Scientific Art Exhibit Formatted for People with a Visual Impairment

Melanie Sorrell (J. Murrey Atkins Library, University of North Carolina at Charlotte, Charlotte, North Carolina, USA; melanie.sorrell@uncc.edu), Derek Norton (J. Murrey Atkins Library, University of North Carolina at Charlotte, Charlotte, North Carolina, USA; DerekNorton@uncc.edu), Jeff McAdams (J. Murrey Atkins Library, University of North Carolina at Charlotte, Charlotte, North Carolina, USA; jmcadam3@uncc.edu), Rachael Winterling (J. Murrey Atkins Library, University of North Carolina at Charlotte, Charlotte, North Carolina, USA; rwinterl@uncc.edu), and Kathleen Dipple (Department of Chemistry Nanoscale Science Ph.D. Program, University of North Carolina at Charlotte, Charlotte, North Carolina, USA; kdipple1@uncc.edu)

ABSTRACT

An online exhibit accessible by people with a visual impairment was created to accompany a university library's physical exhibit of microscopic images generated by researchers on campus as "scientific art." This online exhibit consisted of a Web page formatted for screen-reading software so that those individuals could hear descriptions of the images and envision the image patterns, shapes, textures, and perhaps colors while learning about the scientific research performed on campus. The library promoted this Web page through various outlets to a wide audience to benefit patrons on and off campus. The exhibit was successful, and lessons learned through this project can be applied by other libraries undertaking similar efforts, to navigate problems and improve efficiency in implementing online exhibits for people with a visual impairment.

Keywords: academic libraries, visual impairment, science education, accessibility, usability, online exhibit, assistive technologies, screen reader, alternative text

INTRODUCTION

In fall 2015, the J. Murrey Atkins Library at the University of North Carolina (UNC) at Charlotte presented an exhibit entitled *Visualizing Science: Microscopic Images from UNC Charlotte*. The exhibit celebrated scientific research conducted with various types of microscopes by faculty, students, and alumni, who presented their work as “scientific art,” with explanations of the goals of their research and statements about how the images were produced. While planning the event, the exhibit committee discussed how to make the exhibit accessible for people with a visual impairment (PVI) and those unable to attend the physical exhibit in person. The idea of an online exhibit was already familiar, as committee members had explored several nanoart competition Web sites during exhibit planning. The committee converted the original exhibit Web site to a single Web page, which served to announce the event and as a portal for uploading image submissions, to an online exhibit of the images (<https://library.uncc.edu/VisualizingScience>).

The committee deliberated how people with a visual impairment¹ might experience the exhibit’s educational content and consulted with the campus Office of Disability Services (ODS) about how best to reach PVI on campus. The ODS emphasized that the online exhibit should have precise descriptions of the images as alternative text, so that PVI could use speech-based screen readers to learn about the images. The ODS Assistive Technology Specialist advised on how to reformat and program the Web page to ensure that speech-based screen readers would easily translate the content.

This paper describes the committee’s efforts to create a Web page compliant with the requirements of screen readers. By chronicling this experience, we suggest methods that other libraries might use in similar projects to increase access for PVI to instructive exhibits.

BACKGROUND

Many libraries are working to improve their Web sites, which are necessary for public access to and equitable dissemination of information (Chen, Germain, and Yang 2009; Comeaux and Schmetzke 2013; Power and LeBeau 2009; Riley-Huff 2015; Southwell and Slater 2012).

Particular attention is paid to Web design that adheres to inclusive principles to improve the user experience, as presented by Yoon, Hulscher, and Dols (2016). Good design practices for screen reader accessibility also include appropriate use of keyboard commands in lieu of mouse functions (Andronico et al. 2006; Gooda Sahib, Tombros, and Stockman 2012; Southwell and Slater 2012; Yoon, Hulscher, and Dols 2016).

In the recent article “Supporting Web Accessibility with HTML5 and Accessible Rich Internet Applications: Insights for Libraries,” Riley-Huff (2015) outlines how library Web developers use Web standards, such as the World Wide Web Consortium (W3C) Web Content Accessibility Guidelines (WCAG) Working Group products and Web Accessibility Initiative-Accessible Rich Internet Applications to provide accessible Web content. Web sites may be tested with online validation tools and accessibility browser plugins or bookmarklets to find any components that might undermine assistive technologies (Billingham 2014; Comeaux and Schmetzke 2013; Conway et al. 2012; Lush 2015; Schmetzke and Comeaux 2009). The Web site Hypertext Markup Language (HTML) is often validated for conformance to W3C guidelines to ensure that

the code is correct, as outlined in the WCAG Overview (2012). Sites may also be checked for compliance with Section 508 of the Rehabilitation Act of 1973 (29 U.S.C. 794d) and implementation standards in 36 CFR §1194.22 (65 FR 80523, Dec 21, 2000), using criteria for accessible Web-based technology noted in Fulton (2011) and illustrated in Cunningham (2012). In addition to relying upon these utilities, Web developers perform or request usability testing by individuals with special needs, especially to evaluate search interface design features (Andronico et al. 2006; Conway et al. 2012; Chen, Germanin, and Yang 2009; Xie et al. 2014; Xie et al. 2015; Yoon, Hulscher, and Dols 2016).

Despite great strides made in disability awareness and accommodations by Web developers, Mesquita and Carneiro (2016) and Myers and Bastian (2010) point out that some students with visual impairments may still feel excluded in higher-education pursuits and social contexts, including art exhibits. Approaches for expanding participation through adapting artworks for PVI in museums worldwide include tactile adaptation of paintings (Krivec et al. 2014; Reichinger, Maierhofer, and Purgathofer 2011), tactile or touch tours and workshops (Hillis 2005; Hirose 2013), and audio guides (Hillis 2005). Ginley (2013) recently noted that information about the artwork in Braille is often placed next to a tactile painting, so that guests may explore the art and the information on the accompanying label. Special guided tours with group discussions are offered at some museums to augment social connections, expand understanding of the items' appearance and structure, and explore the history behind the artworks (Hillis 2005; O'Brien 2013).

Certain accommodations were already in place to make the *Visualizing Science* physical exhibit accessible for PVI, such as using dark black ink and a large font on printed identification labels. The committee considered embossed printing of each image and a Braille research statement as an identification label. However, without a guide, the most severely affected PVI would not know where to place their hands to touch those surfaces. When approached with the idea of creating tactile prints of the images and Braille content, the ODS office expressed a preference for an online display, because many UNC Charlotte students with visual impairments use the Internet and rely upon screen readers for their coursework.

Screen-reader software is a widely used Web-site assistive technology (Andronico et al. 2006; Gooda Sahib, Tombros, and Stockman 2012) that translates text into audible language (Harper and DeWaters 2008) or Braille (Gooda Sahib, Tombros, and Stockman 2015) and helps PVI to form a mental picture of what is being read. This community may choose from a variety of screen readers, including free, open-source, and commercial software, depending upon the browser and platform used.

The library offers screen-reading software on public computers, in addition to other accessibility services. The Atkins Library Accessibility Services page (<http://guides.library.uncc.edu/accessibility>) has information for patrons registered with the ODS, so that they may reserve study rooms equipped with magnifiers that provide text enlargement and enhancement, large-print keyboards, and personal computers with two screen-reader software packages installed, Windows-based Job Access With Speech, a.k.a., JAWS 17.0 (Freedom Scientific), and Read&Write Gold 11.0 (Texthelp, Ltd.). In addition, desktop personal

computers with the JAWS software are distributed throughout the building. The Voice Over 7.0 (Apple, Inc.) screen reader is built into the operating systems of the Macintosh desktop computers in the building, and Read&Write Gold 6.0 is also installed on some of the library's Macintosh computers (Fansler 2016)

The library's Software Developer had created the original exhibit Web site (see Figure 1), which informed potential exhibitors about the exhibit and served as a portal for uploading images. He later volunteered to convert the Web site to a one-page online exhibit (see Figure 2) accessible to PVI via a screen reader. The Science Librarian provided the content and worked closely with the Software Developer in formatting the Web page and establishing that it met Section 508 and W3C standards for accessibility and usability.

Figure 1: Original exhibit Web site header, for participants to upload images and research statements.

Figure 1 caption: The original Web site included several pages of information for potential exhibitors, to provide information on the image submission process and about the physical exhibit.

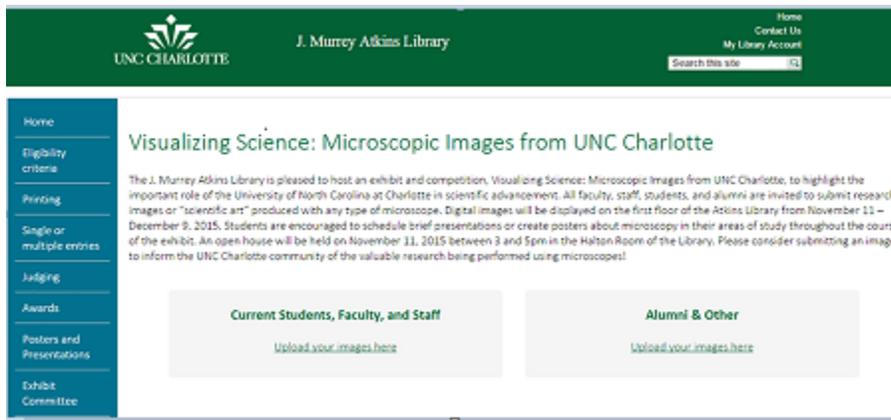
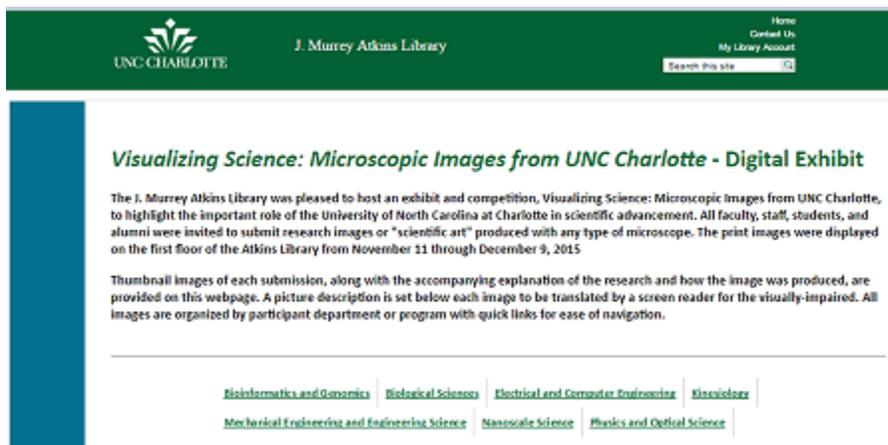


Figure 2: Current Web page header.

Figure 2 caption: The Web site was converted into a Web page with an explanation of the physical exhibit and statement that this digital exhibit is formatted for screen readers.



CONTENT PREPARATION FOR WEB PAGE DEVELOPMENT

The key to formatting the online exhibit so it could be read by speech output technology was to place a brief description or alternative text of each image in the element's "alt" attribute, to allow a screen reader to describe the image verbally to the reader. This alternative text is separate from the lengthy exhibitor statements of research goals and description of how microscopes produced the images, which were printed as identification labels for the physical exhibit. Instead, the brief alternative text descriptions focus on describing the size, shape, texture, and colors of the images, so that any reader with a visual impairment, regardless of the degree of impairment, can create a mental picture of each image.

Many Web sites use very basic alternative text that simply lists the items shown in a photograph or illustration, such as "this is a picture of a dog" or "three people, smiling, outdoors" (Guynn 2016). It is more difficult to create alternative text describing scientific subjects precisely and

accurately, especially in the case of microscopic objects measured in micrometers or nanometers. Also, some of the research materials used to create the images are unfamiliar to the lay public. The target audience for each brief description was a college freshman with a visual impairment and without a science background. Therefore, it was important to avoid advanced scientific terminology and to emphasize the size, shape, texture, pattern, and colors in the image.

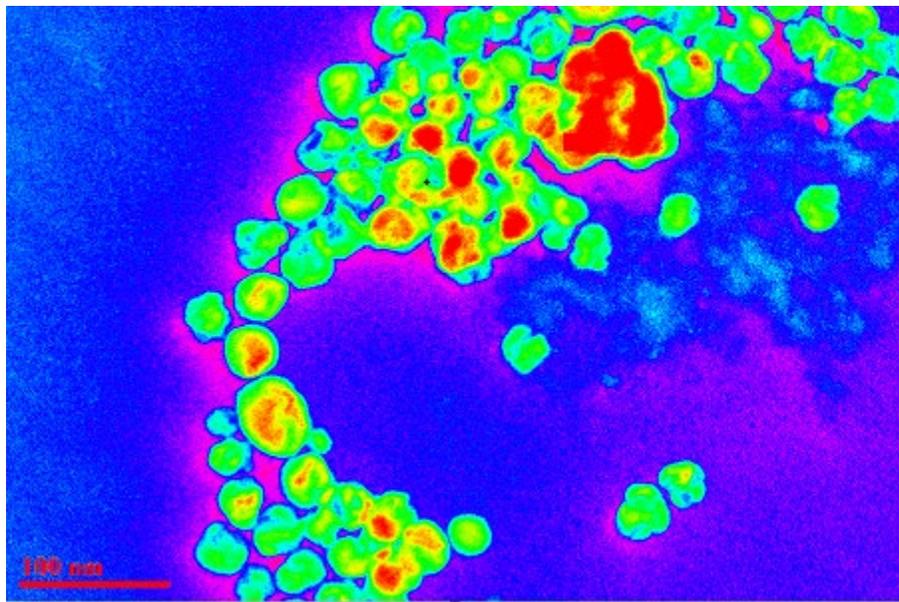
Creating the alternative text was not part of the original submission requirements for exhibitors, but the exhibitors supported the concept of an online exhibit and formatting it for PVI. The Science Librarian composed the text and worked closely with each of the exhibitors on this task, because the creators retained the copyrights on their original images and research statements. It took considerable time and effort for the Science Librarian to create descriptions of geometric shapes and directions in each of the 43 images, which had such diverse subjects as sand dollar larvae, vibrational patterns, hepatic sinusoids, and raster scan patterns. Each description had to be no more than three or four sentences and to be understandable by the lay person. Some of the content of the brief descriptions was the result of protracted, challenging negotiations between the Science Librarian and the exhibitor, sometimes reflecting compromises. Figure 3 is an example of one participant's image with its identification label and brief alternative text description.

Figure 3: “Absorb the Spectrum” image

Figure 3 caption:

The identification label for Kathleen Dipple's “Absorb the Spectrum” image read, “A transmission electron microscope (TEM) at a 50 K magnification was used to generate the image. The program, Image J was used to alter the colors of the image. The image is of

gold/silver sulfide nanoparticles, which can be used for improved photovoltaic devices. The scale bar is 100 nm.” The brief description on the Web page reads, “This image is set on a blue background with numerous, mostly circular particles with a green hue and pink backdrop. Some particles and clusters of particles are colored bright red and yellow. Particles range from 25 to 50 nanometers in diameter.”



TECHNICAL PRODUCTION

The Software Developer had created the original Web site with Debian Linux, Apache, MySQL, and PHP, which allowed the exhibitors to upload their images and research statements (identification labels). The home page of the original site included information on the exhibit, such as the date and time, submission criteria, student seminar and poster presentation opportunities, and a list of exhibit committee members. To submit images and research statements, exhibitors logged in with their campus usernames and passwords, which allowed the image submissions to be automatically associated with the correct users. Upon submission, the image title, username, research statement, and timestamp were saved to the submissions table in the database. Exhibitors uploaded images in TIFF and JPEG file formats with a maximum file

size of 15 MB. DOCX and DOC file formats were accepted for the research statements. Upon a successful upload, the image and document file were zipped together in a folder, along with a programmatically generated text document that contained the exhibitor's university profile data (e.g., username, class designation, department, academic major or discipline). This zipped folder was saved on the server with the exhibitor's university username as the folder name.

The committee wanted to keep the same Uniform Resource Locator (URL) for the accessible digital exhibit, so the Software Developer converted the original site into a clean, simple page design, to ensure easy reading. The images were then addressed. Since most major browsers do not natively support TIFF images, the first step was to convert all of the images to PNG, a Web-safe format. At this stage, the resolution of the images was reduced, to prevent the images from being copied and used inappropriately.

The code to decrease the image resolution is shown below:

```
$files =
glob('/exhibit_upload/exhibit_images/*.{jpg,tif,tiff,TIF,TIFF,JPG,JPEG}',
GLOB_BRACE);
    foreach($files as $file){
        $thumb = new Imagick($file);
        $thumb->setImageFormat('png');
        $thumb->setImageUnits(imagick::RESOLUTION_PIXELSPERINCH);
        $thumb->setImageResolution(52,52);
        $thumb->scaleImage(350, 350, true);

        $thumb-
>writeImage("/exhibit_upload/web_safe_images/" . basename(str_replace(array(".j
pg",".tif",".tiff",".TIF",".TIFF",".JPG",".JPEG"), "", $file)) . ".png");
        $thumb->destroy();
    }
```

In order to develop an accessible Web site, strict adherence to HTML5 standards is imperative, because most screen readers rely on this structure to be able to correctly parse the content and

organize the page elements into predefined categories. The following code shows the markup structure used to output the images displayed on the Web page:

```
<div class='exhibitSubmission'>
  <a class='backToTop' href='#top'>Back to top</a>
  <h2 class='exhibitSubmissionTitle' title="$title" >$title</h2>

  <p class='describe'>$descrFile</p>
  <div class='exhibitSubmissionDescription'>
    <p class='descriptionTxt'>$webSafeDescription</p>
  </div>
</div>
```

Most exhibitors typed their research statements in Microsoft Word, which led to many instances of “smart quotes” (true typographic quotation marks) and other “smart characters” (such as curved apostrophes and em-dashes) automatically inserted by Word. These characters are not recognized as Unicode Transformation Format – 8-bit (UTF-8) characters and do not display correctly on a Web page using UTF-8 encoding (the dominant encoding for the Web). The submitted research statements and accompanying file names were therefore run through a PHP function that matched and converted all non-UTF-8 characters to their corresponding UTF-8 characters.

For each exhibit image, the Web page includes the newly created low-resolution image and title, the research statement written by the exhibitor, and a brief description of the image included as the image’s alternative text. The screen reader, depending upon its settings, reads all text (headings, alternative text, and identification labels) aloud as it mechanically moves down the page from left to right and top to bottom. The screen reader uses certain keyboard shortcuts available to the user for smooth navigation through the page. PVI can browse the H2 level

heading image titles and skip down to an image of interest using the control, tab, and down keys. The user also can slow the screen reader and read each line separately by using the down key.

In the original version of the online exhibit, the brief alternative text description was hidden by default, through the use of cascading style sheets, and was displayed only when a sighted user moused over an image or PVI navigated to the image with the keyboard, and the screen reader automatically read the alternative text. Besides the alternative or “alt” attribute used here, another attribute, the "longdesc" attribute, provides a link to a document containing the longer text, is occasionally readable by third party software (WebAIM 2015), but is not currently supported by any major browser (W3schools 2017). In the committee’s experience, the alt attribute is widely accepted by popular browsers and screen readers; therefore, the alt attribute was incorporated for brief and longer alternative text.

An integrated approach was used to validate the Web page, detect violations of a defined coding standard, and evaluate accessibility through the use of several testing methods, including a software-based accessibility checker, HTML_CodeSniffer (Squiz Content Management Solutions). This is a free bookmarklet that allows the site to be scanned and produces a report based on the selected standards. The report includes errors, warnings, and notices and describes accessibility concerns and their locations on the page. The *Visualizing Science* Web page HTML was validated with the WCAG 2.0 AAA criteria and was found to be in compliance with Section 508 standards when run through the HTML_CodeSniffer.

Although accessibility checkers are helpful in checking the accessibility of a given page, the results still need to be reviewed manually. The developer must determine which errors affect the usability of the page and which do not, or cannot be addressed. For example, some of the errors may not affect the ability of the page to be read by a screen reader or may derive from elements that are unalterable, such as the institutional page header or included code libraries such as jQuery UI.

Care was taken to ensure that PVI could navigate through the library's Web site to the entry point of the *Visualizing Science* Web page. Although not on the library's home page (<https://library.uncc.edu/>), the link can be found by scrolling down to "Discover Unique Collections," clicking on that link (<https://library.uncc.edu/atkins/discoveruniquecollections>), and scrolling through the exhibit links to the *Visualizing Science* link. Though not prominent, it is a permanent link. The pages are preserved for future generations and for all to see through the university's Division of Academic Affairs after being captured by the Web archiving service, Archive-It! (Internet Archive).

USABILITY TESTING

Two usability testing sessions were performed to discern whether the online exhibit could be improved for screen readers. Tasks were designed to evaluate the efficiency, effectiveness, engagement, and error tolerance of patrons with visual impairments navigating the Web page, as well as how easily they could learn from the content. Testing was covered by a preexisting Institutional Review Board (IRB) protocol, #13-01-04, entitled "UNC Charlotte Atkins Library Usability Project," under which users from representative groups are observed to provide better

understanding of their interactions with Web interfaces and software and to demonstrate whether the library’s digital content is meeting those needs (Kim Wu 2013) .

The Usability Coordinator worked with the Science Librarian and Software Developer to develop pretest questions (Table 1) and task-based usability exercises (Table 2). Predefined tasks were navigating through the library’s Web site to find the *Visualizing Science: Microscopic Images from UNC Charlotte* Web page, finding information contained in the introduction at the top of the Web page, and answering specific questions about the displays of images, brief descriptions, and research statements. Post-test questions (Table 3) designed to provide constructive feedback, asked about Web page features that were either useful or proved to be a hindrance.

Table 1: Pretest Questions

Table 1 caption: Questions presented to identify participant background and technological competencies

Pretest Responses		
Question	Participant 1	Participant 2
What year are you in school?	Graduate Student	Graduate Student
What is your field of Study?	MA in Linguistics	PhD in Urban Education
How often do you use the library’s services (physical/digital)?	A few times a week	A few times a week
What do you use the current library for (physical/digital)?	<ul style="list-style-type: none"> • Website • Research (Articles) • Hang out between classes 	<ul style="list-style-type: none"> • Research (EBSCO)
Have you had any issues with library services? If so, what have they included?	<ul style="list-style-type: none"> • Assistive technology room (101C) is uncomfortable due to hot temperature 	<ul style="list-style-type: none"> • Research material formats are usually not readable instantly with

	<ul style="list-style-type: none"> Public Desktops automatically muted Finding specific databases 	assistive technology software
What assistive software do you use?	<ul style="list-style-type: none"> JAWS 	<ul style="list-style-type: none"> Text-to-Speech Dragon Natural Speaking
What browser do you utilize?	Internet Explorer	Internet Explorer

Table 2: Tasks

Table 2 caption: Tasks designed to evaluate Web page navigation

Tasks			
	Purpose	Outcome	
		<i>Participant 1</i>	<i>Participant 2</i>
Task 1	The task was designed to determine if participants could navigate to the digital exhibit.	The participant selected the link in the digital task list using JAWS to open the exhibit.	The participant used Dragon Naturally Speaking to increase the font size on the digital task list and right clicked the link to open the exhibit.
Task 2	The task was designed to determine if participants could locate specific dates of the physical exhibit.	<i>Participant 1</i> JAWS read the introduction paragraph to the participant. The participant sped up the audio of JAWS.	<i>Participant 2</i> The participant used text-to-speech to read the introduction and complete the task.
Task 3	The task was designed to determine if participants could locate a specific image when given the title, “Electron Paths.”	<i>Participant 1</i> The participant used a short cut to search for the heading, “Electron Paths” and then the assistive software read the first sentence of the image description to complete the task.	<i>Participant 2</i> The participant used the keyboard shortcut “Ctrl+F” to search for “Electron Paths.” The participant referenced this task as an example of why jump-to navigation should be added to the exhibit.
Task 4	The task was designed to determine if participants could access the alt text description for a specific image when given the title, “A little forest?”	<i>Participant 1</i> The participant used a short cut to search for the heading, “A little forest?” and then read the alt text. The participant questioned how the images were organized in the exhibit.	<i>Participant 2</i> The participant located the “A little forest?” image, but could not access the alt text. The participant explained the accessibility software they used does not read alternative text or pick up text accessed by

			cursor movement. This led to the recommendation to evaluate the images' brief description.
Task 5	The task was designed to determine if participants could locate the third image in the exhibit when not given the title.	<i>Participant 1</i>	<i>Participant 2</i>
		The participant used JAWS to select and read the third heading to complete the task.	The participant located the third image in the exhibit by scrolling. The participant commented they do not like scrolling.
Task 6	The task was designed to determine if participants could locate a specific image when given the title, "Awareness" and then locate details located in the description.	<i>Participant 1</i>	<i>Participant 2</i>
		The participant used a short cut to search for the heading, "Awareness," then the assistive software read the image description to complete the task.	The participant located the "Awareness" image. As the participant's assistive software read the description, the participant made a comment that the abbreviations should always be spelled out and equations explained because screen readers will misread them. This led to the recommendation - content should be in layperson's terms; and uncommon abbreviations and equations should be spelled-out or explained.

Table 3: Posttest Questions

Table 3 caption: Questions to initiate feedback about Web page features tested during the session

Post-test Responses		
Question	Participant 1	Participant 2
Which feature do you find the most useful? Why?	"The headings and the descriptions; the headings made it easy to search."	"The image descriptions"
Are there any features that are difficult to navigate or find?	"Nope"	"It is difficult to navigate through the different displays; it would be nice if there was a way to jump to sections of the exhibit like Wikipedia."

Are there any features missing from the website?	“Nope”	“A jump-to navigation and a form of instructions to access the picture description.”
--	--------	--

Through collaboration with ODS, students who use assistive technologies were recruited via e-mail to participate in the testing session. Of the seventeen students invited, two agreed to take part. Because this activity was not intended to be a formal, qualitative study, but instead an opportunity to learn what improvements could be made to the Web page, the committee was satisfied and grateful for the two participants. Both were graduate students and unfamiliar with the digital exhibit. The incentive was a \$5 Target gift card.

The Usability Coordinator, acting as the test facilitator, greeted the students upon their arrival at the library’s assistive technology room and guided them through the IRB-approved informed consent form. The test sessions were conducted on a Dell desktop computer with JAWS 17.0 for one student and on the other student’s own laptop computer with Dragon Naturally Speaking 12.0 (Nuance Communications, Inc). A Vixia HF M52 camcorder (Canon USA, Inc.) recorded the screen activities and the audio of the test sessions. The Usability Coordinator presented the students with the tasks, answered their questions, and prompted them for responses. In addition, she took notes during the sessions and analyzed the data produced. Qualitative data were gathered through observations, pre-test conversations, task attempts and completions, and post-test conversations of each session. The conversations between the Usability Coordinator and participants were critical for information gathering. After both sessions, the Usability Coordinator watched the recorded sessions and noted usability concerns, along with participant

comments. During testing, the participants accelerated the accessibility software audio, making the Usability Coordinator's attempt to transcribe the audio a futile effort. In addition, time did not allow for a word-for-word transcription.

Even with the small sample size, recommendations to improve the Web page usability for PVI could be made to include the following modifications:

- In the version of the Web page tested, all users had to scroll through the list of displays in alphabetical order by image title. If a user knew the name of a display, the keyboard shortcut “ctrl+f” or a heading search could be applied in JAWS. However, most users would not know the name of a display. To increase the efficiency, effectiveness, and ease of learning, the displays should be organized by program or department, rather than alphabetically by title, and “page-jump” anchor links to reduce the amount of scrolling required.
- After the displays are organized by program or department and the “page jump” anchor links are added, the introduction should be revised to reflect the changes.
- In the test sessions, it was observed that Dragon Naturally Speaking did not read alternative text or text accessed by cursor movement; most assistive technology software uses the keyboard, and not the mouse. The brief alternative text description should be placed below the image and be viewable by default, to ensure that it will be seen by all users and read by the majority of assistive technology software. It should be formatted as subtext, to ensure readability.

- Uncommon abbreviations should be defined at every instance where present in the text, not just at the first appearance. Equations or symbols do not read correctly through assistive technology software, and should be explained in the text.

The committee was able to make some of these adjustments. The images were organized according to department or campus program, and links were added enabling users to jump directly to a particular department's or program's displays. The department and program links were placed immediately below the introduction, which was updated to reflect the changes. The brief alternative text description was made a subtext and moved below each image, so that any speech reader would find and translate it. In addition, a "back to top" link was added to each display block. Use of abbreviations and symbols was not immediately addressed. Adding the definition every time an abbreviation is used throughout the research statement may be undertaken in the future, with the permission of each exhibitor. The right arrow symbol in one research statement was not immediately changed because the exhibitor had used this symbol as an accepted convention in scientific writing; however, this could be addressed in the future with the exhibitor's approval.

The Usability Coordinator asked both students to provide feedback after the changes were implemented, using their own computers. Only one responded, but said he was pleased with the modifications and happy to support the usability testing process.

OUTREACH

To advertise the existence of an online exhibit formatted for PVI, the Open House welcome poster stated that enhanced accessibility was available on the Web page. However, the ODS discouraged adding a phrase to the bottom of the exhibit welcome poster that online access was available for PVI. The ODS felt that the explanation would single out those with disabilities. Therefore, the committee relied on word of mouth and social media to inform the campus community with visual impairments of the existence of the online exhibit. The library posted the exhibit's marketing image on its Facebook page, which was sufficient for sighted persons; however, testing showed that JAWS did not read the link, image text, or content below the image in the Timeline post. The ODS shared the library's post on its Facebook page, but for JAWS to read the text in the post, it was necessary to click on the individual post. The information within the image was not readable by the screen reader, because the image was a graphic without embedded alternative text. JAWS also did not read the tweet that the library posted on its Twitter feed. In future efforts, advertisements to PVI through social media should go through the same formatting as the Web page, to ensure that the messages are readable by screen-reading software.

When contacted by the committee, the North Carolina State Library for the Blind and Physically Handicapped posted a link to the *Visualizing Science* online exhibit on its Facebook page. As organizations throughout the state rely on this state library, the online exhibit could potentially reach many patrons who do not otherwise have this kind of opportunity to learn about science.

FUTURE DIRECTIONS

The committee hopes that other libraries will benefit from these experiences and the following lessons learned.

Correcting the non-UTF-8 characters in the research statements was very time-consuming, so for future exhibits, research statements should be submitted via an HTML Web form, rather than being uploaded as Word documents. The UTF-8 character set will thus be forced, and the text will come through cleanly. The following code can be used for this purpose:

In PHP:

```
header('Content-Type: text/html; charset=utf-8');
```

In HTML5:

```
<meta charset='utf-8'>
```

Composing a brief alternative text description based on the research statement and image was challenging, as several scientific disciplines were represented, and a number of research statements lacked the basic information needed by the layperson in order to understand the research. It was helpful that the Science Librarian has a background in the physical and life sciences, enabling her to compose the brief descriptions for many types of subject matter.

An alternative approach would be to have the exhibitors write the brief descriptions for the alternative text. However, although the exhibit's submission guidelines requested that the research statements be written in layperson's terms, many were not. Also, a number of exhibitors wrote descriptions that did not give one a sense of how the image looked. Unlike scientific

colleagues, visitors to the physical or online exhibit do not need precise details about the research in order to enjoy and learn from the exhibit images. It took diplomacy and some compromise to finalize some of the descriptions. Ultimately, the original images and statements belong to the exhibitors, and the Science Librarian felt it was her role to guide them in composing the brief descriptions for use as alternative text on the Web page.

Despite the additional work required, the exhibitors were enthusiastic about the committee's efforts to convert the Web site to an online exhibit and make it accessible to PVI. A nanoscale science graduate student exhibitor wrote, "This online exhibit has offered me a unique opportunity to help expose those with visual impairment to some TEM images of nanoscale particles that I made. It was important to be a part of something that allows more individuals to experience the scientific wonder that I get the privilege to appreciate every day. By means of accessibility, this has the potential to evoke scientific curiosity and inspire far more people."

It is unknown how well PVI can create mental pictures that closely resemble the original image just by hearing the screen reader dictate the brief description. Perhaps the best way to evaluate these brief descriptions would be to read them to sighted or individuals with visual impairments, who would draw what they have envisioned. Those drawings could then be compared with the displayed images.

After reading about what art museums offer, the library could have made the physical exhibit more accessible by offering special tours for PVI, possibly with some scientists present to read the brief descriptions and explain their research. Perhaps grant money could have been requested

for computer-assisted creation of three-dimensional tactile samples of the main subjects of scientific images, similar to what is described in “Methods for Creating and Evaluating 3D Tactile Images to Teach STEM Courses to the Visually Impaired” (Hasper et al. 2015). The library owns desktop 3D printers. Coordinating with the library, students could initiate projects to create designs and upload the files to print objects from the images. These plastic objects could be presented to PVI, along with the brief descriptions and research statements, for a more thorough representation of the images.

It is essential to confirm the effectiveness of social media outreach to PVI. Although the ODS re-tweeted the library’s exhibit tweet and shared the Facebook post, the information was not completely accessible, and the committee did not realize until after the announcements were posted on social media that some important information could not be interpreted by screen readers.

The committee may never know what impact these efforts had on PVI regarding exhibits, but we believe this is a first step in trying to reach out to the disabled community, and we hope that other libraries will seek ways to use technology to make their exhibits accessible.

CONCLUSION

The committee pursued this online exhibit, in addition to the physical exhibit, so that PVI could become more familiar with ongoing research at UNC Charlotte and have the opportunity to enjoy “scientific art.” Producing an online exhibit and providing assistive technologies allows this academic library to expand opportunities for PVI to experience exhibits that were previously

inaccessible. Other libraries planning exhibits in physical spaces are encouraged to pursue similar online experiences for patrons with visual impairments and those unable to visit the library in person.

The online exhibit integrated well into the overall project, but publicizing the site to reach the visually impaired community required creativity and a willingness to network outside the library. Building connections with PVI and organizations that serve them is vital. The Web page URL is permanent, and we hope the Web page will continue to educate others, now that the physical exhibit has been dismantled.

This was the first attempt by the committee members to produce a Web page with special emphasis on PVI. Reports of scientists and clinicians with visual impairments inspired this undertaking, as members of the UNC Charlotte community may look beyond the beauty or art in this exhibit's images and find intellectual appeal to stimulate their studies (Griffin N.D.; Minkara 2015; Supalo 2002; Tompa 2014; Vermeij 2011). The library was fortunate to have a Software Developer who could build the original event Web site and reformat it for screen readers under a tight deadline, to coincide with the exhibit's Open House event. Advice from the ODS contributed to improving the Web page.

The *Visualizing Science: Microscopic Images from UNC Charlotte* exhibit was a success for the library; it included an Open House to celebrate the opening of the exhibit space in the lobby, a field trip to the library by a local retirement community, coverage by a local newspaper, and a short write-up in the library's internal newsletter. The event allowed the library to work closely

with faculty, alumni, and students to showcase scientific endeavors and initiate discussions on how the library can continue to support the curricula and research programs.

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NOTES

Archive-It! (Internet Archive) <https://archive-it.org/>

Dragon Naturally Speaking (Nuance Communications, Inc.) <http://www.nuance.com>

HTML_CodeSniffer (Squiz Content Management Solutions)
http://squizlabs.github.io/HTML_CodeSniffer/

JAWS (Freedom Scientific, Inc.) <http://www.freedomscientific.com/Products/Blindness/JAWS>

Read&Write (Texthelp Ltd.) <https://www.texthelp.com/en-us/products/read-and-write-family>

Vixia HF M52 camcorder (Canon USA, Inc.)
<https://www.usa.canon.com/internet/portal/us/home/support/details/camcorders/support-high-definition-camcorders/vixia-hf-m52>

VoiceOver (Apple, Inc.) <http://www.apple.com/accessibility/mac/vision/>

ABOUT THE AUTHORS

Melanie Sorrell is the Science Librarian serving the Departments of Chemistry and Biological Sciences, the College of Computing and Informatics, and the interdisciplinary Nanoscale Science Ph.D. program at UNC Charlotte. She earned a Doctor of Veterinary Medicine and Master of Science in Veterinary Science degrees. After practicing for 15 years, she began her studies at the

University of North Carolina at Chapel Hill before graduating with a Master of Science in Library Science degree. Her biomedical sciences and pathology background were most helpful in recruiting and communicating with exhibit participants.

Derek Norton earned a Bachelor of Arts degree in Management Information Technology and Web Development from Mercyhurst University and is the J. Murrey Atkins Library software developer. He is responsible for the development and maintenance of the library website, custom web applications, and server administration. Derek is pursuing a Master of Science degree in Cyber Security from UNC Charlotte.

Jeff McAdams earned his Master in Library Science degree from Emporia State University in Kansas. He works as the Science and Engineering Librarian at UNC Charlotte, where he is primarily involved with information literacy instruction, research consultations, and collection development for Engineering, Math, and Physics.

Rachael Winterling is the Usability Coordinator at the J. Murrey Atkins Library and is responsible for the life cycle of a usability project through initiating, planning, executing, and closing. She gathers and analyzes qualitative data through task-based testing, focus groups, card sorting, interviews, surveys, and paper prototyping. Rachael earned a Technical Writing graduate certificate from UNC Charlotte and a Project Management graduate certificate from Western Carolina University.

Kathleen Dipple earned her Bachelor of Science degree in Chemistry from Appalachian State University. As a doctoral candidate in Nanoscale Science at the University of North Carolina at Charlotte, she is investigating the development of nanomaterials for highly efficient solar devices by coupling metal nanoparticles to quantum dots to improve solar energy absorption.

ORCID

Melanie Sorrell <http://orcid.org/0000-0002-5773-9389>
Derek Norton <http://orcid.org/0000-0003-2554-5499>
Jeff McAdams <http://orcid.org/0000-0002-6273-5390>
Kathleen Dipple <http://orcid.org/0000-0002-9919-7266>

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APPENDIX

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FOOTNOTE

¹The definition of “visual impairment” used here is based upon the International Classification of Diseases code classification H.54 from the World Health Organization’s International Statistical Classification of Diseases and Related Health Problems 10th Revision (2016) and refers to defects ranging from mildly diminished sight to blindness in which no light is perceived, even after treatment or refractive correction. The reader is referred to the medical literature, standards, and government documents regarding related terms, such as visual impairment, vision impairment, blindness, and low vision; application of levels of visual acuity to distinguish between disability and impairment; and the subcategories of visual impairment. These resources are listed in the Appendix.
