Inclusive Digital Interactives

Best Practices + Research

Smithsonian | Institute for Human Centered Design | MuseWeb

September 2020

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Introduction to the Publication

Today, more than ever, vital watchwords for museums and cultural organizations are Diversity, Equity, and Inclusion — DEI. An "A," meaning accessibility for people with disabilities, is sometimes inserted into the alphabet message — DEAI; but often, even if accessibility is proclaimed important, providing access to facilities and public programs as well as tackling deeper issues of employment and attitudinal discrimination against people with disabilities go unaddressed. The irony, of course, is that people with disabilities are an integral part of each of the other groups addressed by DEI/DEAI. So, ignoring inclusion and equity for people with disabilities — who are also people of color, in the LGBTQ community, and/or of marginalized national, ethnic, religious, or linguistic groups — means ignoring key characteristics of large numbers of people that museums are working to attract and serve.

It is also important to recognize that DEAI in the context of people with disabilities does not only mean that museum buildings meet physical accessibility standards, programs provide sign language interpreters, and service animals are allowed into the facilities. Equity and inclusion for people with disabilities also means making people feel welcomed and ensuring that they are core members of the museum community as leaders, staff, developers, consultants, and visitors. Ben Jones said in his article that inclusion is "… about giving all museum visitors a scaffold to tell their own stories … to enable visitors to become the storytellers ..." Inclusion for people with disabilities means giving individuals the chance to see and tell their own stories in museums as well as to access the stories of others.

This book focuses on the inclusive design of digital interactives for visitors and staff, one segment of museums' larger program offerings. Access Smithsonian, the central accessibility office for the Smithsonian Institution, initiated this project in order to spur innovation, encourage information sharing, and motivate cultural organizations around the world to consider accessible and inclusive digital interactive design as an essential component of their greater DEAI efforts. An international call for proposed articles resulted in a wealth of submissions, which were winnowed to sixteen by an advisory committee of eight renowned experts in inclusive digital design. The completed papers were also reviewed by committee members and project collaborators. As intended by Access Smithsonian, this publication brings a diverse group of strong DEAI case studies with guidance that can be applied broadly.

The publication's authors make clear in their articles that truly inclusive design requires a shift in attitude and the design development process. Designers have to rethink how interactives' content, approach, and use of technology are molded into a program and reconsider who the audience is and what it means to enable everyone to have access to the information presented. Museums must begin the design process with inclusion as a primary goal and consider not only who is the targeted audience but also who is being left out and how to remedy that exclusion. Cooper et al., writing about their design of interactives for the United States Olympic and Paralympic Museum, state "[W]e endeavor to work to the principle that if any person finds they cannot engage or interact with what we are designing and producing, the correct word is 'unusable.' If we all start to apply that simple shift of perspective when asking: Is this design usable? — then we move to a mode of working that really works for everyone — an approach that all should be eager to develop further, continue to apply universally to our work, and share as a paradigm methodology."

The publication authors' broad consensus on how to make digital interactives accessible, inclusive, and usable is to bake that goal into the process at conception, and have it, as Sarah Banks stated, "underpinned by stakeholder involvement at every stage." Senior leadership, curatorial, exhibition, exhibition technology, education, and visitor services staff, she said, need to commit to inclusive design throughout development to production and beyond to post-opening maintenance. It is equally essential to deeply involve a diverse group of people with disabilities iteratively in formative evaluation, design development, production, installation, and summative evaluation. Mesiti Caulfield et al. emphasize that "…it is critical to value the voices of those who share their own expertise and lived experiences."

Finally, as Antlej et al. advise, museums need to not only stretch the parameters of their own inclusive design process but to urge technology developers to design for inclusion within their products. Museums must take on the role of "public platforms," they suggested, to experiment alongside developers with new technology, discover the strengths and weaknesses of products and processes for inclusion, and demonstrate how the inclusive design of interactives better serves museums, cultural organizations, and many other types of businesses and organizations as well. Sharing information and analyzing both successes and failures are crucial to progress.

The publication's partners, advisors, and authors urge readers to increase the knowledge base established by these articles and continue to build on each other's work. We see this publication as an initiator of many future conversations, ongoing experimentation, and successful solutions. Our collective motto for inclusive digital interactive design should never be "it's as good as it can be for now." Instead, we should always strive for "let's find a way to make it better immediately."

A word about terminology:
Language that relates to disability differs around the world, whether person-first (e.g., person with a disability), disability-first (e.g., disabled person), or a wider choice of terminology. We believe that it is essential to listen to whom we are speaking about and use *their* language. As in so many cases, there is no one correct answer. For that reason, we have not changed the disability-based language of the authors to be uniform in this publication as we believe all the terminology used is respectful.

Additional Resources on Terminology Regarding People with Disabilities:

- Disability Language Guide, Stanford University: https://disability.stanford.edu/sites/g/files/sbiybj1401/f/disability-language-guide-stanford_1.pdf
- National Center on Disability and Journalism: https://ncdj.org/style-guide/

Other Terminology that Appears in Various Articles:
Assistive Listening System (ALS): An amplification system utilizing transmitters, receivers, and coupling devices to bypass the acoustical space between a sound source and a listener by means of induction loop, radio frequency, infrared, or direct-wired equipment. [NOTE: This is an *assistive*, not "assisted," listening

system, as is it is often misnamed in other media.] (ADA Standards for Accessible Design, Sec. 106 Definitions)

Audio Description (AD): Audio description, as defined by the U.S. Access Board, "is an audible description of the visual content of a presentation, synchronized with the existing soundtrack. Typically, appropriate portions of the audio description are narrated during what would otherwise be natural silences in the presentation." (U.S. Access Board, Section 508 Standards, Video and Multimedia Products, Section 1194.24, https://www.access-board.gov/guidelines-and-standards/communications-and-it/about-the-section-508-standards/guide-to-the-section-508-standards/video-and-multimedia-products-1194-24) **The terms audio description, video description, visual description, and verbal description are all used synonymously in this publication.**

Captions (open and closed) vs Subtitles: Title III of the Americans with Disabilities Act (ADA) defines captioning as follows:

- *Closed movie captioning* means the written display of a movie's dialogue and non-speech information, such as music, the identity of the character who is speaking, and other sounds or sound effects. *Closed movie captioning* generally requires the use of a captioning device for delivery of the captions to the patron. (ADA Title III Regulation, Section 36.303(g))
- *Open movie captioning* means the written on-screen display of a movie's dialogue and non-speech information, such as music, the identity of the character who is speaking, and other sounds and sound effects. (ADA Title III Regulation, Section 36.303(g))
  [Note: Closed captions are not always seen on the screen and must be turned on for viewing by a decoder or media viewer software. Open captions are always on-screen and cannot be turned off.]
  vs
- *Subtitles* are a written on-screen display of dialogue that assumes the viewer can hear (even if not understanding a foreign language audio presentation) and do not include information about non-speech elements.

Universal Design (UD): Universal design is "[t]he design of products and environments to be usable by all people, to the greatest expect possible, without the need for adaptation or specialized design." https://www.humancentereddesign.org/inclusive-design/history/
The terms inclusive design, universal design, design for all, and human-centered design are all used synonymously in this publication.

Project Collaborators

Partners:

- Access Smithsonian is a catalyst for consistent and integrated inclusive design that provides meaningful access to the Smithsonian Institution museums and content for visitors with disabilities. https://access.si.edu/
- Institute for Human Centered Design is a 42-year-old education and design non-profit dedicated to enhancing the experiences of people of all ages, abilities, and culture through excellence in design. https://www.humancentereddesign.org/
- MuseWeb supports, catalyzes, and undertakes innovative projects that transform the business of culture, helping the cultural sector become more sustainable, accessible, and relevant. https://www.museweb.net/

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Inclusive Digital Interactives

Best Practices + Research

Chapter 1

Scaffolding to Build Inclusive Interactives: Ben Jones' Digital Design Approach

An Interview by the Editors

Smithsonian | Institute for Human Centered Design | MuseWeb

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Introduction

In Jones' way of thinking, inclusive design is really just good design: it is design that addresses the fact that everyone has strengths and weaknesses; its operation doesn't have to be explained — how to make it work is clear from the design itself; and while inclusive design isn't one-size-fits-all, it makes interactives usable by the broadest public, with built-in alternatives for getting to the same content in different ways.

How does one take these broad aspirations and turn them into real interactives? The following represents the scaffolding and tools that Jones considers essential to creating accessible, inclusive programs that engage and delight visitors across the spectrum of age, ability, and culture.

Jones' Core Principles of Inclusive Design

Jones believes the most important feature of an inclusive interactive is the story. Designing for inclusion is about giving all museum visitors a scaffold to tell their own stories – inclusive interactives enable visitors to become the storytellers, talk with others about the interactives' content, and work their way through the programs to achieve the objectives. A good example, he said, is the *Garage* exhibit at the Rock & Roll Hall of Fame, where visitors learn to play instruments with the interactives slowly leading them through the process. Visitors try different songs, set their amplifiers, and at the conclusion of the interactive program, can play part of a song. They may not be Jimi Hendrix at the end of the experience, but they are excited about what they accomplished and can share that excitement with friends and family. The interactive sets visitors up for success, allows them communicate with an expert, and lets them tell their own stories.

To build in maximum flexibility and inclusiveness, Jones says, digital designers should provide multiple methods and options to share the same story. One possibility is to uniquely identify each visitor and tailor the interactive to better suit individual needs. But, he stresses, the idea is *not* to simply throw technology at the problem: the frequent result of that approach is that *no one* understands what to do or how to use the interactive.

Instead, he emphasizes, key to the inclusive design of digital interactives is to begin with the interactive's objectives and then brainstorm innovative, multisensory approaches to reach those objectives in ways that work for a broad range of people. If an interactive is designed with a predominantly visual approach, for example, it's hard to back up and try to make it work for people who don't learn visually. Too often, the result is layers and layers of effort to make inherently visual material accessible in non-visual ways. Jones believes you have to go back to the beginning, analyze the goal, and determine a balance of visual and non-visual approaches to the materials.

One example of a not-totally-successful effort was when a museum refreshed an existing interactive to become more inclusive. The interactive's design started from a purely visual approach: graphs that compared actions. There were truly innovative and sincere attempts to make the original information accessible for visitors who could not read the graphs: sound effects added to data points; audio read aloud, based on what you were touching; tactile overlays on a touch screen; and a variety of haptic feedback systems. In the end, the museum created a whole new interface unlike anything anyone had used before. However, that very lack of a familiar interface and those complex methods of interaction resulted in no visitor knowing how to use the interactive. When it was tested, it took some visitors over an hour to understand what was presented.

To design interactives for inclusion, Jones believes you have to break the interactive down into smaller pieces and create different ways of accessing the same content. That way if one method doesn't work, maybe another one will; and it's not necessary to create special modes to make a single approach accessible.

Everyone gets the same experience; but they choose what part of an interactive to spend their time on. Multiple options allow people to self-select what they feel comfortable with and like best.

Jones said the chief goal is to ensure people feel they belong in the museum. Part of this feeling of belonging is, of course, that visitors see themselves represented in the museum's content and in others who work in and visit the museum. Another very important part of belonging is not being made to feel silly about making mistakes. Digital interactive designers can inadvertently set people up to fail, and a visitor's first response is to take the blame for that failure: "I should've known." Designers need to find ways to set visitors up for success, to support the visitor who can't read, who can't use the touchscreen, who can't understand oral English, or who can't see where the "back" button is located. Feeling you belong, feeling like you are part of the story, and that you have a story to tell is, for Jones, essential.

Jones' Short List of General Best Practices for Inclusion

Complex, flowery language has no place in a museum. Don't trigger someone with Hippopotomonstrosesquippedaliophobia (the fear of long words). You don't know the age or education of your visitors. Verbose or overly scientific words might make them feel excluded. Write with clear, concise language.

Make every sentence count. Do more with less. If you have lots of information to convey, create a hierarchy.

Use size, weight, color, bullet points, and fonts to draw attention to the big point and then dive into the specifics. Communicate the most important parts first. From a distance, visitors should have an idea of what each interactive is about and can decide if they are interested in it or not.

A museum isn't a novel, it's a magazine. Flipping through it, you should be able to quickly identify where you'd like to spend your time. Speaking of flipping through pages, the least effective type of interactive is the content browser, says Jones. The content browser tends to be the place where page after page of text, images, audio, and videos that couldn't fit into the gallery go to die. Even if the content is interesting, the format is overwhelming. A better approach is to create interactives where visitors play an active role in the experience. Don't try to recreate Wikipedia; let visitors learn through play.

When you're designing an interactive, use a familiar interface. Don't reinvent the wheel or use new symbols or words. It's much easier to use existing concepts that people already know. A trash can in a red button most likely means "delete." A green check mark tends to be a symbol for "done" or "finished." Stick with universal symbols that are used in websites, apps, or games. And locate them consistently on the screen.

When you're designing multiple interactives in an exhibit, try to establish consistency between them. Consistency not only in visuals, but in the order that you present information and the steps you ask your visitors to take.

In the *Garage* exhibit, all of the interactives have a title screen that tells the visitor what the interactive is about. It prompts the visitors to scan their wristbands and then displays a short stop-motion, animated video with an overview of what they are going to do. The visitor can then use the interactive. After completing the interactive program, there is an outro video (closing sequence and/or credits) which then loops back to the title screen.

Having a repetitive structure keeps visitors at ease. You know what you are in for when you start an interactive. The Rock & Roll Hall of Fame uses touchscreens for all of the interactives in the *Garage* exhibit and uses a consistent visual language for different interface elements. All of the buttons look like pieces of masking tape with black Sharpie text written on them. The museum did change the interface slightly for the Drum Lesson interactives because the touchscreens were so far out of reach. For the drums they built a physical button box that is nestled in with the high hats and floor toms. If done right, having consistency within an exhibit simplifies the exhibit development process and makes it easier for visitors to understand the story you're telling.

Jones' Lenses for Viewing the Inclusive User Experience

Reach

Are your visitors able to reach your interactive? Try sitting in a wheelchair and using your interface. Are you physically able to wheel under or turn to orient yourself to use the interactive? If you're using a touchscreen can you reach the top touch areas of the screen? One strategy used for several interactives at the Rock and Roll Hall of Fame is to only use the bottom half of a touchscreen as it is closer to the visitor. An easy fix for reach is to have multiple versions of your interactive and place a few of them at lower heights. Having mobile seating allows access for visitors who don't have the stamina to stand for long and for visitors using wheelchairs to then reach the same height as everyone else. It's a flexible way to fit the needs of your visitors.

Dexterity

Does your interactive require fine motor control? Are the buttons so close together that you could accidently press the wrong one? Or are the buttons so far apart you have to make large movements? Don't force someone to use their entire range of motion in order to use your interactive. Ask your visitors to confirm actions like "start over" or "delete" to accommodate for accidental presses. These aren't new ideas, these are just good design decisions.

Pacing

Give visitors time to understand before moving on. If it makes sense within the program, give them the ability to skip forward or back. The Rock and Roll Hall of Fame allows this functionality in the lesson interactives in the *Garage* exhibit. They give visitors control over the playback of the lessons. They're also tracking analytics for each lesson to identify pacing problems so they know which lessons need to be reworked. If you notice the majority of visitors skipping ahead then you should get to the point faster. Conversely, if they keep rewinding they are most likely having trouble understanding and you should slow things down.

Design for Play

Does using the interactive require prior subject knowledge? Do you need a specific goal? Simply interacting with a system and seeing the results may be exactly what the visitor needs. "If I pluck this string or press this key or hit this drum, it makes a sound." Cause and effect. For some younger visitors and certain visitors with brain-based disabilities that is the perfect experience. All of the lesson interactives in *Garage* allow for visitors to simply play. No lesson, no structure, just a safe place to experiment.

Visual Clarity

Can you read your designs from a distance? Does your text blend into the background? Use contrasting color in elements so they are legible.

Avoid handwritten text or thin typefaces. Try to keep your text legible: sans serif fonts tend to be best for body text. Try turning your designs into grayscale and see if you can still distinguish your interface.

One tip Jones' high school art teacher always told him was to squint his eyes to check values and contrast when looking at artwork. He still squints his eyes to check his designs to this day. Thanks, Mrs. Hanson!

In addition to checking values, check for red/green color combinations. It is the most common color combination that presents problems for people with color blindness, which affects 8% of men and 0.5% of women in the United States (https://www.aoa.org/healthy-eyes/eye-and-vision-conditions/color-vision-deficiency?sso=y). Don't solely use the colors red and green to color-code buttons or other elements in your interactive. If you must use red and green, complement them with icons, patterns, or words. Jones had a roommate who was color blind and he would frequently have problems with the signature pads when making credit card payments. He was fine if the buttons had a green check mark and a red "x"; but some of them only had red or green buttons and then he'd have to ask the cashier for assistance in making his choice.

Tactile

Some visitors might not be able to see at all. If you couldn't see the interface of your interactive could you still use it? Tactile interfaces tend to work well, but you still need auditory feedback. In the *Hall of Fame* exhibit, the Inductee Moments interactive uses an arcade spinner to select from a carousel of induction speeches similar to the old iPod wheel or a Nest Thermostat. Although it's possible for some to just use a touchscreen, the knob gives tactile feedback that is combined with audio so both sighted and blind visitors know where they are in the program and what they're selecting.

Sound

When you're designing an interactive, sound effects as feedback to user input can work well. Fighter video games are great at audio feedback and, as a result, blind players learn the patterns of the sounds and can beat the games.

Not all museums are as quiet as art galleries. The Rock and Roll Hall of Fame has the volume "turned to 11" and that can be overwhelming for some. The museum worked with Kulture City to offer visitors sensory bags with sound cancelling headphones. The museum chose not offer special days dedicated to visitors with autism because they felt that by offering special days you segregate visitors and people might not know when to visit for reduced or muted audio.

When it comes to interactives, the museum tries to set the volume consistently to a normal level and then allow visitors to turn the volume up or down. Volume is reset after each use, but they are working towards remembering each user's audio preferences from one interactive to another. If the interactives remember the preferred audio levels, visitors can focus on the content.

But, what if the visitor can't hear a single word or sound in the interactive? Pair audio feedback with visual feedback and make sure video content is captioned. Captions are helpful for everyone: the Rock and Roll Hall of Fame has some interactives that offer headphones for audio playback, and the museum always has at least two sets of headphones provided so friends or family can listen in. However, friends and family don't always opt to put on the headphones because with captions, they can still follow along and be part of the experience. Captions are also helpful if the person talking on-screen is hard to understand. Here's looking at you, Ozzy…

Language

If you couldn't read a word in the exhibit, could you still use the interactive? Could you walk away with at least some level of success? If your labels and interactives are only written in English, you are excluding a huge audience. While museums can't provide translations in all languages, providing information in the most common languages of frequent visitors as well as in plain, clear English with good illustrations and international icons will make a big difference for many.

The Future

Ideally, you've looked at your interactives through the lenses listed above, but sometimes the most effective way to communicate with someone is to ask them their preference. Museums of the future will react to visitors and deliver content to them in a way that is accessible to them. In order to make that happen we might identify individuals with Code 128 and QR code formats, RFID tags, or even, when there is an effective and reliable way to use and control it, biometric data. The point is if you want to tailor your experiences you need to know who is using your interactives — pick a method that works best for your museum and your visitors.

Conclusion

In Jones' opinion, the most inclusive interactives allow the visitor to become the storyteller and insert themselves into the experience. At the Rock and Roll Hall of Fame they shine the spotlight on their visitors and capture moments of expression. Visitors love designing their own band logos, recording photo booth videos of their first concerts, and jamming out with strangers in the *Garage* exhibit. The Rock and Roll Hall of Fame hopes that by providing a welcoming experience and a scaffold, visitors will feel comfortable and included. *Rock and roll is a spirit that connects us all.*

Inclusive Digital Interactives

Best Practices + Research

Chapter 2

The United States Olympic & Paralympic Museum: Designing Digital Interactives for People with Varied Abilities

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Smithsonian | Institute for Human Centered Design | MuseWeb

September 2020

Introduction

Centre Screen is an audiovisual (AV) and interactive media production company based in the UK, which, at the time of writing this article, is working with the United States Olympic & Paralympic Museum (USOPM) to produce a diverse suite of AV and interactive software exhibits across the museum's themed gallery spaces.

Since 1986, Centre Screen has worked throughout the world with visitor attractions, theme parks, major museums, and heritage sites to create digital content that inspires, educates and entertains. Skilled in communicating a variety of subject matter from social history and sport science to contemporary art and natural history, our focus is always on captivating and compelling storytelling for every visitor.

The United States Olympic & Paralympic Museum

"All sports for all people."

– Pierre de Coubertin, Founder of the Modern Olympic Games

The USA is a dominant force within the Olympic and Paralympic movements and the United States Olympic & Paralympic Committee (USOPC), the non-governmental body responsible for overseeing, supporting and entering teams in both Games, has been working hard to invest in and help advance Paralympic athletes and sports.

It is against this backdrop that Spring 2020 will see the opening of the United States Olympic & Paralympic Museum (USOPM), where equivalence of status is foundational to the very title of the institution.

USOPM is situated in Colorado Springs, Colorado, already home to the U.S. Olympic & Paralympic Training Center. Covering some 60,000 square feet, the museum will house the United States Olympic & Paralympic Hall of Fame, 450 historic artifacts and documents, and over forty film and digital interactive installations, all of which will celebrate Olympic and Paralympic athletes and their place within the inspiring histories of the movements.

As a member of the Olympic Museums Network, the U.S. Olympic & Paralympic Museum has held true — from concept to build — to its promotion of the values of sport, Olympism and Paralympism. Woven throughout the narrative of its 13 themed gallery areas, and core to its target learning and emotional outcomes, is the belief that the practice of sport is a human right to which everyone should have access, "without discrimination of any kind, with mutual understanding, friendship, solidarity and fair play" (Olympic Charter, 2019).

> With the goal to be the most accessible museum in the world, the USOPM is working diligently with exhibit fabrication partner, CRĒO Industrial Arts, and interactive media partners, Kiss the Frog and Centre Screen, to construct a space that offers a world-class experience regardless of physical ability or cognitive impairment. (United States Olympic & Paralympic Museum, 2020)

In an interview with a local NPR station (Brownell, 2019), CEO of the museum, Chris Liedel describes the building as a place to inspire "Olympic-sized" aspirations. Centre Screen's job as digital content creators has been to help serve that ambition, and stated goal of becoming one of the most accessible museums in the world.

A Shared Inclusive Ambition

It is from these roots that the museum's ambition grew beyond achieving the 'gold standard' of accessibility to that of achieving a visitor experience shaped around inclusive design.

With Paralympians and Olympians sharing equal billing, the museum was an opportunity to create an inclusive experience through its content and design; its heroes and visitors; its architecture and, of course, its interactives. Our shared vision from the outset has been to prioritize inclusivity and consider everyone in our design thinking.

The question that has dominated our thinking throughout the entire project — a question that carries its own idiosyncratic challenges, characterized by the absence of mandated industry regulations — is exactly how the team would achieve inclusivity in the field of AV and interactives, Centre Screen's area of expertise.

Web accessibility has been moderated, and even regulated to some degree, under the Web Content Accessibility Guidelines (WCAG) (https://www.w3.org/WAI/standards-guidelines/wcag/). Experience has been pooled and codified, rules have been laid out; developers can utilize web accessibility evaluation software and, although they are always subject to improvement, there are clear guidelines.

Contrast this with museum accessibility — although regulations exist for facilities such as toilets, signage and announcements, there are no compulsory guidelines, statutes, or universal industry standards for interactive accessibility. This can create both positive consequences and potential challenges. The key positive consequence is that creators are given the opportunity to develop groundbreaking standards. However, limited legal necessity beyond ADA compliance can create conflicting budgetary imperatives and differences of opinion over the prioritization of accessibility.

For inspiration and counsel, the team looked to the Olympic and Paralympic values that underpin the museum and all it celebrates, paying particular attention to the adoption of adaptive technology in Paralympism.

Olympic and Paralympic Values

Olympism and Paralympism, combined, have a total of seven core values: Excellence, Friendship, Respect, Determination, Courage, Equality and Inspiration. In his *Fundamental Principles of Olympism*, outlined within the Olympic Charter, Pierre de Coubertin — the father of the modern Olympic Games — described the Olympic values as cultivating "a way of life based on the joy found in effort, the educational value of a good example and respect for universal fundamental ethical principles” (2019).

Just as the Olympic Movement uses sport to further human interaction and cooperation, the Paralympic Movement uses it as a vehicle for wider disability rights and social inclusion. As part of this agenda, the Paralympic Movement has always championed the sporting use of adaptive and innovative technology capable of combining with humans to produce startling results.

In our own way, the team has tried to mirror this approach in innovating the technology needed to make the USOPM AV sequences and interactives as inclusive as possible. In collaboration with CRĒO Exhibits and USOPM leadership, we have undertaken regular, rigorous user testing and applied a collaborative approach to developing and deploying genuinely inclusive experiences.

Our Approach to Inclusive Design

Below, we will examine in detail how the team has used the positive and negative implications of unregulated inclusive museum interactivity in the real world. We will highlight our user testing process, our close working relationship with Paralympians, and the vital necessity of these collaborations to the success of the project. We will also discuss technology, its impact on inclusivity, and its participation in both sports and visitor experiences. Finally, we will consider the best way for the industry to move forward, building on previous experience and using resources such as this publication to create genuinely inclusive visitor experiences.

Inspired by the work and guidance offered by museums and institutions which have navigated this path before, such as the *Smithsonian Guidelines on Accessible Exhibition Design (SGAED)* (https://www.sifacilities.si.edu/ae_center/pdf/Accessible-Exhibition-Design.pdf) and the Principles of Inclusive Design, as shared by the Institute for Human Centered Design (IHCD) (https://www.humancentereddesign.org/inclusive-design/principles), USOPM and its project partners aspire to create a meaningful experience for all who pass through its doors, not just budding athletes; inspiring visitors of all backgrounds and abilities through fully inclusive means, without added tools or special additions.

We further hope that our perspectives will contribute to the wider pool of knowledge informing the design of inclusive digital interactives, and are delighted to be a part of this publication.

Universal design (UD), the architectural practice that underpins much of inclusivity, could be described as a 'helpfully unstable theory' — not dogmatic, not set in stone, but open to change and improvement. This publication will, with the contributions of its members, continue to grow that improvement, providing a place where developers, contractors and designers can publish and share their experiences of creating genuinely accessible visitor experiences — digital and physical — learning from each other and progressing towards true inclusivity.

Realizing the Vision

While the interactive experiences are a final touchpoint for visitors, the accessibility considerations start well before our involvement. There is no benefit in housing an accessible, screen-based experience in a building that is inaccessible; Centre Screen was therefore fortunate to join the project at a point when many of the accessibility foundations were already in place.

The foundations of this multidisciplinary approach included expertise from architects Diller Scofidio + Renfro, exhibition designers Gallagher & Associates, strategic museum consultant Gallagher Museum Services, custom fabricators CRĒO Exhibits, content partners Barrie Projects, hardware engineers BBI Engineering, RFID integrator Stark RFID, and the Olympic & Paralympic Museum team. These teams pulled the project together with a shared vision of inclusivity and the museum's ambition to bring equality of experience to all, with accessibility as the central story of this building.

Centre Screen collaborated closely with a number of consultants and user testing groups throughout production. Most notably, Jan Majewski and Anoopa Sundararajan at IHCD were an invaluable source of knowledge and experience that we were able to call upon at all key stages of the project.

Alongside these core collaborations, we were fortunate enough to work locally (in the UK) with a number of user testing groups that helped us better understand how to ensure that our media was, for example, sensory friendly, or accessible to visitors with vision loss. We also worked with local school groups with a wide range of children of diverse ages and backgrounds, and with a variety of access needs.

Figure 1: A Centre Screen co-design session for the USOPM Winter Interactive Wall. The challenge here for the group focused on creating a rich interactive wall (4no. 55” screens) that was usable by all visitors. The thoughts of the group addressed physical access, comprehension and visual/audio design. Credit: Centre Screen Ltd/Lancasterian School.

These groups helped us co-design and shape the usability of all of our digital products. Our user-centered process varied from scripted usability sessions, to free-play sandbox testing, as well as tackling particular creative challenges together.

For example, one exhibit spans nine 55-inch screens, creating a huge interactive video wall with a map of the USA. The software then powers an exploratory experience based on a rich dataset of U.S. Olympic and Paralympic athletes, visualizing their geography and sporting achievements. However, there is no straightforward, audio equivalent to this.

Instead, we worked with a local group to understand how, for those unable to see or comprehend the visual approach, we might convey the same learning outcomes. Working together with a group to tailor that experience, based on what is achievable technically and what a visitor might need, resulted in an experience design lead steadfastly by the requirements of end users.

Utilizing RFID to Enable a Personalized Museum Experience

The process for media delivery in large-scale museum projects tends to start long before AV and interactive designers receive briefs; the exhibition design team and content design teams will have worked with other contributing parties to establish concepts for all media experiences. In many cases, this includes defining much of the hardware and many of the intricacies of the content experience. Our task is to collaborate with project partners to move these concepts into a delivery phase.

For the USOPM, our challenge at this stage fell into two clear areas:

1. **The strategic visitor journey**: How might the team map out intuitive, independent routes throughout the museum that allow all visitors to enjoy, learn and participate equally?
2. **Inclusive media interpretation**: How do we design and calibrate each digital media experience to facilitate the global solutions mapped out above?

We shaped our strategy in two ways:

Firstly, **we design inclusively**. Broadly, this was defined by Ron Mace, founder and program director of The Center for Universal Design, as "...the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design" (The Center for Universal Design, 2008).

In this instance, it means designing all media elements, from scripts and shoots, to interfaces and exhibition spaces, so that all visitors can participate.

A simple example of this is the standardized inclusion of captions and American Sign Language (ASL) interpretation for all visitors; these elements can easily be integrated up front as a key part of media design, without having to make any changes to encompass them later.

Secondly, **we facilitate seamless personalization**. Where accessible versions or settings may cause a jarring experience for the many, we populate them in real-time for those who require them. We ask visitors once, up front, to determine the services and settings that they will find most useful throughout the museum journey, for example, audio description, larger font, or higher contrast. Those settings become their digital fingerprint throughout the museum experience, carried on their personal RFID profile and recognized instantly — from a distance — on any media interface visitors encounter, be it a monitor, an immersive large-scale projection, or an audio speaker.

To enable this, Centre Screen worked with Stark RFID on the infrastructure and with Kiss the Frog on the software delivery.

RFID is a simple enabling technology that allows light-touch data to travel wirelessly from one source to another (https://www.museumnext.com/article/rfid-and-its-use-in-museums/). The same technology might be used in your contactless bank card, the keycard you use to enter your workplace, a ticket to enter a concert, goods tracked around a warehouse, or to identify pets and livestock.

For a museum like the USOPM, RFID technology turns a traditional ticketing experience into a more sophisticated onboarding process, designed to help museum visitors understand the services available and then make their experience as seamless and fulfilling as possible.

After purchasing their ticket, visitors are given a lanyard, shaped like a backstage, access-all-areas pass from the Olympic or Paralympic Games. Their pass is then personalized at a login station via a short onboarding process. At the time of writing, Centre Screen is also working with project partners to facilitate visitor registration via mobile devices.

Visitors select additional audio and visual services ensuring that, from this screen onwards, their journey can be independent. They are also encouraged to identify up to five sports that they enjoy to allow us to tailor their content journey too. This does not mean that the museum shows only basketball if that is the only choice the visitor makes; the assumption is made that they like the action of a ball, a net and a small field of play. Perhaps, therefore, the visitor will be interested in sideways editorial journeys into sports like handball, goalball and water polo.

Figure 2: Centre Screen user testing an alpha version of our RFID registration with Olympic and Paralympic athletes. Using an approximation of the final hardware, participants are asked to independently complete the registration process. The team monitors and notes any challenges faced, talking with participants to understand their expectations and ways we could iterate the beta version of the software to increase inclusivity. Credit: Kiss the Frog.

Along the way to translating the theoretical into something deliverable, the team encountered some interesting challenges.

We used story mapping techniques to help the team consider the onboarding process. For example:

- How might a blind/low vision visitor independently associate their physical pass with the software to onboard?
- How might a family or a school group complete the onboarding process without having to re-enter data numerous times?

- How might we order questions about accessibility services in a way that enables visitors to complete the onboarding process by, for example, triggering a screen reader?

Of course, these challenges do not exist in isolation and need to be balanced against the museum's business, marketing and operational needs: for example, the collection of email and ZIP code data.

At the time of writing, we have established a tested and finessed Version One for opening. No doubt, the practical challenges inherent with opening and running a popular museum will present new scenarios and from here, we will work with the museum's operational team to ensure that staff and visitors are able to use their real-world experience to influence future iterations of this onboarding process. Ultimately, the goal will be the perfect balance between seamless throughput and independence for all.

A Journey to Creating Inclusive Interactives

Our first task in creating interactive experiences was to find consistent solutions across the museum; from standard touchscreens to immersive environments and both physical and digital interactive games.

While the team wanted to create consistent user interfaces, the visitor interaction points around the museum differ from gallery to gallery. Different shapes and sizes of screens and projections exist, so we came up with some consistencies to work across all of them.

Centre Screen created design guidelines for the museum using a range of sources that included best practices for digital design from gov.uk (https://accessibility.blog.gov.uk/2016/09/02/dos-and-donts-on-designing-for-accessibility/), Microsoft's inclusive design resources (https://www.microsoft.com/design/inclusive/), and the Smithsonian's guidelines on inclusive museum experiences (https://www.si.edu/access).

We focused our design thinking on:

- **Consistent UI:** Whatever the visitor's method of interaction, whatever the orientation or size of screen, how might we create a consistent language, both visually and semantically?
- **Universal keypad control:** For visitors who cannot control a touchscreen, how do we offer consistent and intuitive ways to navigate content, and how do visitors know where the keypad will be?
- **Sensory needs:** When a visitor enters the museum with a need for a lower-sensory experience, how might we inclusively avoid sensory overload and offer toned-down content where required?
- **Blind and low vision visitors:** If a visitor can't navigate around an experience visually, how might we offer an equivalent experience via sound? Of course, this area also includes a variety of visual considerations from color contrast to color blindness.
- **Deaf and hard of hearing visitors:** For visitors who cannot hear content, how might we design understandable rich media experiences?
- **Universal reach and sight lines:** Where screens are a variety of shapes and sizes, hung at various heights, how do we ensure that the user interface is always accessible for all, and our content always visible to all?

Positioning of Interactive and Visual Elements

Our early design work attempted to gather many of these challenges into wireframes that would determine our content and interaction design.

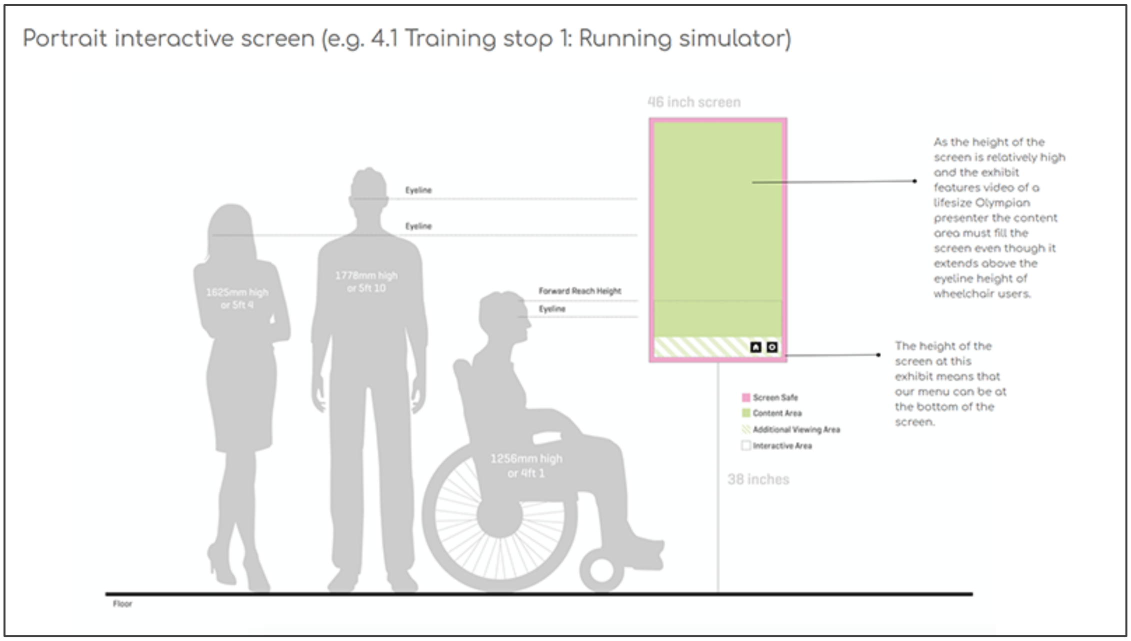

Figure 3: Early wireframing of a portrait screen. In this instance, the height of the screen presented some challenges and vastly reduced the interactive potential. Knowing the parameters we had to work with, we were able to shape the media design to ensure that any interaction takes place in the small dashed area towards the lower end of the screen, accessible by all. Credit: Centre Screen Ltd.

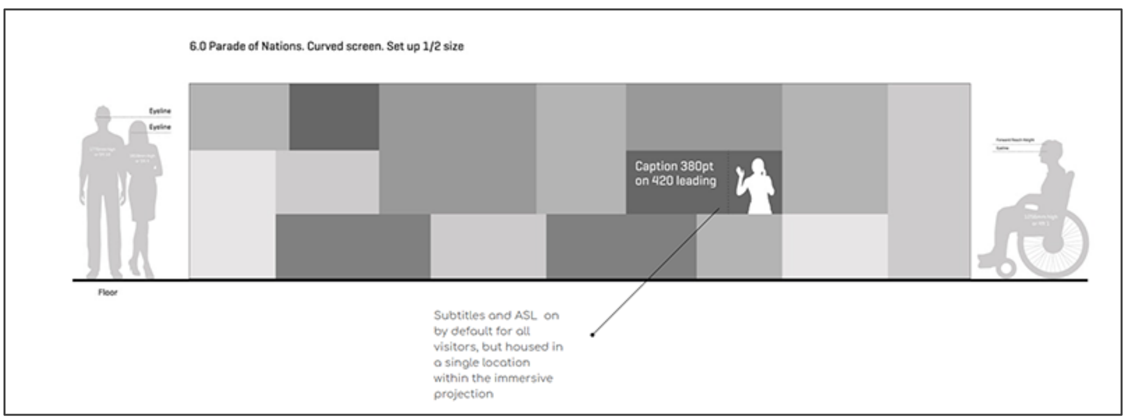

Figure 4: Early wireframing of an immersive screen. Here, visitors will enter a 270° projection, immersed in the ‘Parade of Nations’ that elite athletes enter to begin their journey at the games. When screens break out from traditional television shapes, we have to consider the best positioning for elements like captions and sign language interpretation based on the potential physical positioning of visitors in the space. Credit: Centre Screen Ltd.

Figure 5: Early wireframing of a video projection playback area. Architecturally, the museum is bold and non-traditional in its formation. Facets are used to break vertical and horizontal line work. The Centre Screen team adopted this design language to composite elements into frames in non-traditional ways, breaking out of the monotony of rectangular screen design and introducing shard-like components to house content. Credit: Centre Screen Ltd.

With the architecture and user journey of our interfaces tested through wireframes and flows, we set about adding the aesthetic front-end layer. We used the exhibition design guidelines and building architecture as our reference points, ensuring a visual balance between interactive screen design, objects, AV and graphic panels in each gallery.

No matter how well-informed the starting point, the design will always evolve as we begin testing, reflecting any changes to content, and incorporating feedback from our thorough and diverse user testing.

By way of example, Figures 6 to 9 shows the Winter Interactive Wall; an interactive display made up for four 55-inch monitors with a touch overlay and thin bezel between each.

Between Version One and Version Four, a few of the design changes included:

- **Improved readability:** The legibility of written copy (the main focus in this interactive) was stronger with white copy on a solid grey background, rather than the varying shades of blue used initially.

- **Flatter user journey for visitors using the universal keypad:** By removing layers of navigation (the pogoing up and down between menus and content), we found that visitors were able to more easily access their favorite content.

- **Better match to the architecture of the gallery:** A move away from facets and straight lines better matched the curvilinear features of the gallery.

- **Vertical scrolling main menu:** This allows visitors to navigate through content easily, regardless of their height. Visitors can scroll up and down from any point on the carousel, rotating like a rolodex, or simply select a sport from the top, middle or bottom. This meant that we wouldn’t have to rely on all users accessing a menu relatively low on the frame.

- **Combining Olympic and Paralympic sports:** Where Olympic and Paralympic sports share enough commonalities, for example, the rules, field, and number of players, we made an editorial choice to tell a combined story. This means that visitors who like snowboarding, but may not have encountered para snowboarding, will do so.

Figure 6: Version One of the USOPM Interactive Winter Wall. Here visitors can learn about all of the sports in the Winter Games, Team USA's impact on those sports, and find out about some notable winners. Credit: Centre Screen Ltd.

Figure 7: Version Two of the USOPM Interactive Winter Wall. This still frame shows how the wall will appear when two of the four screens are in active use (screens two and four), with an attractor screen loop playing out ambiently on the first and third screens. Credit: Centre Screen Ltd.

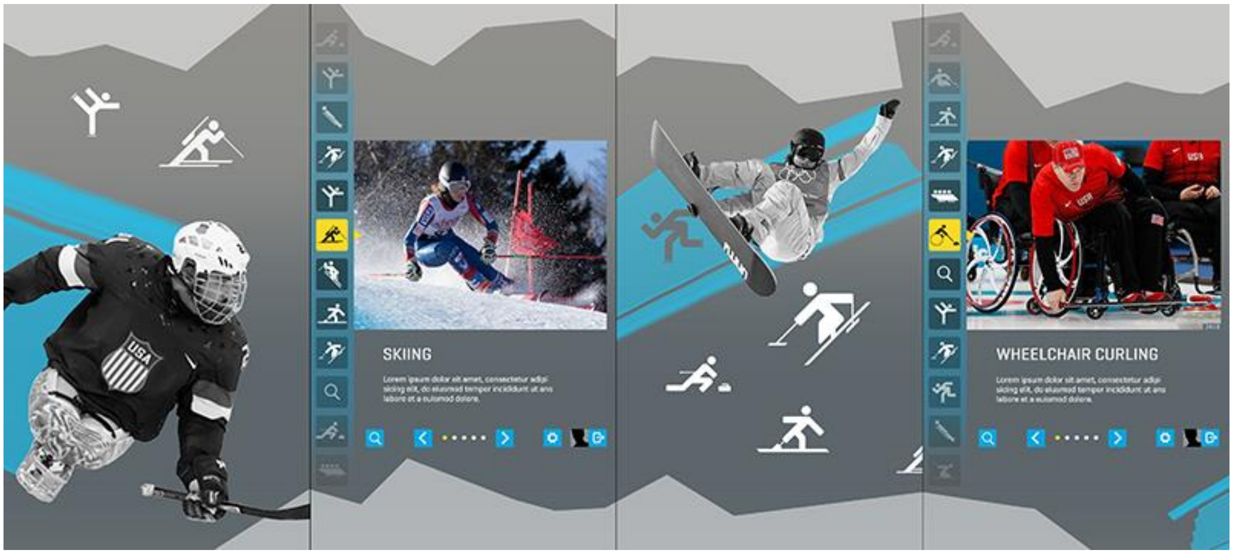

Figure 8: Version Three of the USOPM Interactive Winter Wall. Here we introduced the vertical menu for the first time, meaning that we could remove the need for visitors to hierarchically navigate up and down through layers of menu to find content. Credit: Centre Screen Ltd.

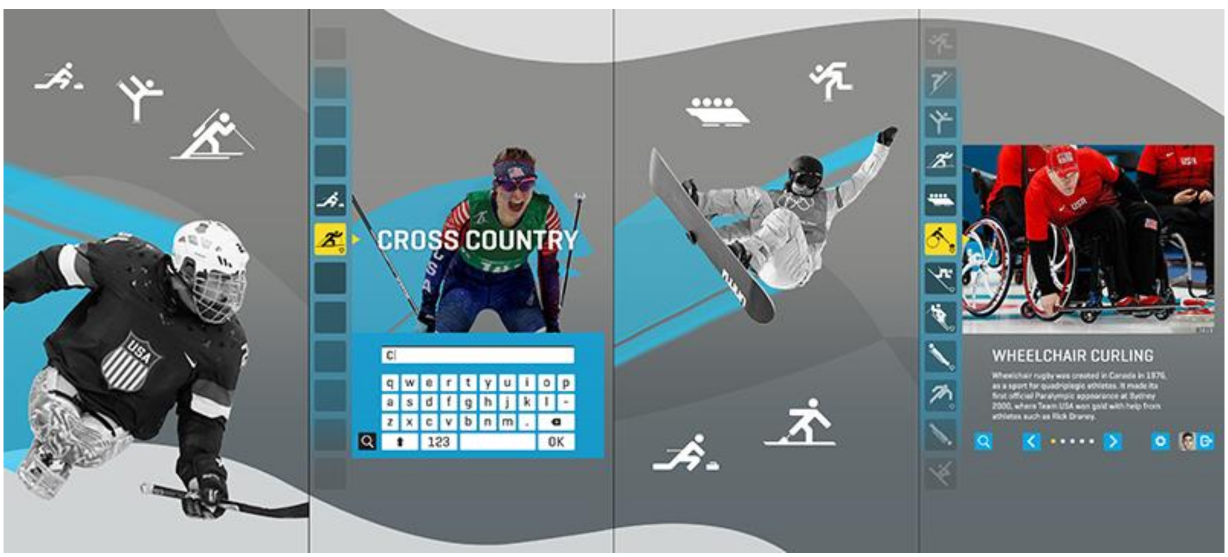

Figure 9: Version Four of the USOPM Interactive Winter Wall. This version tested best with audiences, allowing visitors to first find out about sports they love (curated via their RFID preferences) and then navigate a vertical A-Z list or search for a sport by name. Credit: Centre Screen Ltd.

Design Process Example: Gallery 4

Gallery 4 at the U.S. Olympic & Paralympic Museum is focused on training and provides a useful case study through which to articulate some of our inclusive design thinking.

At this point in the museum, the journey has already taken visitors through the purpose and history of the Games and shown the digital footprint of Team USA's paths to success. We would also expect visitors to be comfortable with the RFID-led personalization by this stage.

In Gallery 4, visitors get the chance to understand what it takes to be an elite athlete, with a focus on training. We begin with a brief introductory film, setting the tone for the gallery and providing an overview of the intense training regimes athletes undertake to become the very best.

Then comes the opportunity for visitors to participate at one of six interactive exhibits focused on training.

At each exhibit, visitors get the chance to learn about a particular skill important to a wide number of Olympic and Paralympic sports. They then have the opportunity to put that skill into practice for a particular sport via a short training exercise.

Selecting Inclusive Sports

How do we create interactive challenges that blend the digital and the physical, challenge the elite as well as novices, and ultimately allow all visitors to participate and learn through play in a safe and engaging museum environment?

In collaboration with U.S. Olympians and Paralympians, custom fabricators CRĒO Exhibits and hardware integrators BBI Engineering, and in full consultation with IHCD, Centre Screen started by analyzing the skills prominent in each Olympic and Paralympic sport, then focused on how the museum's exhibition spaces could be used to create practical training exercises that allow for learning as well as fun, stimulating gameplay. Practicalities ruled out a number of initially exciting ideas; others were rejected as they simply could not be made inclusive.

Breathing training, for example, was noted as a hugely important skill in many sports. However, using digital technology, hygienically monitoring and scoring a visitor for their ability to breathe within gameplay, in a manner authentic to Olympic or Paralympic sports, ultimately proved impractical.

The team drew up a short list and tested those ideas against potential user profiles. It was important to select a range of sports that would interest and inspire all visitors while creating a balance of Summer and Winter, Olympic and Paralympic, for all genders, all ages, and approachable by all visitors. They also had to be designed inclusively and assisted by technical solutions that would facilitate participation for all.

While this was always intended to be a vibrant, active space where the visceral movement of elite sports is represented by visitor participation, we also knew that it wasn't a gymnasium, and that many visitors wouldn't desire (or wouldn't be able) to break a sweat as part of their museum visit.

Case Study 1: Speed Training

We began with speed training. While this is the most active of all of the training stops in this gallery, it is also the most familiar sport for many. Although visitors are unlikely to beat world records, everyone can move down a track in a manner that best suits them. As they do so, they will learn about the tools and techniques employed by U.S. athletes. Almost all visitors will have experienced a race of some kind.

We felt it important that visitors have the choice to either race against someone like themselves, or simply someone they would like to race against: male, female, modern, historic, Olympic or Paralympic (including wheelchair, blade and blind/low vision sprinters).

The visitor journey begins at an introductory screen on which Olympic champion Carmelita Jeter talks through the key elements of sprint training, supported by ASL interpretation and captions. A universal keypad and screen reader enable additional controls for navigation and interaction as well as to adjust settings.

Jeter describes each visual we see on screen so that the setup can flow without the need for potentially overwhelming additional audio description.

Figure 10: Centre Screen user testing an early prototype of the Sprint game with U.S. Olympic and Paralympic athletes. The challenges here included both interacting with the introduction screen as well as the track. Along the course, we use sensors to track and score visitor movement. At the finish line, we have a run-off zone, with a cushioned wall. Stopping distances, and signposting the finish, were of prime concern for this user testing session. Note: the early prototype was created before we were able to confirm the on-screen presenter. Credit: CRĒO Exhibits.

Next, a call to action includes an overview of how to participate with audio and visual design working together to signpost visitor progress during the race.

This additional audio gives visitors a sense of their relative position on the course via hidden sensors that track their movement. Crucially, we indicate when the visitor is reaching the final part of the track to ensure that any blind/low vision visitors are able to slow and stop before reaching the 'crash mat' wall, something we found sighted visitors did naturally during testing.

The race is inclusively designed. Participation takes place on a track accessible by all. Visitors are welcome to sprint, jog, walk, wheel or travel down the track in whatever manner is most comfortable to them, with no judgement — even the fastest visitors will be left in the digital dust trails of the virtual athletes they are racing against!

During the race, a large projection shows the athlete the visitor has chosen to race against, as well as a particle cloud representing each visitor, that mirrors their movement along the track. All information portrayed visually on this projection is also conveyed with audio equivalence.

Fig 11: A very early mockup of the track and project, not to scale. As visitors make their way along the sprint track, sensors capture their movement and a representation of each visitor is projected on an adjacent wall, following an Olympic or Paralympic sprinter. Credit: CRĒO Exhibits.

Upon completing the race, the visitor reaches a final screen where they receive feedback from the athlete as well as race data, photography and video, which will be saved to their 'digital locker' online via RFID. All of the accessibility services selected earlier will be available at this screen.

Case Study 2: Aim Training

We considered several sports involving aim, including:

- Shooting/biathlon (the idea of visitors participating with guns in an open-carry state was something the museum was keen to avoid).
- Basketball (perhaps a little too obvious, given the multitude of basketball games in arcades).
- Boccia (hard to replicate accurately with digital technology, this is much more of an analog aiming game).

After much deliberation, we settled on archery to explore further as an ‘aiming’ sport. As with sprinting, archery is enjoyed in both the Olympic and Paralympic Games.

But unlike sprinting, archery is not a sport we can assume all visitors will have experienced. As such, we found through early user testing that we needed to provide the visitor with both an overview of the sport and detailed information on how to engage with the physical bow in the museum context.

Initial testing with the prototype bow and our early gameplay software allowed us to design the bow inclusively. We wanted to retain authenticity, but make compromises where necessary. For example, in order to make the exhibit equally usable by both left and right-handed visitors, we avoided aligning the sight to one side.

Rather than having a large and small bow, we settled on a medium-sized bow that all visitors could use, supported by architecture that allowed simple vertical movement to change the height and add some freedom to spin for the optimal standing or sitting position.

Figure 12: User testing an early prototype of the archery game with Paralympian athletes. We taped out a usability zone on the floor in which we focused the RFID reader, ensuring that we can accurately identify the user of the bow without any need for the visitor to interact with the screen. The physicality of the bow and its relation to the gameplay were our main areas of focus in this session, ensuring that all could approach the bow and with some simple instruction, understand the technique required for success. Credit: CRĒO Exhibits.

We worked with a number of Paralympians to test the prototype bow. While sighted visitors would be able to see the target, calibrate and aim, we needed a solution for those who could not. One of our users during testing was a blind/low vision swimmer who was able to work with us to co-design a solution for audio-led aim.

Our goal was to provide adequate, clear information to visitors, without overwhelming them, and to be authentic to the skills of the sport. We wondered if sound design akin to the audible feedback of a parking sensor might help guide visitors to the target. Parking sensors are proximity sensors for road vehicles, designed to alert the driver of obstacles while parking via visual and audio feedback. We hoped that the same dynamic feedback could be achieved in sync with moving the bow.

We were introduced to Team USA’s blind/low vision shooting team at the United States Olympic & Paralympic Training Center. While there are currently no Paralympic disciplines of this ilk, trials will take place at Tokyo 2020 with the possibility of introducing the sport at future Games.

Figure 13: Observing low vision shooters at the U.S. Olympic & Paralympic Training Center. Shooters use audio signals driven by a sensor on their gun to help them to accurately locate their target. We observed and noted how this technology was used at an elite level, before interviewing a number of shooters and coaches to understand how best we could learn from their success and create a version that didn't need elite level coordination to utilize. Credit: Centre Screen Ltd.

Working with the blind and partially sighted shooters at the training center was incredibly revealing as we witnessed the high degree of accuracy they could achieve when aiming via a sound guide. Having experienced the audio guide at an elite level, we were able to find opportunities to simplify that system for museum visitors. For example, from our sound design and testing we found that the audio tone still worked with a subtler range of frequencies. There was no requirement to know the difference between up, down, left and right. Instead, this was simplified to: "As an audibly-led visitor, I need to know my relative position to the target."

While this audio approach doesn't communicate every piece of data that we could offer to the visitor, we found during testing that it provided enough information for participants to cognitively process, without overloading.

Throughout audio design we used *The Sonification Handbook* as a reference point. This summary from its section on psychoacoustics captures the balance of audio information needed for visitors:

> In the context of auditory displays, it is important to ensure that the fidelity of a display is well matched to the encoding capability of the human auditory system. The capacity of the auditory system to encode physical changes in a sound is an important input criterion in the design of an auditory display. (Carlile, 2011)

Having obtained user feedback, we sought to further enhance the experience. The same publication suggested a direction: “...the addition of reverberation to a display can substantially enhance the sense of ‘presence’ or the feeling of ‘being in’ a virtual soundscape” (Carlile, 2011).

As a gameplay mechanic, the addition of low-frequency tones, via a subwoofer, helped us retain the visceral impact necessary to cue reaction points.

We found that this approach enabled participation for all, and early testing has shown that aim can be just as accurate for those using sound as for those using sight. Indeed, to further the inclusive nature of this exhibit, we are currently testing the gameplay with the audio design enabled for all visitors.

Figure 14: User testing an early prototype of the archery game with Team USA athletes. As the software was at prototype stage, we used an informal testing style whereby our production team worked with participants to fill in the blanks of the software. This helped us to understand what we needed the software to do in order to facilitate independent gameplay. Crucially, this is achieved without the cost overhead of a museum member of staff being required to help on site. Credit: CRĒO Exhibits.

A Quick Tour Around the Rest of Gallery 4

This pattern of inclusive thinking and design continued throughout Gallery 4. Other training activities include balance, strategy, memory, and reaction.

Balance: Initially, this had been scoped as a dance mat game focused on gymnastics. However, this felt restrictive for wheelchair users. We needed a solution that would allow all to participate, and let us score their participation via the software. We settled on a skeleton sled (https://www.teamusa.org/USA-Bobsled-Skeleton-Federation) from the Winter Games. Using an angled, upright sled, visitors can lean in to navigate a course by distributing their bodyweight at the right times, with appropriate force. For those who cannot use a huge amount of force, the game is still enjoyable and playable. For visitors in a wheelchair, or those who use a cane or crutches to walk, we found that the structure of the sled facilitated their needs. With a simple and easy way to adjust the height of the sled, the position and size of the projected display enabled all to participate. For those who cannot see the ‘balance-o-meter’ visual to aid their movement, or for those who prefer an audio guide, we added an audible equivalent, following similar principles to those used in the sound design for archery. Again, at the time of writing, we’re testing this as an inclusive gameplay layer.

Figure 15: User testing an early prototype of the Skeleton game with Team USA athletes. Through testing proof of concept technology, we were able to begin our full software design process based on what we had seen working and avoid putting resources into elements of gameplay that wouldn't work for all visitors. Working with elite athletes from Team USA's varied roster, we were able to gain a diversity of opinion on many factors of gameplay and create authentic experiences for all. Credit: CRĒO Exhibits.

Strategy: Conscious that all of the activities in this gallery so far involved some degree of physical exertion, we also wanted to ensure that the concept of training was not limited to the common clichés. Brains are as important to all Olympic and Paralympic sports as brawn. Borrowing from game theory (the study of strategic interaction), we put the visitor in the position of the decision-maker, testing their action intelligence to make strategic decisions in the heat of the moment, with a clear mind to focus on the outcome.

> Game theory is the science of strategy. It attempts to determine mathematically and logically the actions that 'players' should take to secure the best outcomes for themselves in a wide array of 'games.' (Dixit and Nalebuff, 1999)

Sporting success for Team USA is built on far more than just the physicality of competition and this felt like a great opportunity to champion the wider teams in sport: the coaches, analysts, and data scientists.

We built a simple, accessible quiz format using archive footage, giving visitors a series of options. None of the options are right, and none are wrong, but some result in a higher chance of success for the team. We based the quiz on sled ice hockey (https://www.teamusa.org/US-Paralympics/Sports/Sled-Hockey). Team USA describes the Paralympic sport as such:

> Just as in ice hockey, sled hockey is played with six players (including a goalie) at a time. Players propel themselves on their sledge by use of spikes on the ends of two three-foot-long sticks, enabling a player to push himself as well as shoot and pass ambidextrously. (United States Olympic & Paralympic Committee, 2020)

While not all visitors would be familiar with the sport, the concepts involved in attacking and defensive work are analogous to many other team sports like soccer, wheelchair basketball, and water polo. Following the design pattern of our other touchscreen interactive content, the additional challenge here was to ensure that visitors who could not see the action clips could fully understand from an inclusive, detailed audio description exactly what was happening and what their options would be, to inform their strategic decision-making.

Memory: Alpine skiing (https://usskiandsnowboard.org/) was the sport chosen to focus on another mental skill. Visitors put themselves in the position of an athlete who needs to visualize a sequence of events. This could have applied to a much more intricate sport, like diving, taekwondo or equestrianism, but we felt that using ski poles as an input would create an authentic, achievable user interface.

As with the skeleton board, we created a prototype with the poles alongside an early iteration of the gameplay to ensure that they could be used by any visitor. We found that spacing them widely enough for a wheelchair user meant that they were slightly wider than the average skiing stance, but the gains for those who needed extra width far outweighed the few concerns we had from others. Again, adding the ability to manipulate the height, and the range of full 360° movement (even though we only actually needed to register lateral movement) meant that all visitors we tested with were able to participate.

We faced a challenge to ensure that the concept of memorization, often so reliant on visualization, was achievable for blind or low vision visitors. Working closely with Team USA Paralympic athletes and the National Governing Body (NGB), we were able to understand how blind and low vision skiers work with a guide in training and competition, then replicated this in a way that could be software-driven. We were fortunate to work with Sarah Will, winner of 12 gold and one silver medal for Team USA at the Paralympics and a member of the U.S. Olympic and Paralympic Hall of Fame. Will brought a wealth of experience to the team, having competed at such an extraordinary level of success, then worked as an instructor in Vail, Colorado. She was able to help create gameplay that would provide the optimal balance of difficulty, fun and accessibility for all.

Reaction: The final game in this gallery is a reaction test, focused on goalball (https://www.teamusa.org/US-Paralympics/Sports/Goalball). Goalball is a sport in which players are blindfolded, relying on their hearing to monitor the movement of a ball with a bell inside. Conscious that a traditional Batak board would not be accessible for many, we replicated a software approximation of goalball and used an Orbbec skeletal tracker (https://orbbec3d.com/productastra-pro/). Visitors are asked to follow a simple onboarding tutorial sequence through which the software can understand their reach and speed of movement. We then tailor a game to their ability. Virtual goalballs appear on a large projection screen — the visitor's role is to act as goalkeeper, virtually blocking the balls. We monitor their reaction time as a scoring mechanic. Our game uses spatial audio to replicate a ball coming from a variety of angles. For visitors unable to hear the detail, or those who would prefer a visual cue, we offer an additional visual layer to enable participation. Our testing proved that the calibration enabled gameplay for all, regardless of their dexterity.

Figure 16: User testing an early prototype of the goalball game with Olympic and Paralympic athletes. Here, an approximation of the hardware setup was created with speakers mounted above the projection and below. The main thing we learned from this session was how detailed calls to action needed to be to allow visitors to participate intuitively in a motion-led game. Credit: CRĒO Exhibits.

Conclusion: A Shared Achievement

Designing the interactive experiences for the United States Olympic & Paralympic Museum has been a lengthy, fascinating, and rewarding process.

As a fundamental principle of Olympism, the official Olympic Charter states that:

> The practice of sport is a human right. Every individual must have the possibility of [practicing] sport, without discrimination of any kind and in the Olympic spirit, which requires mutual understanding with a spirit of friendship, solidarity and fair play. (2019)

The exceptional opportunity to design interactive experiences that express the positive values of Olympism and Paralympism has allowed us to explore new ways of working guided by those very principles; a unique synergy of subject and process.

Beyond these values there are, of course, the wider, societal issues of true equality and the manner in which we should judge inclusive design. Since, after all, what is the opposite? We are now mindful to not use the word ‘inaccessible’ to describe something that doesn’t work for able-bodied people. Instead, we endeavor to work to the principle that if any person finds they cannot engage or interact with what we are designing and producing, the correct word is ‘unusable.’

If we all start to apply that simple shift of perspective by asking, "is this design usable?" then we move to a mode of working that really works for everyone — an approach that all should be eager to develop further, continue to apply universally to our work, and share as a paradigm methodology.

The lack of compulsory industry regulations regarding inclusivity in the field of AV and interactives was initially a major challenge. Now it feels like our greatest opportunity. The creativity and collaboration this necessitated has been our most rewarding and lasting outcome. When developers, contractors and designers share their experiences of creating genuinely accessible visitor experiences we all make progress towards true inclusivity.

We feel that the best way for the industry to move forward is to build upon this experience, draw from resources such as this publication, and continue to develop a strategic methodology that is in itself a collaborative, and above all, inclusive process.

Acknowledgements

Centre Screen's design and user testing journey has been facilitated, supported and advised by the U.S. Olympic & Paralympic Museum, U.S. Olympic & Paralympic Committee, CRĒO Exhibits, Gallagher Museum Services and the Institute for Human Centered Design. We are endlessly grateful for the opportunity to participate in the delivery of this wonderful project.

We wholeheartedly thank our project leaders and partners from U.S. Olympic & Paralympic Museum, U.S. Olympic & Paralympic Committee, Gallagher & Associates, Gallagher Museum Services, CRĒO Exhibits, Barrie Projects and Kiss the Frog, who have collaborated with us across the research and user testing.

Our heartfelt gratitude also goes to the Olympic & Paralympic athletes of Team USA for their ongoing insightful input, advice and expertise, and Sherry Von Riesen of the U.S. Olympic & Paralympic Committee for the invaluable coordination across the user testing sessions.

We also thank Jan Majewski and Anoopa Sundararajan from the Institute for Human Centered Design for their continued guidance and expertise, which has greatly improved our focus and design strategy throughout the project.

Any errors are our own and should not tarnish the reputations of these esteemed persons and the above-mentioned institutions.

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Inclusive Digital Interactives

Best Practices + Research

Chapter 3

An Ongoing Experiment: Developing Inclusive Digital Interactives at a Science Museum

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September 2020

Introduction

> One of the most pervasive messages of my childhood was, 'Not for you.' That's something that's incredibly destructive for the life of a child. Places like science museums can dispel those messages more than almost any place else. I remember my few visits to museums as just wonderful. I believe everybody should have that experience. And I do mean everybody.
> - Betty Davidson, Ph.D., Museum of Science, Boston

Betty Davidson initiated the Museum of Science, Boston (MOS)'s journey toward the inclusion of people with disabilities in the 1980s — before the advent of the Americans with Disabilities Act (ADA), and long before digital interactives became commonplace in museums. At that time, she worked as a museum volunteer, and was inspired to seek funding from the National Science Foundation (NSF) to develop the museum's first inclusive exhibition — *New England Habitats*. After receiving the grant, she modified the museum's natural history dioramas to include simpler text, images, audio labels, smell boxes, taxidermy specimens visitors could touch, bronze sculptures, and tactile models. She also worked closely with evaluator George Hein who found that the refurbished exhibition improved the experience for people with and without disabilities (Davidson, Heald, & Hein, 1991). Their collective work changed exhibit design practices at the MOS for decades.

If you work at the Museum of Science, you've likely heard the above story. It is one we tell all new employees during our orientation program. While truthful, the story is incomplete. The museum's journey toward inclusive practices is a much more complex story that spanned many years, if not decades. Through the years, the museum's exhibition teams have tended to inclusive design to varying degrees. In the 1990s, only a few exhibition projects included the inclusive design features Dr. Davidson pioneered in *New England Habitats*. In the early 2000s, most exhibitions attended to inclusive design, but not all. Although inclusive design is now standard practice at the Museum of Science, the ways in which we achieve inclusion continue to evolve. As the world changes around us, so too must the museum. This is particularly true for digital interactives, where the technologies that enable these experiences are continually advancing, which creates opportunities for new pathways for inclusion as well as changes in audience expectations.

Continually evolving our exhibit practices to be more inclusive takes constant vigilance. As we looked toward the future and sought ways to ensure that we are always advancing our inclusive design practices, we began to ask — what does organizational change toward inclusion look like in a science museum context and how can this change be sustained over time?

In this article, we provide an answer to this question by sharing findings from a study we conducted that explored change toward the inclusion of people with disabilities at science museums across the country. We then discuss how we applied the study's findings to establish systems and supports that enable ongoing organizational learning about inclusive digital interactive design. Finally, we describe what we have learned about ways to design inclusive digital interactives in a variety of contexts and how we have improved our efforts over time. Our hope is that our experience will inspire you to also engage in a continual process of organizational learning that leads to the development of museum experiences where everyone feels welcome and supported to learn.

Study of Organizational Change Toward Inclusion in Science Museums

In 2011, we conducted a qualitative, multi-case study to explore what the change process looked like in science museums that had taken actions to be more inclusive of people with disabilities. Guided by two overarching frameworks — organizational learning and the social model of disability — this study sought insights into the following question: what are the contexts and processes that facilitate, sustain, or impede a science museum's change toward practices that are inclusive of people with disabilities? (Reich, 2014)

We chose three science museums to be the focus of this study, none of which were the Museum of Science. The chosen museums varied in size and geographic region within the United States, but shared a documented history of efforts to include people with disabilities. We visited these museums on three separate occasions, and used these site visits to gather data through observations and interviews with people with disabilities and staff members, observations of museum work, and collection of documentation such as reports, pictures of exhibitions, and programmatic plans. Our data analysis focused on generating descriptions and interpretations of the individual museums and the collection of museums (Stake, 2006), and included opportunities for member checks by staff members of the chosen museums as well as inclusion experts from the broader museum field (Merriam, 1998).

Through this study, we generated descriptions of the kinds of processes and contexts that facilitate change toward inclusion in science museums, and those that foster or impede the development of more inclusive practices.

What the experiences of these three museums specifically pointed out is the need for us to view change toward inclusion not as a one-time endeavor or as the purview of one particular individual, but rather, as an ongoing process that is embedded within the work of a broad range of organizational areas.

There was never a moment when the museums were suddenly fully inclusive of people with disabilities. Rather, each museum was engaged in a process of continual improvement, often unintentionally. Each museum had areas and practices within it that fostered inclusion of people with disabilities and those that presented barriers to inclusion. Also, the inclusive practices of each museum tended to be episodic, with some projects or particular time periods promoting greater inclusion than others.

Although none of the three science museums were completely consistent in their inclusive practices, our findings did point to a number of shared contexts and processes that were present across all three, which connected to their inclusive practices and sustained change toward inclusion. It is from these shared conditions and processes that potential actions for change emerge.

Action 1: Involve people with disabilities in the work of the organization. All three museums intentionally hired people with disabilities as staff members, volunteers, consultants, and advisors with the specific aim of creating a more equitable workforce. Not only did this practice lead to more people with disabilities working at the museums, it also promoted the importance of creating an environment that is welcoming and inclusive of people with disabilities.

Involving people with disabilities in their work shifted the notion of inclusion within the organizations: it was no longer an ideology intended for an abstract audience, but rather a specific practice aimed at improving the museum for real individuals, including their colleagues. These experiences were so powerful that lessons learned by one staff member were passed along to other staff members and became part of the organizational narrative. This was true even for staff members with one kind of disability who had the opportunity to work with individuals with other disabilities.

Action 2: Reach a broad range of staff members by embedding information about inclusive practices into museum communications, professional development, and large projects. The need for organization-wide understanding extends past the need to make the entire museum accessible and connects to longer-term stability of inclusive practices. If the practices employed by one area of a museum are not valued throughout the organization, they can meet internal resistance, making them harder to sustain. Implementing inclusive practices fully and sustainably therefore requires a shared understanding and commitment by all. With this aim, the three museums shared information broadly and intentionally through required professional development offerings, at meetings attended by all staff members, and by embedding inclusive practices into large-scale projects that involved work across a range of organizational areas.

Action 3: Engage in a process of ongoing experimentation and reflection around inclusive practices. Although change can occur slowly over time by embedding inclusion within existing work in a way that enables ongoing experimentation and reflection, it generally follows a more punctuated pattern where specific events precipitate periods of substantial change. Such periods can follow the development of a new large-scale exhibitions, the opening of a new building, or an extensive collaboration with an external partner such as another science museum or community organization. Substantial change is most likely to occur when the inclusion of people with disabilities is listed as one of the stated goals for the initiative, and when new strategies are tested with people with disabilities either formally, through evaluations, or informally, through conversations and observations.

At each museum, the change that took place during these periods tended to go beyond small iterative adjustments to include large leaps in the overall approach, philosophy, or goals. Staff members who worked on these projects became highly knowledgeable about inclusive practices and subsequently became identified as internal champions for the inclusion of people with disabilities. These internal champions remind others about the importance of including people with disabilities and often become recognized as resources for those seeking help and advice for how to make the environment more inclusive.

Action 4: Promote the idea that design strategies that benefit people with disabilities improve the museum experience for other audiences as well. The notion that designs intended for people with disabilities can improve the design for people without disabilities has been extensively advocated by individuals who promote the use of universal design (UD) (Story, Mueller, & Mace, 1998; Bowe, 2000; Rose & Meyer, 2002) and has been proven to have merit by studies conducted in a variety of fields (Davidson, Heald, & Hein, 1991; Reich, 2006; Johnstone, Thompson, Bottsford-Miller, & Thurlow, 2008). Findings from this study further suggest that when organizations highlight the benefits of inclusive practices for other audiences, those practices are more likely to be sustained.

The idea that inclusive practices benefit a broad range of visitors seems to be an important part of the rationale that museums present for continuing those practices and regularly embedding them in their work. It also appears to be integral to developing inclusivity as part of an institutional identity. Therefore, it is important that museum professionals explicitly share the ways in which inclusive practices benefit a broad range of visitors when sharing information with colleagues and partners.

These four actions outline a strategy that science museums can employ to make their museums more inclusive of people with disabilities. While simultaneously sharing these findings with the broader museum field, we also made an effort to apply them to our own work so that we could better fulfill our aim of creating environments and experiences that are welcoming and inclusive of all.

Organizational Change and Inclusive Design at the Museum of Science

Based on the findings from this study, we have instituted a number of processes designed to promote ongoing organizational learning about inclusive practices. Our aim is not just to sustain the change, but to systematically improve our inclusive practices over time. Although this is an institution-wide effort at the Museum of Science, the description below is limited to a discussion of the actions we have taken to ensure that the digital interactives in our exhibits are designed to be as inclusive as possible.

We involve people with disabilities in the development of digital interactives. Our exhibit teams include staff members with disabilities. We also have established an exhibit accessibility advisory committee that routinely provides feedback on our exhibits as we develop them. Members of the committee are all experts in the design of inclusive learning experiences (including the use of technology to facilitate inclusion), and many of them also have disabilities. During our advisory committee meetings, we ask for reviews of our exhibit plans at various stages of development — early conceptual planning, prototyping, and final design. Their feedback helps to bring ideas forward from other fields that expand our thinking of ways to develop inclusive exhibits.

We continuously communicate the importance of inclusion through our existing channels of communication, sharing information about our inclusive design practices during meetings and embedding inclusion as a topic in professional development sessions. In addition, we have formed a committee called the Universal Design Exhibits Committee that is comprised of representatives from various departments within our division. This committee meets monthly with the sole purpose of discussing ways to advance our inclusive design practices. Beyond meetings, we embed prompts in our team documents that remind us to think about inclusive design at all stages of exhibit development. We use this documentation not only as a reference for team members, but also for the contractors and consultants we hire. Other examples that summarize our approach to universal design are the UD page on our website (https://www.mos.org/UniversalDesign) and the full-scale universal design poster we have created. The poster is particularly powerful as we display it in multiple areas of our working space so staff can easily refer to it.

We intentionally engage in a process of ongoing experimentation and reflection around inclusive practices, utilizing different kinds of projects for different levels of learning. When we begin new large-scale projects, we now start by identifying a challenge we wish to address through this project that builds upon our past achievements and pushes the boundaries of inclusion even further. We address these new challenges by inviting visitors with disabilities to participate in the formative evaluation of each new exhibition. Such testing is critical as it ensures that what we create will be effective for all audiences and serves as a punctuated point in time when the team can reflect on where they feel they have successfully achieved their inclusive aims and where more work is needed. Beyond experimenting through existing projects, we have instituted a new research and development agenda for the museum, and actively seek funding for projects that are specifically designed to advance the inclusion of people with disabilities in science museums.

We always keep what we learned through Betty Davidson's early work about inclusive design — that designing experiences for people with disabilities also improves the experience for people without disabilities — at the forefront of our discussions. It is for this reason that we have chosen universal design (UD) (Connell et al., 1997) and Universal Design for Learning (UDL) (Rose & Meyer, 2002) as the overarching frameworks that guide our exhibit development process. The principles of UD, which extend from the field of architecture, provide guidance on the physical design and usability of the interactives. The principles of UDL, which were created within the field of education, provide a necessary framework for thinking about the structure of the learning experience. In particular, these guidelines highlight the need to attend not only to a diversity of ways that visitors receive information, but also variability in the ways visitors can interact and emotionally engage with the experience. In recent years, this framework has led us to conduct a number of research and development projects that specifically address emotional engagement for all learners (Rappolt-Schlichtmann & Daley, 2013; Rappolt-Schlichtmann, Evans, Reich, & Cahill, 2017; Rappolt-Schlichtmann & Todd, 2020).

Guided by the actions above, inclusive design at the Museum of Science has continued to evolve. While we started by focusing on physical access to exhibits, since the early 2000s we have strived to ensure that each exhibit's content and main messages are also accessible to all. Findings from our summative evaluations have shown us that we have largely achieved this aim. We learn new ways to become more inclusive from each new project. Although we have made mistakes along the way and we sometimes fail, our overall trajectory has been a positive one — our inclusive practices are stronger now than they've ever been before.

Examples of Inclusive Digital Interactives at the Museum of Science, and What We Learned Over Time

Described below are examples of some of the inclusive digital interactives we have developed in the past five years, and what we learned from the development of these interactives. These stories, presented in chronological order, were written by the members of the Universal Design for Exhibits Committee and collectively represent the various departments and expertise of the exhibits and research division at the MOS. By sharing these stories, our hope is that our process for organizational learning will become clearer, and that you may glean new insights on inclusive design that can inform the practices of your own organization.

Project 1: Creating Museum Media for Everyone (Completed in 2014)

Creating Museum Media for Everyone (CMME) was a project funded by the NSF that brought together a diverse group of professionals from a range of technology and accessibility domains to advance the science museum field's approach to researching, developing, and evaluating inclusive digital interactives. This project yielded a number of white papers and exemplars that describe mechanisms museums can use to create more inclusive digital interactives (https://www.openexhibits.org/research/cmme).

One of the exemplars we developed was called "The Museum Wind Lab," which was a computer-based, multisensory interactive that enabled visitors to explore data about the wind energy generated from the turbines on our roof. Our idea for this interactive, which emerged from a design charrette we held with professionals from diverse fields of study, and with lived experiences (Beyer, Lindgren-Streicher, & Reich, 2014), was to provide visitors with ways to explore these data using haptic, visual, and auditory representations.

To develop and test this exhibit experience, we used:

1. personas to guide development (Iacovelli, 2014b),
2. prototype testing with individuals with disabilities who took part in the charrette, and
3. prototype testing with general visitors and visitors with disabilities, consistent with our typical practices.

We developed the persona profiles based on data from prior formative evaluations, and these profiles helped us to anticipate visitor experiences. Testing with visitors and colleagues with disabilities was critical in order for us to gain insights into their experiences, while general visitors also helped to provide clarity about usability, learning, and interest.

Our first prototype for the interactive presented visitors with both sound and air pressure cues that represented a graph showing power produced by two wind turbines at different wind speeds (Figure 1). During prototyping, many visitors experienced a host of difficulties when trying to derive meaning from the multisensory features we included. For example, most visitors did not make any connection between the air, sound, and visual graph, while a few sighted visitors missed the visual graph completely. At times, visitors used the exhibit in unintended ways, such as playing the prototype like an instrument or thinking it was a game in which you manipulate the wind speed or power with your fingers. Additionally, some visitors did not notice that the computer screen was a touchscreen, but unintentionally activated it when pointing to the screen. When prompted to use the touchscreen, visitors were unclear as to whether anything was happening because scatterplot points on the graph were hard to see. Visitors were also confused when there were no sound effects in areas with no data points. Overall, visitors experienced sensory overload and were not able to make sense of what the exhibit was supposed to convey (Iacovelli, 2014a).

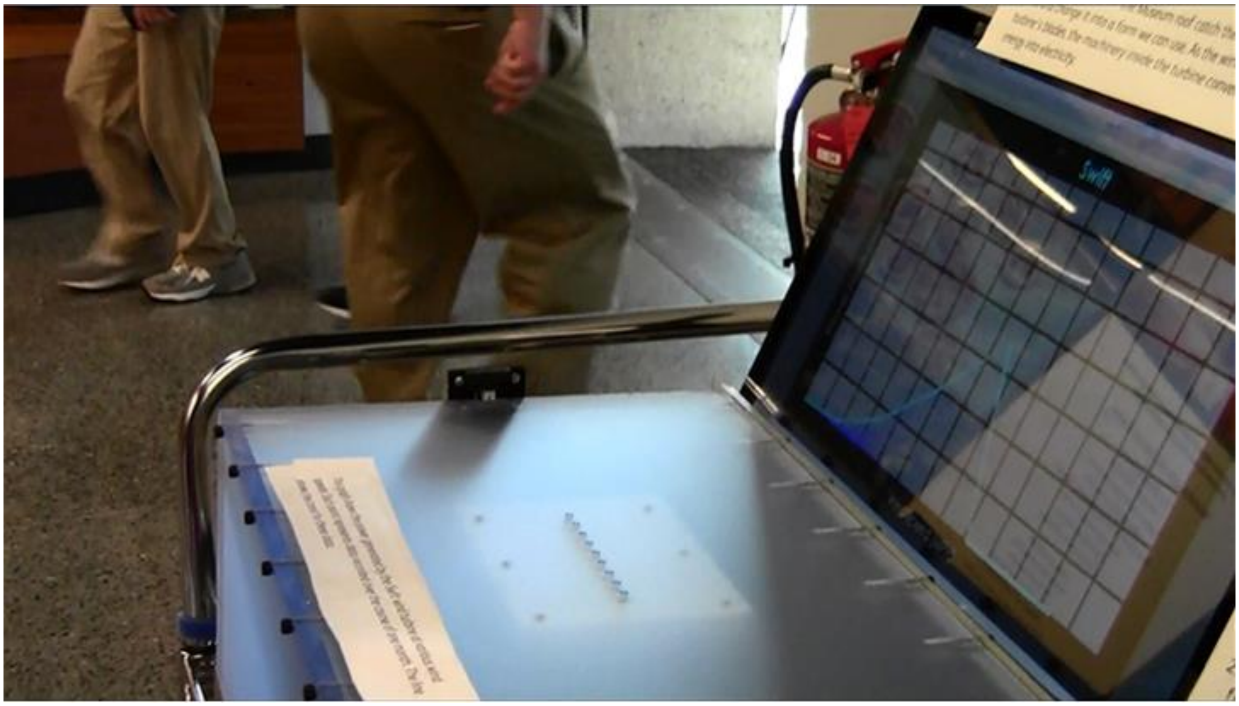

Figure 1: This early prototype of "The Museum Wind Lab" used sound and air pressure cues to represent graphical data about power produced by the museum's wind turbines. Photograph by Malorie Landgreen. Courtesy of the Museum of Science, Boston.

Visitor responses suggested that there were too many sensory experiences included in the prototype, making the exhibit content and instructions hard for them to understand. This feedback encouraged us to minimize sensory cues in the exhibit, including disabling some touchscreen capabilities, eliminating air pressure cues, and removing tactile elements from the buttons. At the same time, we added new features, such as broadcast audio for all touch actions on the graph, including a static sound when visitors touch a no-data area of the screen. The final exhibit includes a screen with a clear, tactile overlay which allows visitors to locate the screen's touchable areas. Visitors can touch the slider or areas of the graph to see and hear the graphical data. The exhibit has buttons that illuminate when the relevant graph is displayed, as well as tactile representations of all of the turbines represented in the graphs (Iacovelli, 2014a) (Figure 2).

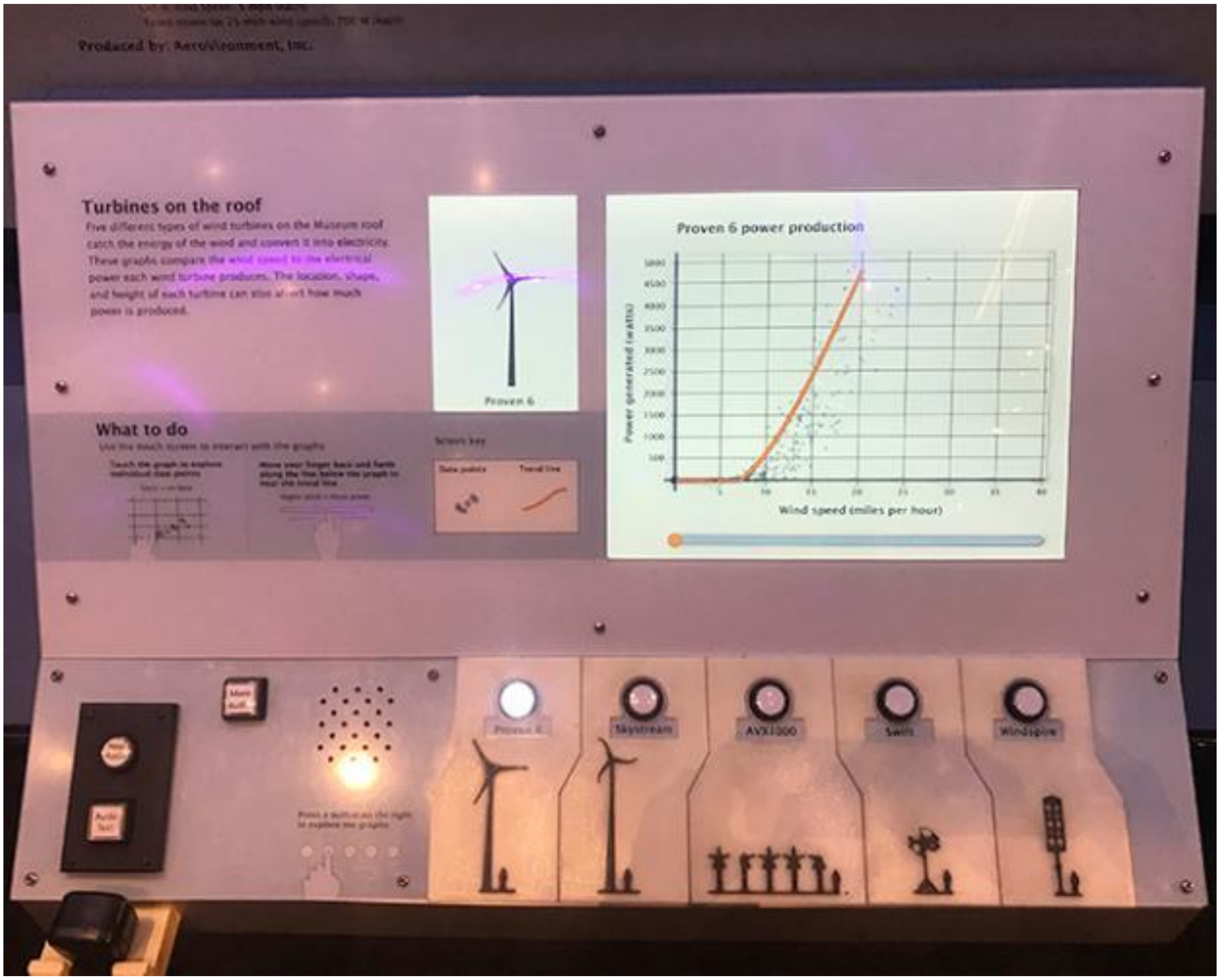

Figure 2: “The Museum Wind Lab” incorporates sound, visuals, and tactile elements to allow visitors to explore the power generated by the museum’s wind turbines. Photograph by Jessica Ghelichi. Courtesy of the Museum of Science, Boston.

Evaluation of this exhibit highlighted that although multisensory elements can be valuable for providing multiple means of engagement, these features must work cohesively to be meaningful to visitors. In the end, it was more effective to represent the data using a combination of visual and auditory cues and to eliminate the air pressure cues that were supposed to provide tactile representations for the dynamic data (O’Hara, 2014). This lesson is one that continually applies to exhibit development in other projects. The method of engaging with an exhibit must match the content being delivered, and it is important to test multisensory features with visitors to understand these design considerations.

Project 2: The Science Behind Pixar (Opened in 2015)

The Science Behind Pixar is a 13,000 square foot exhibition currently touring both nationally and internationally. When we first developed this exhibition, our goal was to help visitors learn about the science, technology, engineering, and math (STEM) skills involved in making computer animated films. More than our previous exhibitions, we knew that *The Science Behind Pixar* would rely heavily on screen-based activities to help visitors practice and experience these skills themselves. It was important to us that the multitude of touchscreens in this exhibition be accessible to a wide variety of visitors.

During our formative phase of development, we conducted accessibility testing to understand how our touchscreen design could be made more accessible. Visitors interacted with one exhibit component, the “Surface Appearance Workstation,” that required the use of on-screen controls to create a virtual object that matched a challenge image (Figure 3). Visitors could move their finger along a slider to adjust an aspect of the object, such as its reflection or transparency. They could also select its color or level of bumpiness from the various options provided, and alter its refraction.

Figure 3: This prototype of “Surface Appearance Workstation” allowed visitors to alter a virtual object using controls located on the right side of the screen. Screenshot by Chris Brown and Brittany Hamtil. Courtesy of the Museum of Science, Boston.

From our testing, we learned that some individuals in motorized wheelchairs had difficulty pulling up close to the interactive, which affected screen visibility and/or range of manipulability. In one group, a child in a wheelchair backed away from the component once his group came close to a solution, letting his siblings get closer to determine if they had the right answer. It seemed that the child could not see the challenge object in the top left well enough to make the comparison. Additionally, his younger sister had to kneel on a stool to see the screen. Another group included an adult in a motorized wheelchair which could not fit under the furniture. As such, he was not able to select the slider at the top of the on-screen menu. Although we had been adhering to our standard of placing controls within a 20-inch reach, we learned from this testing that we needed to place controls lower on the screen to account for the fine motor control required for the activity. The testing also highlighted the importance of visitors being able to pull up alongside a component and reach the controls, especially when it is difficult to approach it head-on (Mesiti & Cahill, 2014).

Accessibility testing also helped us learn more about visitor use of the on-screen features within the control panel. The touchscreen controls, including the sliders and swatches, were difficult for two groups to manipulate. Some visitors had difficulty selecting sliders, while some others had trouble selecting swatches due to their small size. Two adults suggested making the active area around the sliders slightly bigger to enable people with limited dexterity to use them. One adult preferred the sliders over the swatches because he found the swatches small and difficult to select (Mesiti & Cahill, 2014).

From these and other findings, we made adjustments to the touchscreen design, such as limiting controls to the lower third of the screen, enlarging the touch radius along the sliders, and making the swatch controls more usable (Figure 4). When conducting the summative evaluation of *The Science Behind Pixar*, we found that overall, the team's strategy of control placement worked well for most visitors. The use of touchscreens enabled the design of interactives with a great range of flexibility and creativity, which many visitors appreciated and used effectively. Touchscreens were not intuitive for all visitors, but some visitors who struggled came up with strategies to successfully engage with them (Cahill et al., 2018).

Figure 4: A visitor uses controls located at the bottom of the screen to adjust a virtual object at "Surface Appearance Workstation." Photograph by Michael Malyszko. Courtesy of the Museum of Science, Boston.

Our summative evaluation also revealed ways in which we could improve our future digital interactives. Although we made an effort to design intuitive controls for *The Science Behind Pixar*, we learned that some visitors would have benefitted from controls that were less complex. We also realized that adding multi-touch functionality to the interactives would have reduced confusion and encouraged collaboration among visitors. Finally, we learned that adding audio does not necessarily provide visitors who are blind with a comparable experience to sighted visitors, especially in an exhibition like *The Science Behind Pixar* where the topic is inherently visual (Cahill et al., 2018). We have incorporated these findings into the development of subsequent exhibits at our museum.

With *The Science Behind Pixar*, we have continued to challenge ourselves to improve our standards in accessibility and universal design. Our new strategies, although not perfect, have shown promise with regards to inclusion of audiences and have been used as a starting point for accessibility in future exhibit design.

For example, the new computer science activities we are developing for the *Engineering Design Workshop* exhibition (opening in 2020) will rely less on touchscreens and will have more tactile controls within better reach. Working on this project has also encouraged the museum to consider universal design as a factor when selecting content for exhibition topics, as we have for our upcoming *Arctic Adventure* exhibition (also opening in 2020).

Project 3: Engineering in a River System (Opened in 2016)

We developed the "Engineering in a River System" digital interactive to be a part of a permanent exhibition titled *The Yawkey Gallery on the Charles River*, which explores the connections between engineering and nature on the Charles River. With "River System," we wanted to invite visitors to investigate the environmental, social, and economic trade-offs of engineering decisions made within a river system. Our goal was that each possible engineering decision would have what could be viewed as both positive and negative outcomes. While we knew this could contradict visitor expectations, we hoped it would spark value-based conversations about the trade-offs associated with each decision.

Our original concept for "River System" was to create a virtual river on a large, flat table (Figure 5). Over time, based in part on what we learned from our experiences with the touchscreens in *The Science Behind Pixar*, our concept evolved into a 3D-sculpted table with projected animations in which tactile pieces could be placed into a physical table and would be detected by an array of Hall effect switches. When put in place, these pieces would trigger multimodal feedback in the form of projected text, animation, and sound effects. This feedback indicated to visitors the consequences of their engineering decisions in that particular section of the river. For example, at the "Land Use" station, visitors could select from different land use options for a small parking lot. Each choice would lead to distinct effects on the river system. For example, keeping the parking lot as-is would cause car exhaust to deposit phosphorus onto the pavement, which would run into the river when it rained. Creating a garden in the lot would mean some of the phosphorus would be absorbed by the plants, allowing swimmers and boaters to happily enjoy the river. However, with limited parking, the beachside café's sales would go down.

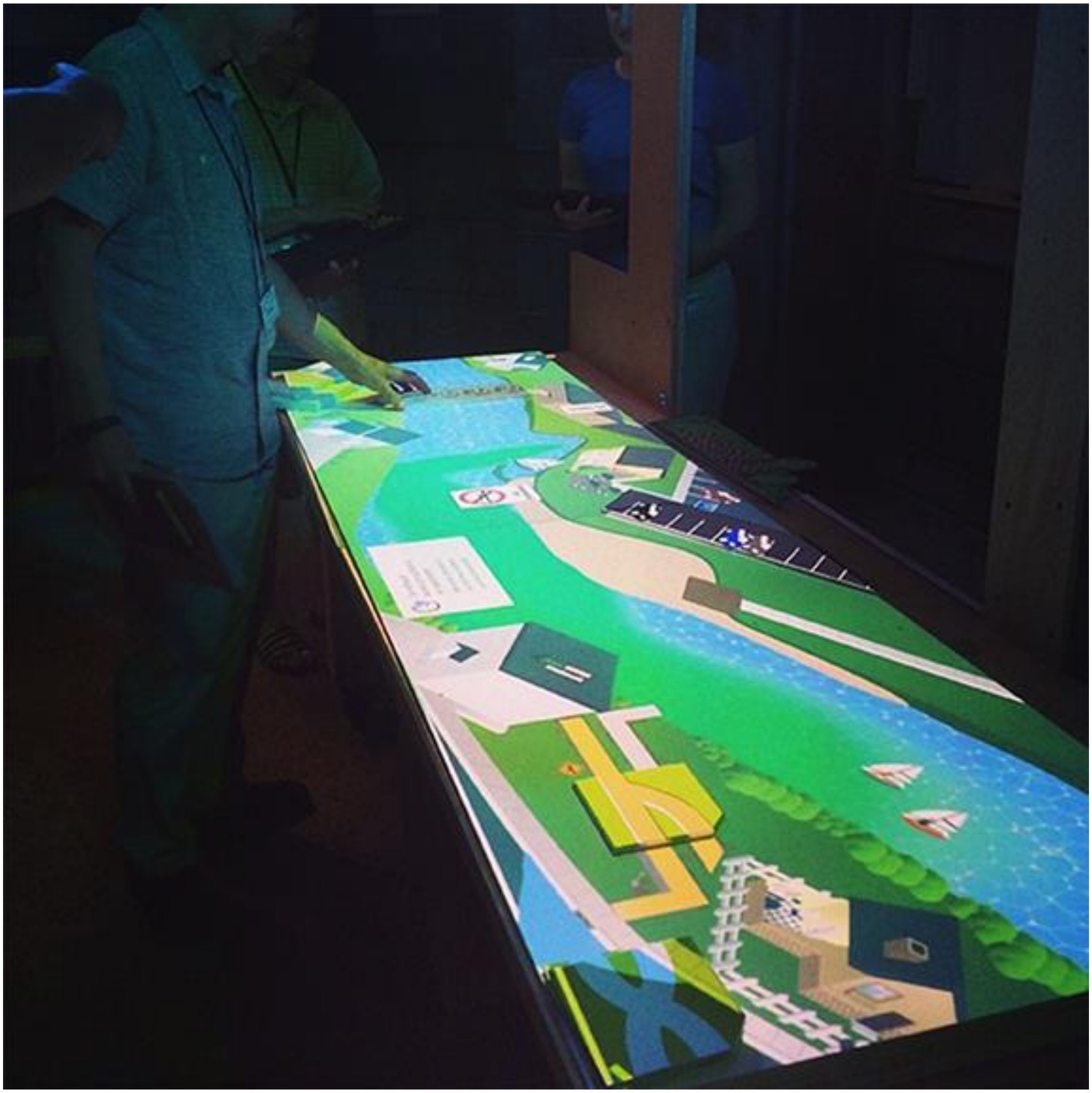

Figure 5: This early prototype of "Engineering in a River System" consisted of a table with projected images. Flat, physical pieces could be set into the table and would affect the river system. Photograph by Malorie Landgreen. Courtesy of the Museum of Science, Boston.

During development, we tested and improved the form factor and features of this exhibit through multiple rounds of prototyping. When we tested our new design with visitors who were blind or had low vision, we found that the 3D design—sloping shores, buildings, and more—could help them understand the river environment. We also adjusted the pace and timing of the text and animations on the table considerably based on prototyping, so that visitors could process the feedback and match text to the corresponding animation. We learned a similar lesson with the audio feedback—timing both the audio description and sound effects right was important for visitors who were blind. We also chose to add an “audio readout” button at each station to allow people to check the status of the piece that was in the slot. Finally, we found that environmental sound effects were engaging for sighted visitors as well— during general visitor testing, several groups said the audio helped them understand the activity better (Lussenhop & Goss, 2015).

Once the gallery officially opened (Figure 6), we recruited a range of visitors with disabilities to participate in the *Yawkey Gallery* summative evaluation study. Through this study, we found that the “River System” had the highest use rate of any element in the gallery for our accessibility groups (95%) and that visitors with disabilities enjoyed interacting with the component.

One mother discussed her son’s experience at the table, stating, “It's interactive, informative. Hearing it really helps for pre-readers. He doesn't usually spend this much time.”

Visitors appreciated the responsive animations and that the component provided both audio and text. One adult explained: “[I] liked having all the labels. I loved the animations, like the fish going through the dam. I liked the effects.,” and added that she found these elements intuitive. Two groups identified the activity and surrounding space as calming. One parent noted, “It’s pretty accessible…nice, calming with the lights.” Visitors also observed that the table was a good height for their group members, including young children and visitors using wheelchairs (Lussenhop, Allison, & Gregory, 2019).

Figure 6: "Engineering in a River System" uses audio, projections, and tactile pieces to prompt visitors to explore the effects of engineering decisions made within a river system. Photograph by Malorie Landgreen. Courtesy of the Museum of Science, Boston.

The "River System" was one of the museum's first exhibits to incorporate interactive, projection-based media. The design of this exhibit, and lessons learned from prototyping with visitors, has influenced the direction for upcoming exhibits. In addition, visitor groups actually seemed to grasp the complexity of the activity's content. An activity about real-world effects of engineering decisions is naturally complex, but after trying the scenarios, visitors often remarked on how there were "pros and cons" and no "right answers." For example, when asked what she learned from the exhibit, one child interviewed in the summative evaluation said, "I learned about how there's no good answers with river dams and pesticides." "River System" won awards for its interactive design and has pushed the museum to think about best practices for incorporating universal design into high-tech museum experiences.

Project 4: Particle Mirror (Opened 2017)

“Particle Mirror” is a full-body, immersive digital interactive that is the focal point of an exhibition titled *Wicked Smart: Invented in the Hub*, which is located right at the entry way of the museum. Due to the gallery’s high visibility, we decided early on that we wanted to make a splash with a new artistic technology experience. It was equally important that it be visually exciting, and accessible to many audiences.

At the time, we had recently completed a collaboration with artist Karl Sims in our *Yawkey Gallery on the Charles River* exhibition project. During the initial interviews with Sims for *Yawkey Gallery*, he had presented an amazingly fun activity using Kinect technology where users stand in front of a projection screen, viewing themselves surrounded by virtual falling snow particles. The particles would appear to rain down on the user, who could manipulate them by moving in space. We decided we were interested in developing this component for *Wicked Smart*, but we knew we would need to supplement it somehow to make it more inclusive. When we first talked about wanting to sonify the component, Sims did not think this could be easily achieved, but eventually engaged sound engineer Bill Walsh to collaborate on the project.

We conducted several rounds of prototyping as we developed “Particle Mirror” with Sims and Walsh. From the first round of prototyping done without sonification (Figure 7), we found that although every group interviewed said they had fun and would do it again, many visitors left confused, not understanding that their movements were actually affecting the virtual particles (Lussenhop, 2016). For the second round of prototyping, we incorporated Walsh’s distinct dynamic sounds into the simulations. Sounds were triggered when a user’s body movements caused a critical mass of particles to collide with one another or with one side of the projection. The sounds became more complex and melodious when the magnitude of particles colliding increased, which could occur when a user vigorously moved their body, or when multiple users interacted. From this round of prototyping, we learned that about half of the museum visitors interviewed now realized that their movements were triggering the sound effects as well as the particle simulations (Lussenhop, 2017b). So the sonification was actually helping our sighted visitors understand the simulation better.

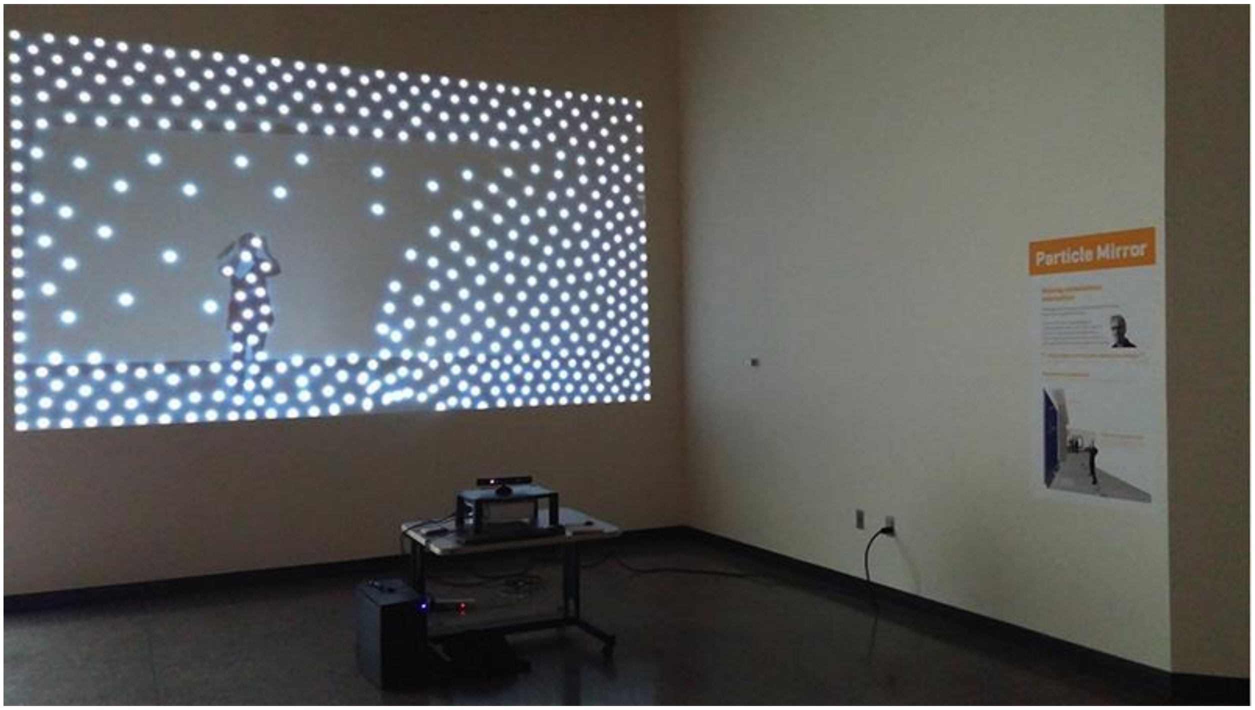

Figure 7: In this prototype of “Particle Mirror,” visitors could move in space to affect the virtual particles collecting on their projected mirror image. Photograph by Alexander Lussenhop. Courtesy of the Museum of Science, Boston.

To find out how our well our sonified “Particle Mirror” worked as a UD solution, we partnered with the local chapter of the National Federation for the Blind (NFB) for our third and final round of prototyping. Visitors who were blind or had low vision unanimously rated their interest level as “so interested I would try it again.” These visitors reported that they understood the way their movements affected the sounds, they found the experience satisfying, they liked that their bodies changed the simulation, and they liked how the sounds corresponded to colors and visuals. The interaction became confusing and disappointing, however, when the visitors felt that the sounds were not reacting to their individual movements. This especially became difficult when multiple users were interacting simultaneously, because the visitor couldn’t tell what effect, if any, they were triggering. Two of the three groups interviewed suggested sonifying movement based on the user’s position in space (Lussenhop, 2017a).

Our ultimate design solution for sonifying the particle simulations was to add a speaker on each side of the projection, and split the sound into quadrants: front and back, left and right (Figure 8). Visitors could then understand that the sounds are based on their personal movement, because volume changes based on moving forward/ backward, and sounds are amplified differentially on each side based on where they are. The unique dynamic sounds selected are each coupled with one of nine visual particle simulations, which last for one minute before switching to the next simulation. The projection is located in an open space, where visitors can opt in or out at any time depending on their interest level (Figure 9).

Figure 8: Depiction of a visitor using “Particle Mirror.” With speakers placed on both sides of the projection, visitors are able to perceive how their own movements affect the sounds of virtual particles. Rendering by Chris Whiting. Courtesy of the Museum of Science, Boston.

Figure 9: At "Particle Mirror," visitors can affect virtual particles and create dynamic sounds by moving their bodies in space. Photograph by Beth Malandain. Courtesy of the Museum of Science, Boston.

In the end, Karl Sims agreed that the simulations were more dynamic and exciting with sound, and that he preferred the sonified versions to the original. Creating the "Particle Mirror" interaction reinforced to us that universal design enriches experiences for everyone. Yet, while "Particle Mirror" is a great example of successfully retrofitting a visual art piece to be multimodal, for the visitors who are blind or deaf, the experience afforded is only a portion of the full experience created. One question we continue to ask ourselves is: is it better to tack on modalities to activities that heavily favor one particular sense, or should we let the sense drive the development and make two components of equal excitement value?

Project 5: Robots (Opening in 2020)

"Robots" will be an exhibit in our new *Engineering Design Workshop* exhibition, opening in Fall 2020. Our goal for "Robots" and other exhibits within *Engineering*

Design Workshop is to create stand-alone engineering design and computer science activities that will complement our successful Engineering Design Challenge programs, also occurring within the exhibition. With "Robots," we set out to create a sequencing activity where visitors would program robots to complete a desired task.

Our first thought was to have visitors program a robot to complete tasks at different physical locations (Figure 10). The visitor would choose which physical tools to attach to their robot, and then program the robot to use those tools (Todd, Anderson, & Weitzman, 2018; Todd, Anderson, & Weitzman, 2019a). We began by developing a tactile touchscreen as our programming method for this activity. At the bottom of the touchscreen, we created a toolbox of tactile program blocks that could each be dragged to one of twelve blank spots at the top of the screen. We wanted the program blocks to be raised in relation to the screen surface, and the open spots for the program to be inset. This method would have enabled two levels of tactile information to exist on the screen, both of which were optically clear to allow the screen graphics to shine through.

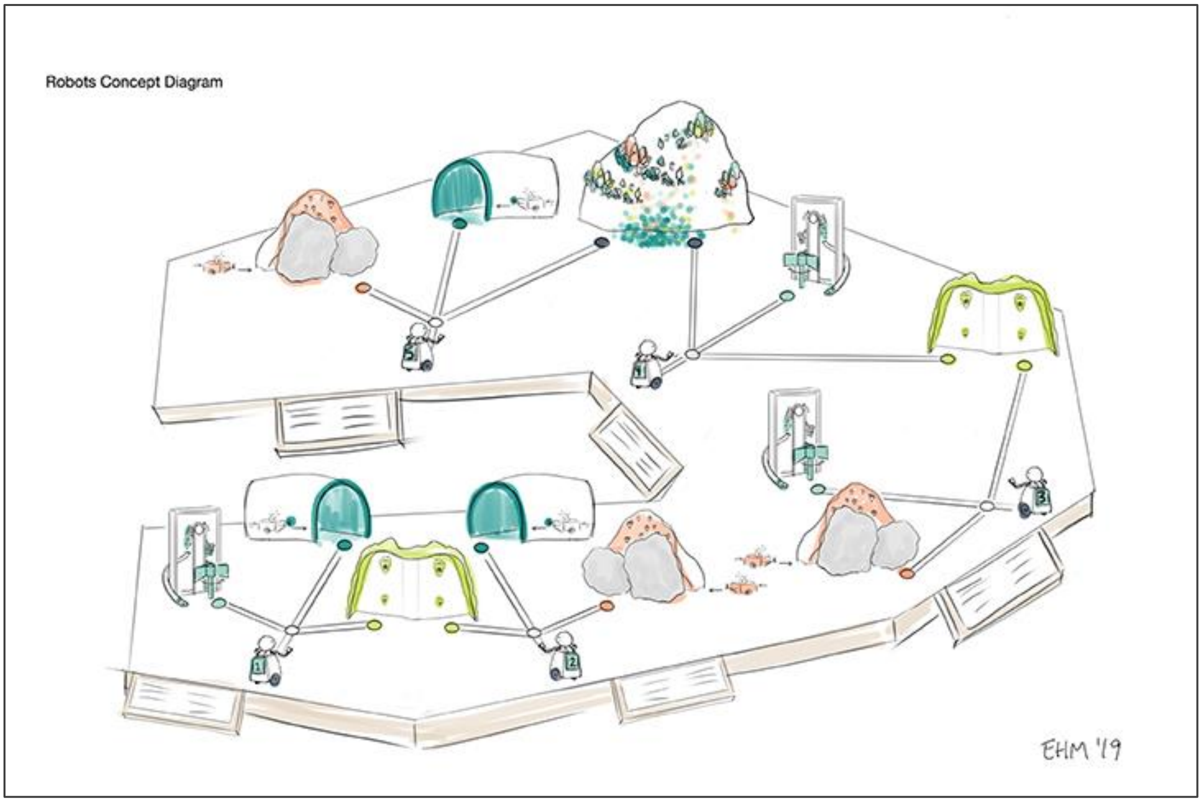

Figure 10: In the early concept for “Robots,” visitors would program robots to complete tasks at different physical locations. Concept diagram by Beth Malandain. Courtesy of the Museum of Science, Boston.

As we worked through a couple of iterations of this touchscreen method, we ran into many roadblocks. One of the biggest problems was that we knew from our work on *The Science Behind Pixar* that we could only use the bottom portion of the screen, which we would not be able to accomplish with this prototype. We started thinking about losing the toolbox and just having open programming blocks with spinner arrows pointing up and down that would toggle between the different programming options. This opened up a whole new set of usability questions, leading our team to conduct some research. By downloading and playing games for users who are blind on our phones, and speaking with our in-house accessibility advisor on intuitive touchscreen use, we learned that there are currently no standard ways to enable gesture use within touchscreens for users who are blind.

This is where our prototyping on the tactile touchscreen ceased for this project. We felt that we could use physical programming blocks more easily and confidently since we had prior experience with them. The blocks were also friendlier to younger audiences and we believed that ultimately, we could make them more accessible. We switched to what we call a "blended reality robot," which is a physical robot that is programmed by the visitor but "magically" sent into a virtual world to complete tasks. We had essentially moved from a situation in which visitors programmed onscreen but the activity happened in analog, to a situation in which the programming is analog, but the activity happens onscreen (Todd, Anderson, & Weitzman, 2019b; Todd, Anderson, & Weitzman, 2019c; Todd, Anderson, & Weitzman, 2019d; Todd, Anderson, & Weitzman, 2019e; Todd, Anderson, & Weitzman, 2019f) (Figure 11).

Figure 11: In the "Robots" prototype, visitors can use physical blocks to program a physical robot before sending it to collect gems in a virtual world. Photograph by Bill Jackson. Courtesy of the Museum of Science, Boston.

In the final version of this activity, the visitor first selects a challenge level for their robot. Then, they arrange physical program blocks in a sequence to direct their robot to collect gems in the virtual world. Each program block has its own color and icon associated with it, and the icons can be identified by touch. At any point during this interaction, the visitor can press the audio on/off toggle and their program will be read aloud to them, or they can press and hold the toggle for one second and there will be an audio description of the selected level. Next, the visitor presses “run program,” at which point the robot passes through an elevator door, and the virtual robot appears on the screen to carry out the program. As the virtual robot is using each tool, audio feedback and a text block inform the visitor of the tool being used and provide hints that enable the visitor to iterate strategically on the next try.

We are excited about this component as we believe it can help exhibit developers push boundaries at any institution interested in creating computer science activities. Nevertheless, it remains to be seen how well it works for visitors. Additionally, while we are satisfied with the direction we chose for "Robots," we will continue to learn how to make tactile icons understandable to both sighted and non-sighted visitors, and will put new designs in front of as many people as possible (Todd, Anderson, & Weitzman, 2019g).

Project 6: Navigating a Glacier (Opening in 2020)

Arctic Adventure: Exploring with Technology is a new exhibition which we are developing in collaboration with Moment Factory, a media producer. In this digitally immersive space, visitors will be invited to use technology to explore a dynamic Arctic environment. The style of the digital interactives in this space is very different from what we have created before — instead of developing kiosks or individual stations, we are creating whole-body immersive experiences that rely on projection mapping technology. In creating *Arctic Adventure*, we knew we wanted a full-body activity that would convey a sense of danger and excitement. Early on, we came up with the idea for “Navigating a Glacier,” an area in which visitors would be challenged to travel across a projected glacier, aided by technology.

Our overall concept with “Navigating” was that visitors would rely on representations of a satellite map and ground penetrating radar to avoid crevasses (deep cracks) when traveling across a virtual glacier. Originally, we wanted visitors to review the satellite map at base camp, look for visible crevasses and plan their journey (Figure 12). Then, they would carry ground penetrating radar with them onto the glacier, receiving haptic, audio, and visual feedback about the presences of crevasses, even those hidden by snow. During initial iterations of the activity, few visitors paid attention to the satellite map, so we created the role of the “navigator,” someone whose primary responsibilities included monitoring the satellite map and directing the “trekker” along the course (Figure 13). We were excited to add this role because we wanted visitors to collaborate during the activity. Fortuitously, adding this role introduced an additional way for visitors to participate. The trekker physically travels across the course while manipulating the ground penetrating radar and must process feedback from the navigator and the radar. The navigator, on the other hand, remains stationary so that they can monitor visual information from the satellite map and direct the trekker. Thus, the trekker and navigator roles differ in their mobility requirements, the sensory experiences involved, and level of communication necessary. Our intention is that each visitor will find a role that suits their interests and abilities.

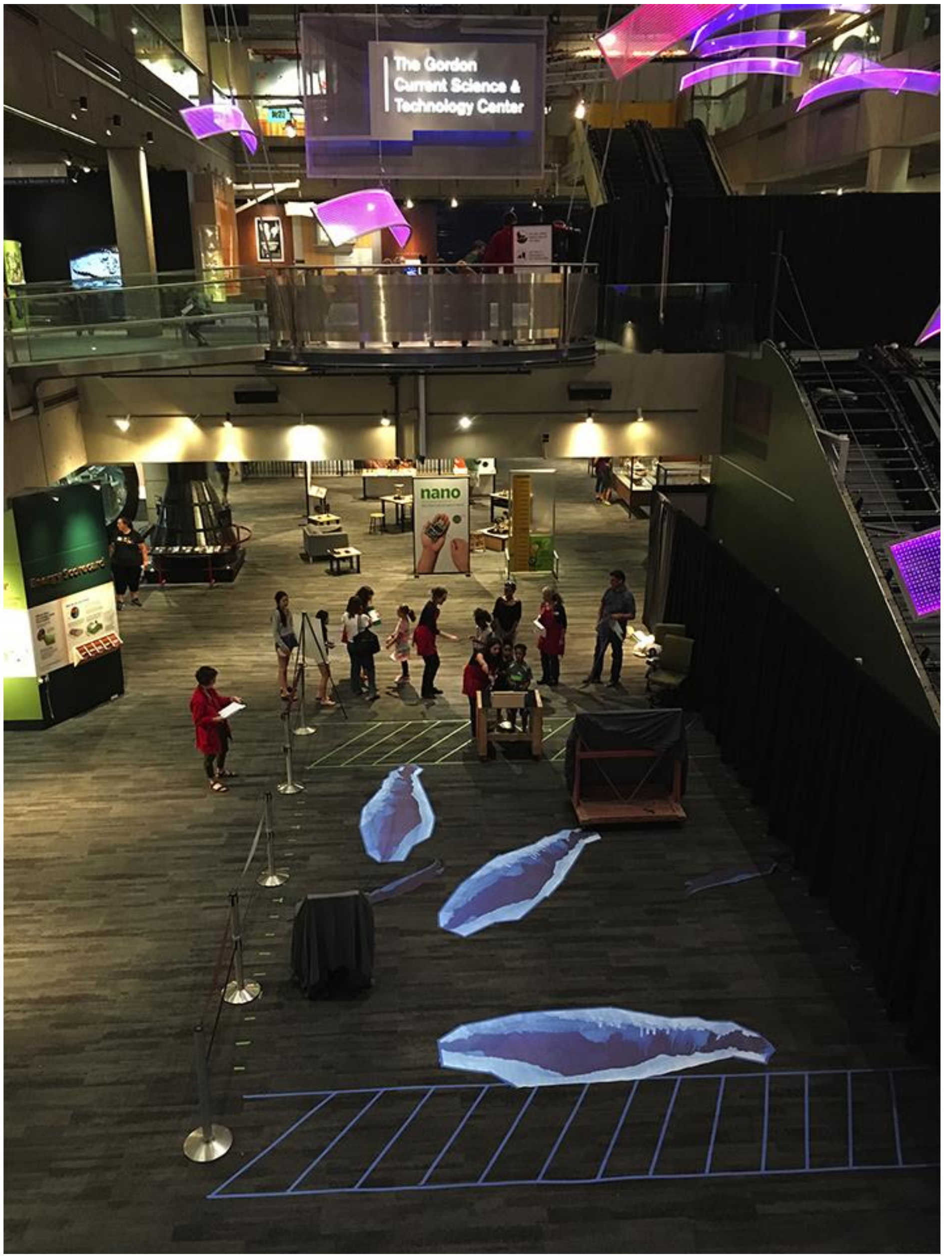

Figure 12: In this prototype of “Navigating a Glacier,” each visitor was encouraged to use representations of multiple technologies to avoid crevasses as they moved across the “glacier.” Photograph by Sara Castelluci. Courtesy of the Museum of Science, Boston.

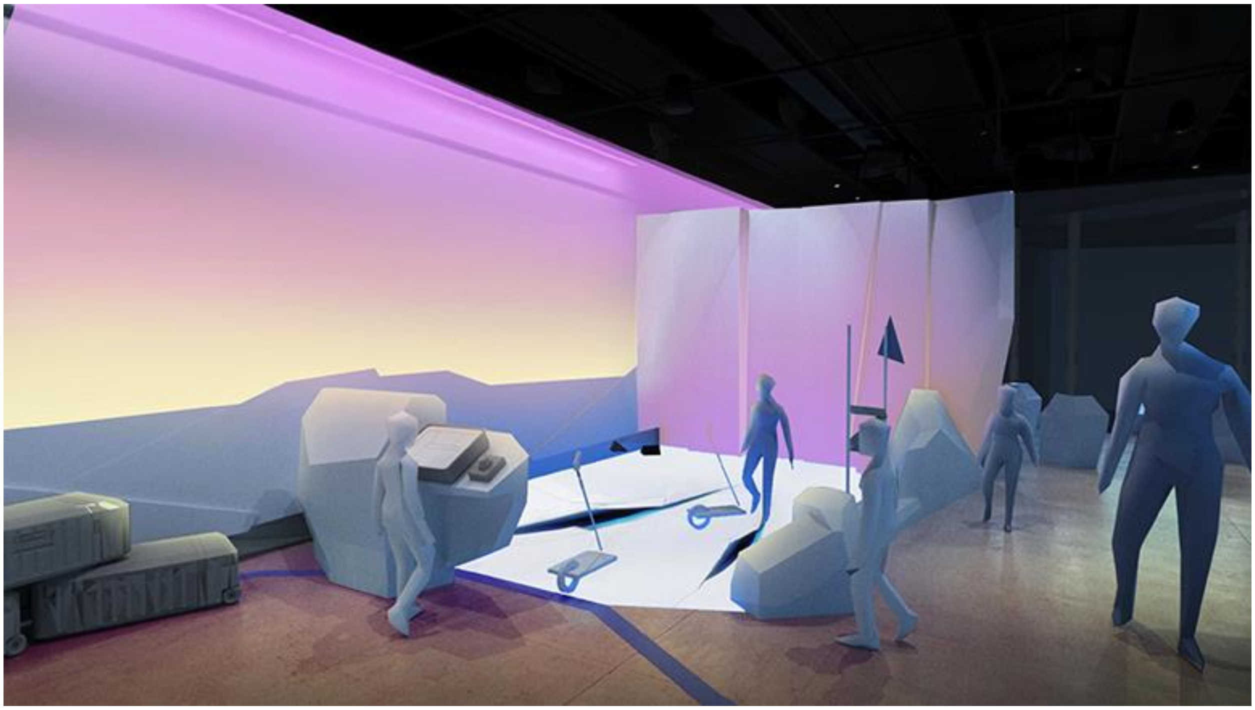

Figure 13: At “Navigating a Glacier,” pairs of visitors will use representations of technology to avoid crevasses as they collect supplies on a projected glacier. Concept, rendering by Moment Factory. Courtesy of the Museum of Science, Boston.

Our extensive prototyping also led to other adjustments of the activity. We found that visitors needed more motivation to travel across the glacier (Allison & Mesiti, 2018), so we introduced a goal: trekkers needed to collect supplies that had been left behind by others on the glacier. If the trekker stepped in a crevasse, the projection would dramatically show a gaping hole beneath their feet, and their supplies would “fall” into the crevasse. This eventually led to another problem — we had not considered the cognitive load required of each player. While the trekker had too much to monitor (crevasses, supply counts, position on the glacier) the navigator was sometimes bored and wanted to play more of an active role. To fix this imbalance, we adjusted the activity so that the navigator could track the trekker’s position on the satellite map and monitor the supply count for them. (Trekkers would be tracked in space using LIDAR (a method for measuring distance using laser light and reflections), and the ground penetrating radar unit would be tracked via infrared LEDs and overhead infrared cameras). It was also the navigator’s role to monitor the approaching blizzard and warn the trekker of its status so that they would return to base camp before its arrival. Another issue we encountered was that visitors showed a lack of understanding of the game's mechanics and of the functioning of the ground penetrating radar. To address this problem, we created a training video that now serves as the activity's instructions. Since we incorporated this video, prototyping has shown that visitors better understand their roles, have a stronger connection to educational goals, and demonstrate less confusion about the game (Allison & Mesiti, 2019).

At key phases in the development of this exhibit, we have incorporated feedback from visitors with disabilities, including visitors with limited mobility, visitors who use wheelchairs, and visitors with low vision. We have learned from these visitors that our instructions needed to be clearer and less wordy, which we then acted on when developing the video. Visitors using wheelchairs have also encouraged us to redesign the ground penetrating radar so they could travel more easily with it. We are now in the process of creating a device that can be comfortably used by people of various heights and physical abilities. Finally, visitors with low vision required more contrast on the screen and the game board in order to participate, something our team was aware of but had not yet successfully achieved (Mesiti & Gregory, 2019). Overall, our accessibility testing provided us with actionable suggestions that we have since incorporated into the activity.

Arctic Adventure represents the museum's first foray into the development of immersive exhibitions. We hope that the dynamic world of *Arctic Adventure* excites our visitors and serves as an effective entry point into the exhibition's educational content. As a part of this experiment with immersion, we are learning how this kind of exhibition can be accessed and experienced by visitors of all abilities and disabilities. We are eager to find out how our approach is received, and will carry what we learn from our summative evaluation into future exhibitions.

Conclusion

At the Museum of Science, inclusive design is an active, ongoing process. Each new exhibit provides an opportunity for us to re-evaluate our practices, incorporate new technologies, and adapt to evolving audience expectations. As we work on each digital interactive, we draw upon our resources — our accessibility advisors, our colleagues with disabilities, our visitors, and each other — in order to create interactives that work for a wide variety of visitors. Through a continual process of learning and improvement, we believe it is possible to create digital interactives that empower everyone to learn.

Acknowledgements

This chapter could not have been written without essential input from Alexander Lussenhop, Alana Parkes, and Ben Wilson. We would also like to thank our accessibility coordinator Nora Nagle and the members of our accessibility advisory committee for their ongoing commitment to inclusive exhibit development.

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Inclusive Digital Interactives

Best Practices + Research

Chapter 4

A Model for Accessible Evaluation of Inclusive Museum Exhibits

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September 2020

Introduction

During the design and development of digital interactives, many questions arise. Will users understand this design? Is this a good design choice for as many users as possible? Have we introduced new problems while trying to solve existing ones? Evaluation can help answer these questions and be about more than reviewing existing standards or checking boxes once the digital interactive is finished. It can be a collaborative process that encourages iteration and supports accessibility. This chapter will provide an overview of an evaluation process that demonstrates how accessible practices can be applied to all phases of evaluation, along with some examples from the authors' professional experiences. The chapter will also provide strategies for making the *evaluation process* itself accessible to a range of users.

The Importance of Formative Evaluation

Just as accessibility considerations begin at the start of the design process, evaluation should too. The process of *formative evaluation* is one that "provides information about how well a program or exhibit functions or how well it communicates its intended messages" (Diamond, Horn, and Uttal, 2016). The aim of formative evaluation is to systematically capture information, such as visitor observations, reported interest, and reported learning, so that exhibit development teams can improve an experience or inform future work (Patton, 2010; Weiss, 1998). This type of evaluation supports the adoption of universal design strategies during development, as making changes later in the process can be prohibitive and costly when developing digital interactives.

Additionally, there continue to be challenges of equity with advancing technology and digital interactives. At times, advances in this field perpetuate existing inequities rather than work to reduce them (Hao, 2018; Noble, 2019; Nourry, 2018). Disability status is diverse and complex, affecting a wide range of individuals. According to a 2018 report from the Centers for Disease Control (CDC), approximately one in four people in the United States have a disability of some kind. When it comes to digital advances such as machine learning and artificial intelligence, these systems learn through the information or individuals put in front of them. Systems not tested with a range of individuals are working with incomplete user data (Hao, 2018). Systemic ableism in technology is an issue, especially when prototypes are not designed to be accessible with assistive technologies or are created without the aim of learning about accessibility improvements for final design (Nourry, 2018).

A common mantra from communities of individuals with disabilities is "Nothing about us without us." As such, it is critical to value the voices of those who share their own expertise and lived experiences. Considering accessible evaluation practices can help teams think critically about how their designs can best meet the needs and preferences of all intended audiences.

An Approach to Inclusion

The authors of this chapter are all in the Research and Evaluation Department at the Museum of Science, Boston (MOS) and our varied experiences with universal design (UD) at the museum inform many of the recommendations herein. The Center for Universal Design at North Carolina State University (1997) defines the concept as "design that's usable by all people, to the greatest extent possible, without the need for adaptation or specialized design." By testing exhibits with a range of individuals with differing abilities and disabilities during the formative development phase, the museum has found that it is possible to create experiences that include everyone in a visiting group.

As such, a UD focus makes it critical that the research and evaluation studies implemented to assess the inclusivity of exhibition design and content development are also accessible for visitors.

The Museum of Science's overall approach to inclusion references several frameworks that demonstrate aspects of universal design. These frameworks all stem from the social model of disability, "where the disability is presumed to result from the interactions of the individual within a specific context that was not designed with his or her physical, cognitive, or sensory characteristics in mind" (Reich et. al, 2010). As such, this chapter will use "person first language" (i.e. "person who is blind" vs. "blind person") to highlight that visitors are people not singly defined by a disability. The museum's view is that the onus for change lies with the design rather than an individual. In practice, this means that all individuals should be able to:

- Physically interact with the space,
- Cognitively engage with the materials,
- Socially interact with one another, and
- Emotionally connect with experiences (Reich et. al, 2010).

This strategy aligns with the four principles of accessibility defined in the Web Content Accessibility Guidelines (WCAG): content and design should be perceivable, operable, understandable, and robust to users (Kirkpatrick, Connor, Campbell, & Cooper, 2018). We incorporate social and emotional accessibility because museum visits are often group experiences.

Because learning is also an important impact of museum experiences, MOS further uses the concept of Universal Design for Learning (UDL) framework. This provides the following principles for better understanding of the "what," "how," and "why" of learning:

- To support recognition learning, provide multiple, flexible methods of presentation.
- To support strategic learning, provide multiple, flexible methods of expression and apprenticeship.
- To support affective learning, provide multiple, flexible options for engagement (Rose & Meyer, 2002).

With these foundations in mind, each section of this chapter will discuss various steps of the research and evaluation cycle, including a brief summary of the work involved, the thought process behind incorporating inclusive practices, suggestions for making the evaluation process accessible, and examples from projects at the Museum of Science.

Before Evaluation Begins

Evaluating the accessibility of digital interactives will involve interacting with people with various disabilities and you should consider how different disabilities might interact with your design. This will help you design the digital interactive to better meet a range of accessibility needs. Some different types of accessibility needs stem from visual, auditory, mobility, and cognitive disabilities. Learning disabilities and autism are also relevant considerations for museums. An important thing to remember is that there is immense variability within these disabilities, and individuals may have multiple disabilities. Therefore, it is crucial to consider a range of disabilities and not to limit your evaluation only to those with one particular disability.

When planning for the evaluation of a digital interactive, familiarize yourself with the tools and technologies that people with disabilities already use. How might these technologies interface with your interactive? What lessons from these technologies could you apply? For example, some might assume that people who are blind would be unable to use screen-based technology. However, screen readers and thoughtful design can make screens easy to navigate, and smartphones and personal computers come with a variety of built-in accessibility tools. While UD principles indicate that your interactive should not *require* "adaptation, modification, assistive devices or specialized solutions," in practice, many people with disabilities bring and enjoy using their own technologies.

It is imperative to understand how to communicate respectfully with people with different disabilities. Most of this is no more complicated than treating them as individuals, as you would any person, but there are some specific points to keep in mind. The chapter on this topic in Shawn Lawton Henry's book *Just Ask: Integrating Accessibility Throughout Design* (http://www.uiaccess.com/accessucd/interact.html) provides a thorough overview. A caveat is that while many resources recommend "person-first language," not everyone prefers this terminology. You should always use the terms that individuals prefer, and it is okay to ask.

Using Personas

Personas are profiles of archetypal users based on real data and may be a valuable thinking tool. Personas read like profiles of real people and are paired with names and photos, but do not represent any one person. They help teams think of their users as real people instead of abstractions. As a data-based tool, personas can be used by a designer to review design ideas or by an evaluator to review evaluation plans.

The persona creation process begins with discussions with the design team to guide information you include in the personas. What do they want users to be able to do? What are their design goals? Next, look at user data. You may have existing data from previous research, evaluation studies, or market research. You may need to interview some real users or other professionals familiar with user experiences. You can review books, articles, and personal accounts as well. Be sure to have a well-defined set of interview questions or topics to gather information about as you compile data. Once you have your data, review it to look for patterns in behaviors and attitudes, using the guidelines from the design team. Look for the spectrum of desires and abilities on different dimensions.

As you go through your notes, you will begin to settle on an appropriate number of personas. The number you need will vary, but keep in mind that too many may end up being too much information for the team to digest or use. Fill out some personal details in the personas, such as occupation, hobbies, family details, and personality. Outline a goal for each persona for using your digital interactives. Finally, give the personas names, summarizing phrases or quotes, and find photos to represent them.

Example: Creating Museum Media for Everyone
In 2012, MOS hosted a workshop for access and education professionals to tackle the problem of creating universally designed data visualization in digital interactives. To guide the group's thinking, the Research and Evaluation Department created eight personas to represent people with varying abilities and comfort with technology and museums. The personas can be accessed here: https://openexhibits.org/wpcontent/uploads/papers/CMME%20Personas.pdf

To create these personas, researchers reviewed previous research and evaluation studies including a focus group about the design of museum programs and an accessibility review of a developing exhibition. Researchers identified individuals in the data and looked for information about their goals in the museum, their experience with technology, museum experience, and their challenges with digital interactives and museums in general. Researchers created scales with different dimensions based on the traits they wanted to highlight in the personas (e.g., "reliance on visual cues for information") and mapped the real users onto these scales. They looked for areas where multiple participants fell together on several dimensions and used those traits together in one persona (Iacovelli, 2014).

Developing Instruments

Instrument development is the process of creating and preparing instruments or tools for collecting data. Often these are observation guidelines, surveys, or interviews, which can be used for capturing feedback for a variety of exhibits or experiences. Standardizing instruments helps you to identify patterns of use across multiple users and to ensure you do not forget to look for or ask about something that is critical to the interactive design.

Instrument development should happen after a detailed conversation with the entire design team about what they are hoping to learn from testing and what questions they have. Some questions may not be realistic to answer, but note all questions regardless. You can review the questions and group similar ones together to make the list more manageable.

When designing instruments for accessibility testing, it can be useful to capture data related to:

1. Navigation/Wayfinding
    - Is it easy for the participant(s) to get oriented to the layout of the interactive?
    - If the digital interactive is set up in a realistic exhibition layout, can the participant(s) navigate through the exhibit and find the different activities?

2. Reach/Use
   - Are all the necessary parts of the interactive within physically reach, easy to use, and manipulate?
3. Information/Instructions
   - Can the participant(s) access all the information provided at the interactive?
   - Is the information available in a format the participant(s) can access?
   - Is the information easy for the participant(s) to understand?
4. Comfort/Aesthetics
   - Are the participant(s) comfortable while using the interactive?
   - Do the participant(s) find the activity aesthetically appealing or attractive?
5. Inclusion/Independence:
   - Can participants use the interactive independently and socially to whatever extent they prefer?

While it is important to keep track of key behaviors or interactions to watch for, keep room for taking detailed open-ended notes, to account for any unexpected behaviors and outcomes during data collection.

Plan to ask questions not only about accessibility, but about interest in the activity and its content as well. Remember that museum professionals design interactives to be fun, interesting, and educational as well as accessible.

When creating interviews or surveys, use plain and simple language as much as possible. Eliminate unnecessary words and phrases. Consider using transitional language to help participants follow along. You might say, “now I am going to ask you some questions about what you learned while doing this activity” or “we are trying to decide where to put the navigation buttons on the activity, so I am going to ask you some questions about that.” However, you should also take care to minimize the length of your protocol so as not to overburden participants. Tell them how many questions you are going to ask, and check in periodically about taking short breaks if needed.

If you are drafting standard questions to ask of all participants, take time in advance to come up with one or two alternative phrasings in case people do not understand your initial question. Relatedly, think about how you might rephrase open-ended questions as “yes/no” questions, as some participants may find those easier to understand and answer. You can also modify scale questions this way. For example, a question with a four-point scale can be broken into two binary choice options. These strategies work well for a variety of people, including visitors with cognitive disabilities or those on the autism spectrum. Finally, allow participants to write down their own answers to your questions if they wish.

Example: Building Computational Thinkers through Informal Exhibit Experiences

In 2014, the Museum conducted a three-year research project titled *Building Computational Thinkers through Informal Exhibit Experiences* (CE21) that explored how educators and designers could support thinking habits commonly used in computer programming and how to customize these learning experiences to meet learners’ diverse backgrounds. The study aimed to look at two groups of participants, novice and expert computer programmers, as they were using several exhibits created for *The Science Behind Pixar* exhibition relating to computer programming and computer animation techniques.

In addition to surveys and interviews, researchers used “video-stimulated, retrospective think-alouds,” where participants were shown a video of their exhibit experience and then asked to detail their thoughts and actions. While think-aloud protocols typically ask participants to recall their experiences while using an exhibit, researchers felt that this would create a cognitive burden for participants who were using several new activities, in addition to research study participation. By incorporating technology and mixed-methods, researchers promoted a positive experience for participants and supported different learning styles by offering multiple ways to offer feedback on their experiences (surveys, interviews, and the think-aloud).

Recruiting Participants

During recruitment, researchers invite groups or individuals to try out an exhibit and offer feedback. They provide participants with a brief overview of the testing process, including methods, duration of the experience, and any potential compensation they would receive for participating. This process can happen before data collection if participants are recruited off the museum floor, or ahead of time as a scheduled appointment via email or phone.

While recruiting off the floor can seem less effective, it is important to consider the diversity of people already present in your museum. Visitors come from a variety of backgrounds and experiences, including disabilities that may or may not be visible. For this reason, this method is best used in conjunction with scheduled testing sessions. Consider including questions such as “Do you have a permanent or temporary disability?” alongside general demographics, and ask about exhibit usability issues as a standard during prototyping. By doing this, you provide multiple opportunities for people with disabilities to be included within the evaluation process.

Scheduling testing sessions entails contacting a series of individuals or groups via phone or email ahead of time. This method offers participants the chance to inform you of any questions or concerns they may have about the experience (e.g., sensory sensitivities) or accommodations they may need (e.g., a sighted guide or sign language interpreter). While it is important to recruit from a wide range of people including people with disabilities, your team may have specific questions. For example, are there concerns about your interactive’s accessibility for wheelchair users? If so, you may want to invite groups that include someone in a wheelchair to give feedback on these aspects. By scheduling ahead of time, you have greater control in ensuring you are capturing not only a range of groups but also the types of audiences your team needs to answer their specific questions.

When seeking out groups to contact, consider your institution’s current relationships, including local organizations, nearby schools, or clubs with a specific focus on disabilities. However, bear in mind the amount of time it may take to plan logistics, particularly with schools, which could take weeks or months. You may also include the perspectives of professionals or expert advisors to broaden the type of information gained. If your team is considering this, make sure you budget to pay them for their expertise as you would any professional advisor or consultant.

As the digital interactive changes, your institution's language and methodology around accessibility recruitment will evolve. By taking time to be thoughtful about how and who to recruit, participants will be more likely to have a positive experience and provide actionable feedback.

Example: The Science Behind Pixar

The Science Behind Pixar exhibition, developed by MOS in collaboration with Pixar Animation Studios, presents the computer science, math, and science skills that go into creating Pixar's animated films. Pixar's animation process was presented through large-scale immersive character models, behind-the-scene videos narrated by Pixar animators, and a variety of physical and digital activities where visitors could try for themselves some of the tasks and skills involved in making a virtual 3D animated film.

During exhibit development, the team recognized that by nature, the topic of animation lent itself to highly visual experiences. They had a range of questions related to how a person who was visually impaired would interact with the content of this type of exhibit. To create an exhibit that was as accessible as possible to all audiences, they recruited three individuals who were blind or had low vision to serve as advisors for this project. The team held focus groups with these advisors to better understand how multisensory experiences might convey the content that sighted individuals see on screen. The team asked questions about whether they had ever seen Pixar films and what their knowledge and interest is in concepts such as lights and cameras. This information helped the team conceptualize how to present visually-based animation concepts to a range of audiences. As prototypes developed, these advisors were invited to help test the exhibits and provide feedback about their design and audio label information. Sometimes this meant adding multisensory elements that helped visitors who were blind or had low vision interact with and understand the educational goals. In other cases, multisensory elements did not provide comparable experiences for individuals with vision impairments and the team has used this knowledge to inform topic selection for future museum exhibits. Although it might have been useful to have deeper accessibility conversations when exhibition topic was chosen, the team used advisor feedback to evolve accessibility strategies during the development stages.

Informed Consent

If your project qualifies as *research* and involves *human subjects*, an Institutional Review Board (IRB) must review it. The Department of Health and Human Service's Office of Human Research Protection (OHRP) includes tools such as decisions trees to help you think through these questions (https://www.hhs.gov/ohrp/regulations-and-policy/decision-charts/index.html#c1). Human subjects research requires informed consent. Even if your project is not human subjects research, obtaining informed consent is a best practice.

For consent to be "informed," subjects need to be told what the evaluation entails in a way that they can understand. "Consent" means that the subject can make a meaningful choice about participating. To obtain informed consent, you must include:

1. A statement that you are conducting research, the activities that will occur, and the expected duration of participation.
2. A description of any risks to the subject.
3. A description of any benefits to the subject.
4. Information about whether and how confidentiality will be maintained.
5. Information about whom to contact with questions or concerns.
6. A statement that the study is voluntary and that the subject can stop participating at any time.

Some types of studies require more information for informed consent. The full list is here: https://www.hhs.gov/ohrp/regulations-and-policy/guidance/faq/informed-consent/index.html.

Often you will get consent using written forms, though some studies with minimal risk will be able to use verbal-only consent methods. No matter the method, you should use “plain language statements” free from jargon. You can also consider using picture boards, graphics, or videos to improve comprehension (Iacono & Murray, 2003). Some users will need Braille consent forms or sign language interpretation. Others may find the process easier to follow if you read the consent form aloud to them. As long as you provide the required information, you can modify the consent process as much as is necessary to ensure that your participants understand what they are agreeing to do.

Government regulations also mention some groups that may be vulnerable to coercion, including children and those with impaired decision-making capacity, and IRB review may require extra care be taken to obtain informed consent in these circumstances. The consent process may go through a third-party, such as a parent, guardian, caregiver, or aide. However, people should also be given the opportunity to provide assent to participate. You should provide everyone with all of the appropriate information about the process, regardless of age or cognitive ability.

Collecting Participant Data

Data collection entails observing and recording how participants are interacting with an exhibit interactive and then gathering feedback from them about their experience. Accessibility testing gives people with disabilities the opportunity to identify barriers and offer feedback on ways to remove them or to point out aspects of an exhibit that positively affect their inclusion within an experience. Hao’s 2018 article “Can you make an AI that isn’t ableist?” writes that people assume “if the system doesn’t know anything about individuals’ disability status, surely it will be fair. But the problem is that the disability often impacts other bits of information.” Through accessibility testing, an exhibit team can work towards removing this form of bias from their exhibits and exhibit design process.

It may be beneficial to include exhibit designers and other practitioners in the data collection session. Watching a participant use your digital interactive can provide a rich amount of instant information. Below are some things to consider when conducting accessibility testing:

- **Be prepared:** Participants may need additional information on the exhibit interactive or clarification on what type of feedback they should provide during testing. For example, participants who are blind or have low vision may need descriptions, instructions, and orientation to the space and interactive. Exhibit practitioners who are part of the testing process help provide this information, which can aid in understanding the accessibility needs for the interactive.
- **Be flexible:** Data collection changes from group to group. Be ready to deliver information in different ways, such as reading information, instructions, or survey questions out loud. Feedback can be gathered in a multitude of ways to fit people's needs and preferences. Some may prefer to write, some may converse with data collectors and exhibit designers, and some may offer little verbal feedback at all. For these cases, the observations of parents or caregivers may be the primary data source.
- **Recognize individual experiences:** As mentioned earlier, experiences and opinions vary between individuals who may have similar disabilities. It is important to be true to the experiences of each individual and remember that one size does not fit all. As such, when taking notes try to avoid paraphrasing and keep as close to the participant's voice as much as possible.
- **Be reflective:** Try to incorporate time to reflect and debrief after each session, particularly if exhibit practitioners are involved. Use this time to make sure your notes are complete and write down any surprises or issues that came up during testing. Reflection aids in helping your team grow and improving your accessibility testing processes.

Data collection can be an intensive process with no two groups alike. By following the above guidelines, you can be ready to not only gather useful feedback but also create a positive testing experience.

Example: Engineering Design Workshop

Engineering Design Workshop is an exhibition opening at the MOS in 2020. Development is ongoing and accessibility testing underway with a range of audiences in order to refine exhibits and improve their designs. The exhibition's primary goal is to engage all visitors in practicing engineering and computational thinking skills as they create solutions to compelling challenges. Many exhibit activities often blend physical and digital interfaces to convey these messages.

One accessibility testing session included four visitors with Autism Spectrum Disorder (ASD), and their two chaperones. Two data collectors met the group in the lobby and explained a little about the exhibit prototypes and overall exhibition. Due to the group's size, this group was divided into two smaller groups, each with one chaperone, so observations could be more focused. Data collection entailed observing the group interact with exhibit components and conducting a brief interview about each exhibit following their interaction. After using all exhibit prototypes, researchers asked participants several interview questions about their overall experience.

It became evident during testing that all of the visitors with ASD were non-verbal and several had cognitive disabilities and limited mobility. The exhibit prototypes ended up being rather complex for this group to interact with, so group observations became the primary data collection method. Data collectors observed the group's actions, such as parts of the activities that individuals seemed excited about and areas of confusion and misuse. Observation notes also included how the chaperone helped facilitate the activity and feedback he shared during the experience about the meaning of his group's interactions. In the interview, the visitors with ASD primarily gave thumbs up or thumbs down about what they were interested in, and we were able to ask focused questions to the chaperone who knew his group well. Observations and basic interview feedback from the chaperone and participants helped the team better understand where labels or pictures might be helpful for visitors who need more scaffolding to get started.

Analyzing and Reporting Data

Analyzing and reporting data are the final steps of an evaluation study. Once data is collected, it is key to analyze and report findings to stakeholders in ways that are both accurate and useful. You may have questions such as: "What are ways to accurately and usefully analyze data with small sample sizes?" Or, "What are ways to report findings so that stakeholders can meaningfully determine next steps and encourage iteration?"

When analyzing and reporting data, portray findings in a way that is genuine to the experience, and respectful to the participant. Be mindful of your own biases and the lens you are using to analyze. Frierson et. al. offers that, "To ignore the reality of the existence of the influence of culture and to be unresponsive to the needs of the target population is to put the program in danger of being ineffective and to put the evaluation in danger of being seriously flawed" (2010). When it comes to formative evaluation, you are asking visitors to share their perspective about your design, and these perspectives reflect their experience and background.

As reflected in the social model of disability, use the data you collect to identify design issues or solutions without putting the onus on the visitor to change.

Typically, accessibility testing data involves qualitative data, which oftentimes means rich, detailed responses and smaller sample sizes. There is no one way to analyze qualitative data, but many approaches emphasize the strong interplay between the researcher and the data (Patton 2002; Corbin & Strauss 2015). The analysis should remain authentic to the testing audience, also recognizing that individual experiences do not necessarily represent everyone who identifies with that disability. That is why the context and description of the individual sharing is important. It is also important to report on all of the data you collect, particularly with small sample sizes. Although evaluation project goals may differ, including visitors with disabilities in a study assists the project team in identifying barriers to inclusion or exemplary practices that foster inclusion. In addition to capturing this information, it is critical to also highlight findings that may be non-disability specific such as content learned/not learned or experiences that were generally enjoyable/not enjoyable.

One way to tackle reporting is via case study or vignettes. This technique helps showcase the detail of responses and presents information that is genuine to your participant's experience.

It is also appropriate to incorporate the visitor's own words or perception of their experience in the report. Often the context around the experience and the dialogue from the interaction is more useful than quantifying behaviors.

It is not the evaluator's place to make value judgments about a participant's experience or attitudes. In sensitive situations, it may be particularly helpful to present results with neutrality and focusing on reporting the observed behaviors and associated outcomes in an objective manner. One suggestion is to have a section presenting the "results" and another section focused on "discussion." By dividing these sections, you are able to present the data in a neutral manner before providing any interpretation.

In addition to reporting to stakeholders, it is valuable to think about ways to disseminate findings to study participants, including the broader community. A formal report may not be necessary; it can simply entail a brief sharing of findings. Study participants appreciate hearing how their experiences and feedback were used, and sharing with the larger community can help promote museums as an inviting place for all. One way to do this is through an annual newsletter sent out to contacts who have signed up to be part of exhibit testing or who have come in the past. Information in the newsletter could include how projects were improved using feedback from visitors with disabilities.

Lastly, reporting formats and preferences might vary. Think through which approach might be most effective given your type of results and intended audience. For example, if you are presenting results to people who are blind or have low vision, make sure you use screen reader-accessible document formatting and that any included images or videos are described either on the slide or in the picture's metadata. If you are presenting to the deaf or hard of hearing community, creating a PowerPoint with concise, clearly-written bullet points or visual graphs might be most effective.

Final Thoughts

In the process of designing accessible digital interactives, evaluation is a critical step that should be included from the beginning of the design process. Summative or "final" evaluations are valuable for reflecting on practice and documenting lessons learned, but formative evaluation is what supports accessible design. Formative evaluation encourages design teams to iterate and be responsive to users.

Remember to consider not only the accessibility of the digital interactive, but the accessibility of the evaluation itself. Being responsive and flexible to users in the evaluation process is part of how you can assure them that you are taking their feedback seriously. A well-thought-out process can be the foundation of fruitful and mutually beneficial relationships for years to come.

Finally, there is always room for reflection on "best practices" and "standards." Technology can advance quickly in a short time. The tools we use to evaluate might change depending on the products tested, and accessibility tools and preferences among users can shift. Do not be afraid to re-evaluate even tried-and-true methods to advance accessibility and inclusion in digital interactive design.

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Inclusive Digital Interactives

Best Practices + Research

Chapter 5

purpleSTARS: Inclusive Curation and Production Creates Inclusive Museums

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Smithsonian | Institute for Human Centered Design | MuseWeb

Overview

The Sensory Objects research project (2012-2015) was funded by the UK Arts and Humanities Research Council. The project encouraged the personal viewpoints of an inclusive research team who engaged critically with museum collections and produced multimedia and sensory art interpretations using various technical tools and creative processes. Our research demonstrated that using technology to critically engage with collections, reflect, and activate a sensory encounter in response, helped engage people with intellectual disabilities (ID) in creating a complementary and more inclusive visitor experience, so widening the public appeal of museums and heritage sites. The follow-up enterprise, named purpleSTARS, combines ‘purple,' the color associated with disability in the UK, with STARS, which stands for Sensory Technology Art Resource Specialists. The purpleSTARS' mission is to bring together artists and technologists with and without ID to transform museum experiences and make them truly inclusive, using sensory and digital media to creatively disrupt and reinterpret heritage sites and museum collections.

Introduction

The purpleSTARS combine media production and creative art practice in a blended mix of multimedia and multisensory processes that enable people with diverse gifts and abilities to work together and actively engage with museum and heritage sites to research and develop new ways in which to make them more inclusive and relevant for people with intellectual disabilities. The purpleSTARS approach to inclusive design is transformative because it applies the self-advocacy maxim of ‘Nothing About Us Without Us’ by actively engaging and valuing people with ID as experts at the heart of the processes that shape our cultural institutions. The technical tools and methods we use scaffold the active engagement of a wide team of people with and without ID. As such, this work disrupts the established understanding of inclusive design as a set of adjustments, proposing in its place, a model of inclusivity gained through practice, that interprets the often-cited 'public ownership' of our museums in a challenging way. We promote inclusive public culture by actively engaging disabled people as researchers, curators and creative producers, with a method that enshrines the definition of inclusive research proposed by Walmesley and Johnson: Inclusive research is research in which people with learning disabilities are active participants, not only as subjects but also as initiators, doers, writers and disseminators of research (2003).

Our model of inclusive research and development (R&D) draws from both contemporary art and media practice and participatory action-research, using technologies for media authoring and the creation of interactive sensory objects to enable people with ID to fully participate. The purpleSTARS bring user-centered mixed-ability teams into public culture and heritage spaces to explore and trial installations, reflect and then produce their own objects and interactions in response, through a personal, critical and creative practice. The result is the development of innovative visitor experiences, led and co-created by people with ID to make museums and heritage sites more diverse and inclusive, as disabled people reinterpret what is on offer and affirm their shared ownership of these public amenities. The wider potential impact of a purpleSTARS intervention is upon the culture of the museum or heritage site. The active and integrated presence of people with ID collaborating with its teams, within the fabric of the museum, prompts a reinterpretation of the site's outreach strategies, as well as the design and curation of its installation, asking significant questions about how the institution engages with its public and interprets the mission to widen engagement.

The purpose of this essay is to share the methods and achievements of the purpleSTARS and the Sensory Objects research project from which this enterprise emerged, with a focus on our unique application of sensory and digital technologies to achieve inclusion for museum collections and heritage sites, working in collaboration with people with intellectual disabilities.

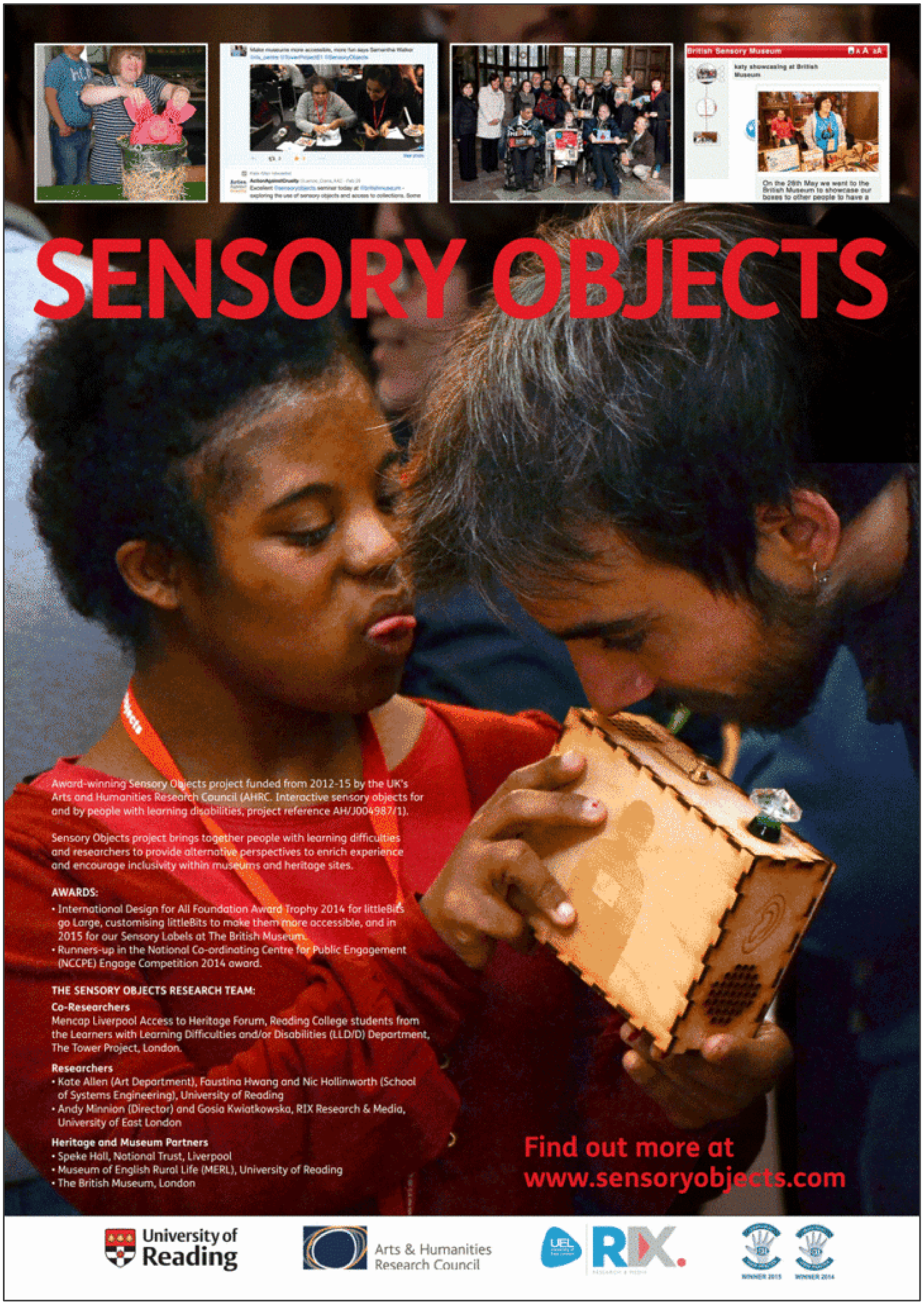

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Figure 1: Sensory Objects research project poster.

The Sensory Objects/purpleSTARS Method

This essay showcases our work with the British Museum, London, and The Museum of English Rural Life (The MERL), Reading. We employ these assignments as case studies to illustrate our developing methodologies that combine digital media, sensory art, and electronics, to create interactive sensory objects and to demonstrate the way in which this work realizes our goal to influence and affect museums. We are a collaborative design team that respects and listens to each other as ‘experts by experience,' whether we are people with or without ID, artists, curators or technology experts.

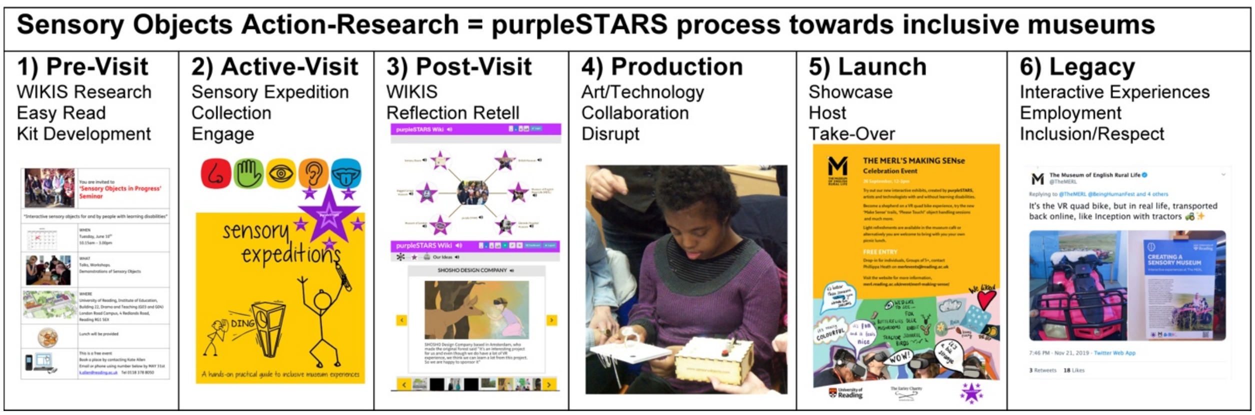

Figure 2: Sensory Objects/PurpleSTARS' 6 Steps towards inclusive museums.

Sensory Objects/purpleSTARS Action Research 6-Phase Timeline

1) Pre-Visit

The *Access to Heritage Guidelines* (Mencap Liverpool, 2009) advise that, "People need to know what a heritage site can offer them," before they make a visit. They recommend that people with ID should prepare by finding out as much as possible beforehand. The purpleSTARS adopt this approach in the preliminary phase of their work plan, using the web to build their knowledge and orientation around an exhibit and its themes before they visit. The pre-visit phase also entails preparation for the researcher’s own active media production and collection of sensory materials, which will be central to their visit. In preparation for this dimension of the work, co-researchers are encouraged to select and prepare the kit they will use for their expedition. We invest in this process, making adaptations to the tools we use to ensure all individuals feel equipped and included as part of the expeditionary team. Certain equipment has been shown to suit each individual's different manipulative skills, visual capability, or capacity for attention and focus. They choose from a comprehensive range of different cameras, recorders, tripods, clamps, and stands to suit their individual needs. We develop an Easy Read program for the visit, creating a simple table with images providing practical information such as dates and times, events of the day, tasks, etc. We have found these Easy Read ‘call sheets’ really valuable, providing an accessible way to understand the structure and focus of the day, and providing a focus for prior consideration of environments, risks, or challenges by the whole team.

2) Active-Visit Sensory Expeditions — engendering an active and critical approach to a museum visit.

The easy-to-understand *Sensory Expeditions* instruction manual guides purpleSTARS' collection of information as they explore a museum or heritage site using as many senses as possible, noting surface textures and identifying things to hear, touch, smell or taste — alongside things they *would like to* hear, touch, smell or taste — but that are out of reach or missing from the collection. The team uses sketch pads, cameras, and tablets, alongside some creative tools and methods designed and customized to facilitate consideration of sensory experiences that otherwise resist capture with a camera and so are more likely to be overlooked.

To engage with auditory senses, we listen to and record sounds from museums and heritage sites. While some places were rich with audio sources such as creaky floorboards or lofty halls where every sound resonated, elsewhere we noticed hushed and reverential silence and our researchers identified the *absences* of key sounds in relation to the collections. This has prompted us to run sound effect production workshops with the team to create sounds that were missed. We also designed a highly accessible ‘sound player’ comprising a small rectangular box and an easy-to-use rotary knob that required minimal instruction to use. We preloaded the player with audio files that corresponded to the museum exhibits (e.g. animal sounds and sounds of farm machinery in a farming museum). The files were visually labelled, then selected with the rotary dial and played back by pressing a large red button. Co-researchers used these devices as they toured the museum, and matched the sounds with the exhibits.

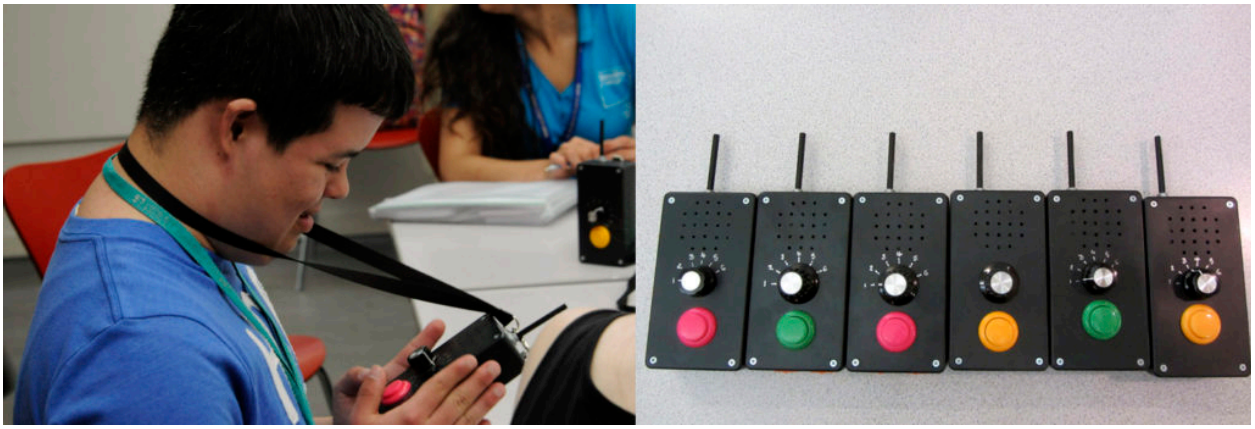

Figure 3: (Left): Sensory Objects co-researcher Guillermo looking at a prototype of a sensory sound player. (Right): Six sensory sound players.

Once we have collected our sensory information on the expedition, we then reflect on our experiences and capture our thoughts back at our home base. We use a mix of digital and creative processes with easy-to-build multimedia websites called the RIX Wikis, and recordable Talking Postcards for the Retelling phase in the third stage.

3) Post-Visit Reflection, Retelling

RIX Wikis and Talking Postcards provide tools and techniques to collate, review and critically reflect on our expeditionary visit. They also allow us to develop individual and shared accounts of the visitor experience as it was for us, and, in thinking about how it could be, creating both a multimedia and a multisensory response to the exhibition or installation.

The Wiki website software developed by RIX Research & Media are a key resource for this purpleSTARS methodology. They are designed to help individuals collate and arrange rich media using the Wiki's mind map navigation design and a slideshow structure to help them select and sequence their media material. Individuals also have the choice to add text and voice-over, or attach links and files to compile a richly-layered interactive multimedia portfolio. During the Sensory Objects project, Wikis have proven to be an effective tool to facilitate research processes in ways that can include the full team. They served as a repository for the data gathered by the research team in their various media formats. The site's navigation provides a scaffold for the organization of the experience into thematic order and chronological sequence. By arranging and annotating media with a Wiki after a visit, we draw on people's memories and share a process of critical reflection. Together, we start curating a discourse around a museum's collection, constructing narrative threads. People have control over their own sections of the Wiki where they can tell personal stories that align to the objects they encountered. They can develop their own contributions by attaching files or adding links to document further contextual research pursued via the web or through access to other media sources.

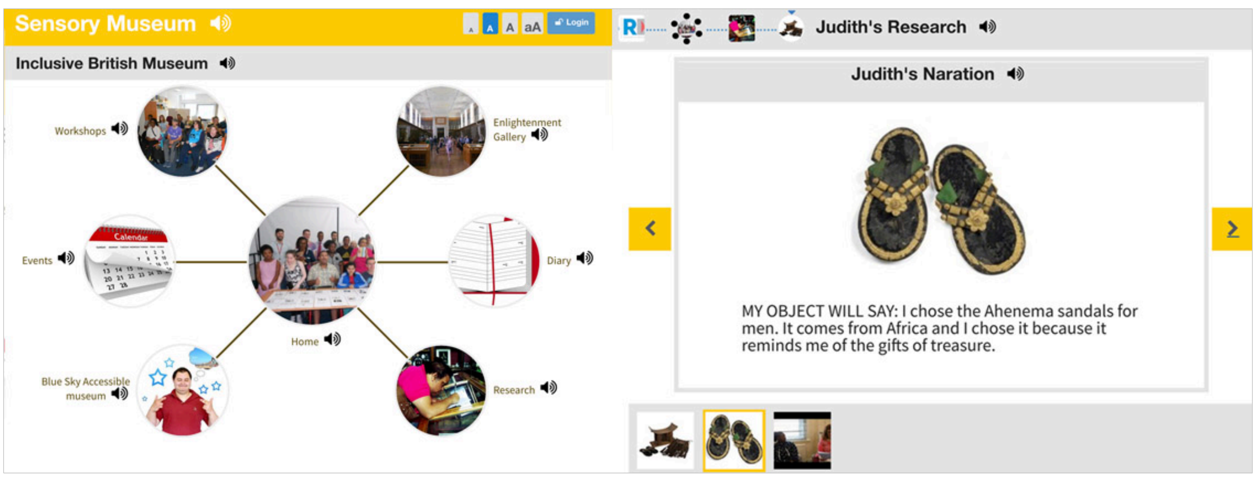

Figure 4: Sensory British Museum WIKI. Two pages from the easy to use webpage.

We thus develop our own unique interpretations of the stories that museum collections hold, using our Wiki websites as digital sketchbooks and tools for data analysis, as well as for developing and communicating our ideas. A single Wiki website provides a portfolio for the purpleSTARS' work as it progresses, with easy functionality to project and share work with fellow team members or with our client partners. The critical engagement with museum collections through our sensory expedition and the re-working of the data collected in adding to the Wikis, are developed with hands-on art workshops using interactive technologies such as the Talking Postcards — postcards containing a voice recording chip with a simple record and play operation. The postcards are employed to capture sensory material: images, sounds, textures and smells. This enables a process of reflection and exploration of the subjective meanings and associations evoked alongside our sensory experiences with a museum collection. This is a process of retelling in which we actively engage and include people with ID, sharing and valorising their unique lived experiences as well as their sensory perceptions to include everyone. Our retelling starts combining digital media and other art materials and processes with the introduction of simple electronic interactive components. We take this forward in the next phase as we then translate our retelling into a re-curation of the story, working on the co-production of a more complex and finished alternative environment or object that can enhance a visit or cohabit in the museum with the original displays. This adds narrative and sensory wealth, encourages further points of access to the collection, and prompts and promotes further reinterpretation by museum visitors.

Usefully, the Wikis and the mini-installations enshrined in the Talking Postcards provide a record of our process that helps to frame and sustain engagement of participants with ID, triggering memories and capturing thoughts that might otherwise be lost, as well as providing a rich archive of background information on how our works are developed.

Figure 5: Examples of using Talking Postcards to create Sensory Labels for the Enlightenment Gallery at the British Museum 2014 pages from the Sensory Expeditions Workbook.

4) Production: Creative Art and Technology Collaboration

Creative art workshops are central to the purpleSTARS process — the sensory materials collected from a museum are brought together to help us discuss and experiment, as well as create stories and sensory objects in response to the museum collection. Working together to share and consider sensory materials incorporates our Talking Postcards experiments alongside clay, cloth, microcontrollers, plastics, laser cut imagery etc. Allowing for everyone to share something, whether a sound, a movement, a drawing, or object, the production process enables all types of content to be shared and acted upon. Hands-on experiments allow for accidents and unexpected outcomes to occur — everything is up for consideration as we enjoy a level ground where everyone can 'have a go.'

This phase exploits the permissive openness of creative art practice, applying a ‘process-driven’ approach that can conflict with the conventional expectations that come with a museum commission and a brief. Museums have expressed concern that they could see no pre-defined outcome from a purpleSTARS workshop, but our engagement in art practice is part of an action research methodology, whereby outcomes are discovered through the process of experimentation and discovery. Our belief is that the freedoms of art practice make the opportunity to contribute more flexible and in the process, original ideas can emerge and prompt unexpected solutions for more inclusive experiences.

Sensory Objects and purpleSTARS' work has repeatedly demonstrated that stand-alone touchscreens do not readily engage visitors, who are more eager to be able to physically engage with museum exhibits. However, this is rarely an option with the majority of a museum’s collection, comprising objects that are too fragile and valuable to handle. We recognized the potential value of the replica objects that museums acquire so as to provide relevant tactile experiences for visitors, and these have become a popular vehicle for the Sensory Objects experience that purpleSTARS developed. The team discovered the power of sensory technologies embedded into replica museum objects that are sufficiently robust to feel, touch and share with other members of the public. The cause and effect enabled by electronic sensors and triggers could trigger sensory surprises from objects and evoke the stories the collections hold in ways more intimate and shared.

Through our design process over the three years of the Sensory Objects research project, short but regular workshops gave our co-researchers the opportunity to discover how to design an artwork that was responsive in some way, for example, choosing a sensor responding to light, sound, touch or the proximity of a user. The idea was to be able to activate and share a moment with a sound, smell, texture or vibration so we could experience a fresh and often unexpected perspective of a museum collection. This triggering of a different point of view provides the opportunity for historic objects to become part of our present time and be enriched by tangential stories and sensory experiences that can make connections for us that are not otherwise available. For example, the *MERL Sensory Cow* allows visitors to press a button under the cow's chin to record and play back their own "moo," enabled by a Raspberry Pi embedded under the cow's life-size body. Making animal sounds and leaving something personal in the museum, we note, has helped to promote an enhanced sense of connectedness, as well as ownership of the museum as an experience, for visitors.

Figure 6: MERL Poster for Research in Action event which led to the MERL Sensory Cow commission. Press the record button under her chin to leave your own Moo. The MERL sensory cow is fitted with a microphone in her ear. A raspberry pi controls her own intranet for recording and playing collected Moos. She also has a smell machine blowing out the smell of milk chocolate and a selection of magnetic tactile examples produced from cows, including a leather hand control patch with a touch sensor embedded to turn sounds on and off.

For our co-researchers with ID, this interactivity added to their sense of ownership and control of the alternative experiences that they created. They were consistently delighted in the cause and effect of a switch or trigger that they deployed to spark the special experience they designed for the visitor. We see that these interactive controls reinforce the rebalance of power relations that the purpleSTARS promote by further emphasizing their agency and advocacy as producers.

For this to be learned and embedded into our practice, as with our media and sensory methods, we found we had to adjust the way these tools were designed, and introduce them to the purpleSTARS team incrementally so as to fully engage the people with different abilities who made up our R&D team. To further this aim, we first explored the idea of cause and effect, illustrated by a picture of a cat, with the 'cause' being a hand stroking it and the 'effect,' the cat's purring. We introduced the technology in stages, with workshop sessions to first demonstrate what was possible in terms of making objects interactive and responsive, then providing accessible tools to facilitate hands-on exploration and experimentation with interactive elements, and ultimately designing and producing our own interactive objects together.

We developed individuals' practical understanding of cause and effect with *Squishy Circuits* (Johnson and Thomas, 2010) — the co-researchers constructed simple electronic circuits using conductive dough made from flour and cooking oil, connected to batteries, buzzers and LEDs. We also added smell to the dough, which everyone found fun to model and easy to work with. With a little guidance, we were able to make simple circuits and experiment with triggering actions, such as switching LEDs on and off, and gaining experience and confidence in assembling electronic components by introducing simple power sources, output devices, and triggers.

As a next step in encouraging the exploration of technologies and what they can offer, we experimented with littleBits (Bdeir and Rothman 2012), an electronics kit that consists of small electronic components (somewhat similar to Lego), which snap together through magnets. Our co-researchers readily engaged with the simple design and magnetic connections of the littleBits, and with some guidance, were able to construct simple circuits that allowed them to explore different methods of triggering sounds, light, and movements. However, these kits demanded a level of manual dexterity that was beyond some of our team. With the expertise of our Sensory Objects post-doctoral researcher Dr. Nic Hollinworth, we designed larger bases onto which to attach the littleBits pieces, making it far easier for those with limited motor control to manipulate the components which were resized as larger objects. This piece of R&D was described in an article entitled ‘Little Bits Go Large’ and was awarded the International Design for All trophy in 2014 (https://extrasensoryobjects.wordpress.com/littlebits-go-large/).

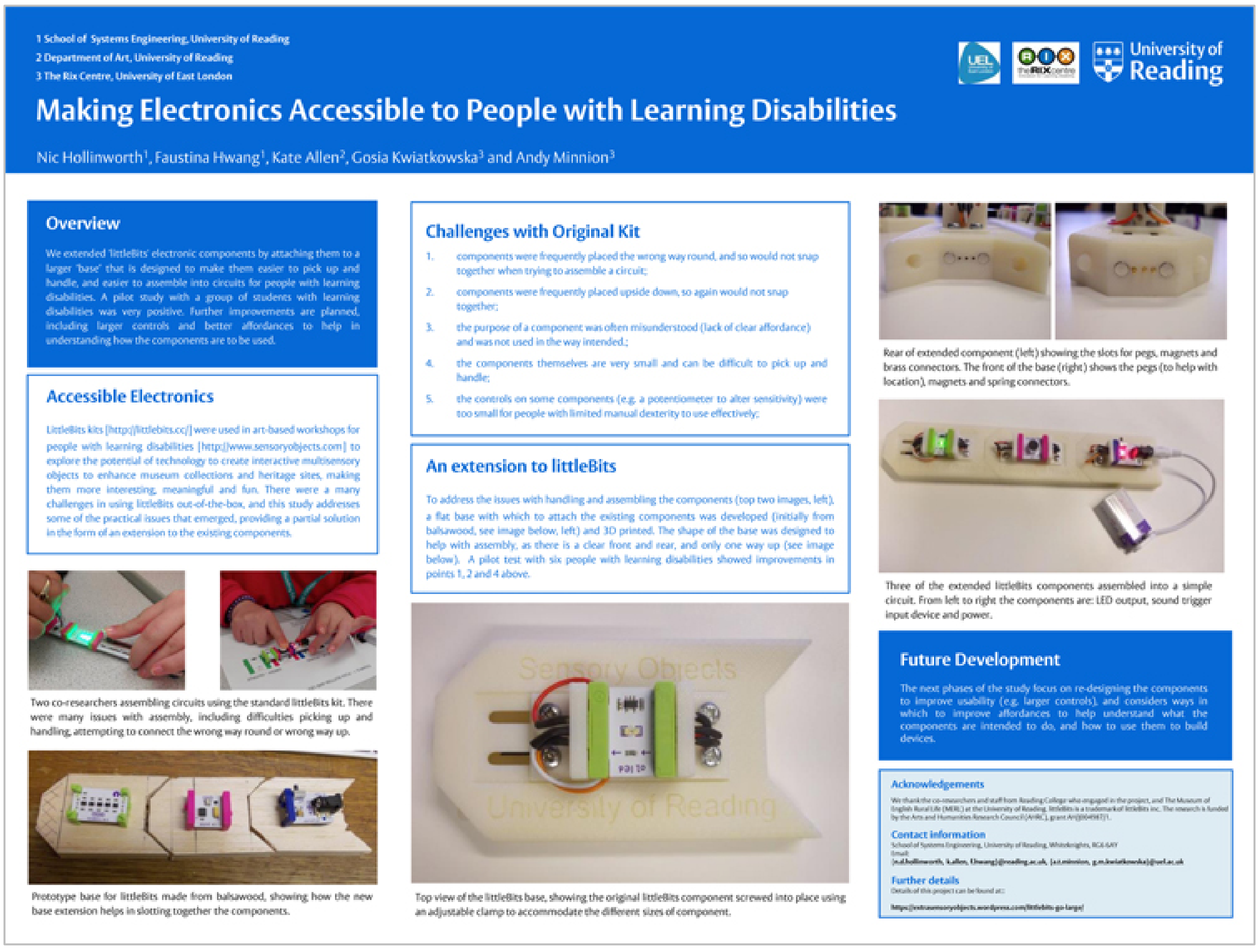

Figure 7: LittleBits Go Large research project poster.

In our work with the British Museum on the Sensory Objects research project, we developed a set of sensory labels by applying these methods. Our labels used an Arduino controller to trigger sounds in unique ways, adding alternative sensory stories and perspectives to some of the objects in the *Enlightenment*

Gallery at the British Museum. The gallery represents an eighteenth-century cabinet of curiosities collected by the museum's founder, Sir Hans Sloane. The collection is displayed in wooden cases, with most items behind glass. Each of our co-researchers chose an object as part of their sensory expedition, researched it, and collated information about the object and the thoughts it inspired in their Wiki. We initially developed labels for the objects with sounds, smells, images and textures using the Talking Postcards mentioned above. Then, in response to the ambitious designs of the labels developed, we progressed to the use of sturdier materials, creating larger, laser-cut wooden sensory boxes to serve as labels. They became remarkable artworks in their own right, each capturing a co-researcher's individual response to, and reinterpretation of, the chosen museum item. purpleSTARS' first employee, Judith Appiah, created a sensory label. She chose a leather slipper from Ghana. Judith drew the slipper and then decided to make a replica in leather to recreate its texture and smell, and to be able to bend it like the original slipper in the collection would, if she was able to touch it. She also wanted to include sounds of Ghanaian music and the sound that sandals and flip-flops make when you walk in them. Through the earlier workshops, Judith had experience using littleBits — she enjoyed using the bend sensor and said that the demos of the littleBits from earlier workshops helped her understand how she could trigger sounds when designing her sensory label. Judith decided to embed a bend sensor in her slipper so when it was bent it triggered the sounds.

Figure 8: Judith demonstrates her Sensory Label at the British Museum.

The idea to create an immersive virtual reality (VR) experience was triggered while observing college students with ID attempting to walk into a projection of an animated forest. On a visit to MERL, the college students requested to show the animation in their sensory room. during the showing we observed students repeatedly trying to walk into the animated forest space. We started experimenting by making a simple VR version of the forest which could be experienced through a VR headset. Most of us really enjoyed the experience and found it very calming. We noted how popular VR was with ID learners who typically had low attention spans for conventional displays. Judith Appiah, the purpleSTARS employee who built the sensory label, suggested a VR version of the forest with changing seasons would make a great outreach exhibit — for example, to be shared in a hospital for those who are unable to come to the museum. We sent our simplified VR version to Shosho, the design company in the Netherlands who had made the original animation. They were very excited about the idea of a VR forest developed by people with ID and offered to work with us to create a version, complete with additional elements suggested in drawings by the purpleSTARS, including a rainbow and a weasel agreed upon during online meetings.

Figure 9: purpleSTARS suggest ideas for a virtual forest.

MERL commissioned purpleSTARS to create a series of immersive experiences. During our *Sensory Expeditions* visit with local students with ID, everyone wanted to sit on the old tractors and Land Rover, but the machines in MERL were either too vulnerable or too valuable. One exhibit of a shepherd's smock and crook featured accompanying information that a modern shepherd would use a quad bike (all-terrain vehicle) to look after his sheep and this prompted the idea to create our second VR experience. Here, production entailed the purchase of a quad bike and a 360 GoPro Fusion camera to film a Dartmoor farmer as he worked with his dog to round-up a flock of sheep on his own vehicle. The 360-degree video was transferred to an Oculus Go headset so the visitor, while on the quad bike and wearing the VR headset, could view and enjoy the immersive VR experience of a farmer working with his dog and sheep on Dartmoor in the museum.

The purpleSTARS were very keen to create versions of their VR experiences to be as inclusive as possible, demonstrating how attuned they are to a specialist understanding of the rights issues that determine inclusion. The team were keen to create audio descriptive versions of the quad bike (https://extrasensoryobjects.wordpress.com/littlebits-go-large/) and shepherd experience for people with visual impairments. They also designed and produced a detachable handlebar version, coupled to a vibrating cushion, to simulate the experience for wheelchair users.

Figure 10: purpleSTARS Julie on VR Quad Bike Experience at MERL; Justin tests wheelchair version of VR Quad Bike experience.

5 and 6) Launch and Legacy

The purpleSTARS engage with the public and share their work through showcase events and seminars and they have found that doing so further develops their relationships with the museums with which they work. The purpleSTARS take over as hosts, presenters and leaders, demonstrating their effective accomplishment as self-advocates. We showcased the sensory labels from the *Enlightenment Gallery* at the British Museum at a special event with all twelve co-researchers present in the gallery. Visitors were invited to inspect our sensory labels. This led to unexpected conversations with the public, who were intrigued — the change in positioning engaged museum workers, who notably shifted their own perspective from seeing the co-researchers as recipients of their workshops to creators and facilitators. Our co-researchers felt respected and proud to share their beautifully-made labels, with personal perspectives on the objects in the collection, with everyone. Support workers were also surprised to see the confidence with which the group engaged with the public and shared their sensory labels. Museum visitors enjoyed sharing alternative perspectives of the collection presented by the co-researchers. Children loved to trigger the sensory label sounds, sniff the ‘smell chamber’ and feel the surface of the laser-cut wood. The British Museum invited the Sensory Objects team back to the *Enlightenment Gallery* during school holidays to share the sensory labels with children of all abilities, and the team have subsequently contributed to the #purplelightup at the Museum for the International Day of Persons with Disabilities.

The legacy of the Sensory Objects research and purpleSTARS enterprise continues at the MERL — the quad bike VR installation is now permanent and is a very popular feature of the museum. Some of the students with ID from the local college work as volunteers to help visitors fit the VR headset and enjoy the experience.

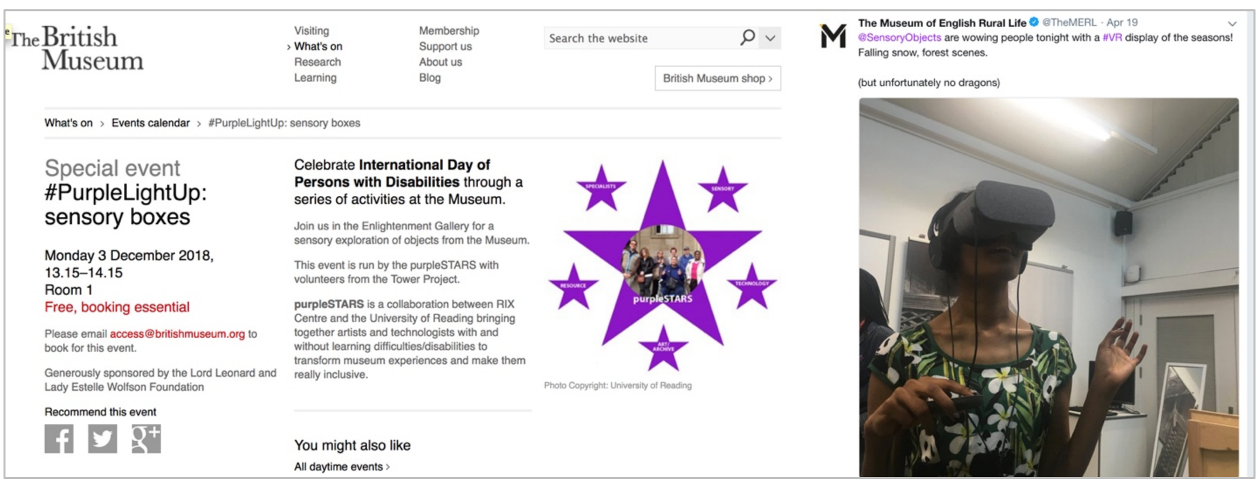

Figure 11: #PurpleLightUp at the British Museum for the International Day of Persons with Disabilities event 2018 and visitor at MERL Lates Digital Take Over Night 2019

Reflections and Conclusions

The work of the Sensory Objects project and its subsequent manifestation as the purpleSTARS enterprise has established the beginnings of an innovative method for making our museums and heritage sites genuinely more accessible and inclusive places. The combination of multimedia advocacy and sensory creativity enshrined in the approaches that we have started to map out in this chapter has proven potential to raise awareness for all stakeholders and frequently catalyze and stimulate the necessary processes of change that are required. These are practical methods to help include diverse people in different ways that can complement each other and combine to achieve more welcoming and inclusive amenities.

The key step that we note, to progress towards better inclusion, is to **rethink the roles** that are considered for the disabled people you wish to engage. Kate Arnold-Forster, the Director of The MERL recognized the powerful effect of this shifting of relationships in her speech to the purpleSTARS:

> I think the idea that you are the researchers is fantastic and you tell us what we should do. It's not us thinking about ideas and trying them out on you, the ideas are being born and developed between us — and that has been fantastic.

Describing and reflecting on our experiences has led to a set of recommended approaches that, together, constitute an emerging methodology. We summarize here, as a concluding draft, purpleSTARS' *Manifesto for the Inclusive Museum:*

- Engage people with ID as co-researchers, creatives, guides, and curators alongside your existing in-house teams to apply the principle of 'Nothing About Us Without Us.'

- Acknowledge how everyone can contribute expertise as 'experts by experience' and actively identify, value, and incorporate those contributions into your teams and their workflows.

- To make this work, you should break your existing processes down into small, manageable steps and be creative about how they might be made easier to understand and engage with (e.g. for data analysis, use chairs with single-word and picture labels to organize research data — in written notes or objects — into the emerging themes, located in different parts of the room).

- Use multimedia authoring, organizing, and annotating tools, such as the RIX Wiki, to collate observations and ideas, and to frame your research study.

- Plan and organize all of your activities for clarity and orientation with easy-to-understand Easy Read 'call sheets' to ensure that everyone is up to speed and engaged with the program.

- Be prepared to make alterations to some technologies and processes so as to ensure that you include everyone. Set time and resources aside to achieve this so that no one is left behind as the project develops.

Our experience is that these methods can enable people with ID to challenge legacy practices that exclude them and catalyze change to make our public culture more inclusive. These are not discrete specialist outreach activities or ‘reasonable adjustments’ to curation design. They represent fundamental change to working practices and introduce new processes to the museums and heritage sites into which they are introduced.

The creative art and media elements of these methods provide important freedoms and establish a space for disruptive things to happen that can help promote change. Process-led approaches carry uncertainty and can alter the ways in which we all work and transform our workplaces. Inclusion means local people seeing your museum as a welcoming space where they belong and as a public amenity to which everyone can make a contribution.

The creative work of people with ID has a special aura. Its appeal is often seemingly new and surreal to audiences who have the opportunity to experience personal perspectives that are rarely articulated or shared in our exclusive culture. Given the right structure, support and license to create, people with ID will provide museum experiences that will make visitors value their own subjectivity and difference, whatever their background. Such inclusive practices make inclusive museums — which are better museums for us all.

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Inclusive Digital Interactives

Best Practices + Research

Chapter 6

Universal Design for — Emotion in — Learning: A Practice for the Creation of Emotionally Accessible Digital Learning Experiences

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September 2020

Introduction

Affective neuroscientist Mary Helen Immordino-Yang once stated that, “without emotion, all decisions and outcomes are equal — people would have no preferences, no interests, no motivation, no morality, and no sense of creativity, beauty, or purpose … Emotions are, in essence, the rudder that steers thinking” (Immordino-Yang, 2015). And, in fact, the modern neuro and learning sciences explicitly tie the process of learning to meaning-making within the context of emotional experience. Reflecting this view, there is widespread agreement within the museum field that engagement, identity and motivation — three emotionally-laden constructs — are critical to informal learning experiences (CAISE, 2019).

Yet, our understanding of emotion in the design of museum spaces is impoverished and lacking attention to the full complexity of human experience (Christenson, Reschly, & Wylie, 2012; Fredricks, Blumenfeld, & Paris, 2004; Rappolt-Schlichtmann & Daley, 2013). Our prior research shows that whether or not we actively attend to emotion in design, visitors are experiencing many varied emotions in museums, ranging from happiness, wonder, and empathy to anxiety, confusion, and even fear. These emotional experiences are quite varied, informed by visitors' background knowledge, ethnic and cultural heritage, other aspects of identity, and experiences of the designed interactives in the moment, as well as their capacity for self-awareness, emotion understanding, expressiveness and emotion regulation (Salovey & Mayer, 1990; Brackett, Rivers, Bertoli & Salovey, 2016). The rich emotional life of visitors within museums includes people with disabilities, who stand to benefit substantially from deep and engaged learning experiences in museum settings, when supported to do so. Indeed, research literature has long described the important role informal learning environments play in sparking and cultivating long-term interest in topics of personal relevance — an experience of critical importance to the success of people with disabilities (Fink,1998; Rappolt-Schlichtmann & Daley, 2013).

However, without attention to emotion in all of its rich complexity, our designs can be rendered emotionally inaccessible, leaving many people out of deep learning experiences that could otherwise enrich and support them to thrive in learning and life. What if we thought about emotion specifically, and for its own sake? What does it mean to set emotional goals in museum design? How are people diverse in their emotional capacity and intelligence in ways that affect their experiences in museum settings? If feeling is, in fact, critical to learning and relating in life, how can we support emotion right alongside cognition in ways that reflect the integrated nature of thinking? In this chapter, we explore the concept of emotional design for informal digital learning experiences and address how Universal Design for Learning (UDL) can be leveraged to create experiences that foster emotional accessibility and support the development of emotional intelligence for all visitors.

What is Emotional Accessibility?

Following the passage of the Americans with Disabilities Act (ADA) in 1990, many museums improved the accessibility of their facilities to significantly expand the reach of their programming and exhibit spaces to people with disabilities. Typical solutions provide for the increased physical presence or accommodation of people with disabilities including, for example, text labels presented in both audio and Braille (Tokar, 2004).

Digital interfaces further extended the potential of these solutions to provide for more dynamic accommodations including just-in-time feedback, visuals with alt text, closed captioning and even device-specific responsive content. While such accommodations have had a substantial and positive impact on individuals with disabilities being able to physically or cognitively access museums, full participation as evidenced through deep engagement and intrinsic motivation for learning still lags (Rappolt-Schlichtmann & Daley, 2013).

Physical and/or cognitive accessibility does not, on its own, provide for engagement — learning does not occur as a consequence of the presence of the accessible label, per se. Rather, the design of supportive emotional conditions promotes the approach and interaction of diverse people with physically accessible exhibits, shaping the emergence of engaged visitor experiences (Falk & Dierking, 2013). To be effective, design for emotional accessibility must, like design for physical, sensory or cognitive diversity, consider the range of human variability in emotional experience. Just as variability in vision can be addressed through specific affordances built into the learning environment, variability in emotional experience can be proactively addressed through design. But how should we think about human emotional experience — what do we need to attend to — so as to create emotionally accessible designs?

To be sure, the experience of emotion is content-rich and more complex than our everyday experience would imply. Affective scientists describe two related but distinct aspects of emotional experience that can be attended to in exhibit design:

Core affect constitutes your general bodily state such as feeling pleasant or unpleasant, energetic or lethargic, and

Subjective feeling constitutes your understanding of your overall experience which we label with familiar terms like happiness, sadness, rage, pride, relief, etc.

In addition to these two aspects of emotional experience it is important to recognize, as designers, that human beings have intelligence and skills based on emotion that vary from person to person.

Emotional intelligence is your capacity to govern and leverage your emotion.

Emotional intelligence includes skills important to museum experiences like self-awareness, self-management (e.g., controlling impulses and motivating oneself), social awareness, relationship skills (e.g., cooperating with others and active listening), and responsible decision making (e.g., evaluating the realistic consequences of various actions so as to support your own well-being as well as that of others). As with physical, sensory and cognitive capabilities, people vary substantially in their emotional experiences of museum spaces and, as such, emotionally accessible exhibits will consider and address each of these three components of emotional experience — core affect, subjective feeling, and emotional intelligence.

UDL: A Framework for Thinking About Emotional Accessibility

The UDL framework can be extended to think about issues of emotional accessibility and, while not perfectly aligned, the approach provides a good and concrete starting point that may be familiar to many museum professionals.

UDL was conceived in the late 1980s by neuropsychologists David Rose and Anne Meyer who were working to respond to the “problem” of people who learn differently — those with learning, cognitive, or sensory disabilities or those who are otherwise neuroatypical. Rose and Meyer noted that the “problem” wasn’t the people at all but rather the “one-size-fits-all” learning environments that are too narrowly conceived, defined and constructed to meet the needs of the rich diversity of learners in the general population (Meyer, Rose, & Gordon 2014; Rose & Gravel, 2010; Rose, Meyer, & Hitchcock, 2005). Rather than describing people as disabled, Rose, Meyer and their colleagues at CAST began to describe learning environments as designed to be disabled or disabling. They conceived of the UDL guidelines as a means to provide opportunities for deep learning through the design of highly flexible methods, materials and learning experiences (Rose & Meyer, 2002; Rose, Meyer, & Hitchcock, 2005).

As neuropsychologists, Rose and Meyer anchored the UDL framework and guidelines to a careful synthesis of relevant research from across the learning sciences. They intended for UDL to represent our best and most current understanding from the research literature for practitioners, educational designers and learning scientists. For example, the framework and guidelines stem from the realization that three broad divisions are often made when describing learning, which are how people:

1. engage and are motivated,
2. perceive information and comprehend, and
3. navigate the environment and express what they know (Bloom, 1984; Luria, 1973; Vygotsky, 1978).

What differentiates UDL from previous and current reform efforts is its orientation to continuous improvement both in the design of learning environments as anchored to the guidelines and in the evolution of the framework itself. Indeed, as the learning sciences shift and develop, so do the UDL framework and guidelines (Rose & Gravel, 2012).

As discussed above, perhaps the most notable shift in the learning sciences over the last few decades (and since the conception of UDL) is our understanding of and attention to the role of emotion in learning. Historically, learning scientists conceived of rational thought as a kind of holy grail in learning design — emotion was something to be controlled, eliminated or trained-up, wholly independent of cognition in learning (Fischer & Bidell, 2006). But the last few decades have seen a kind of renaissance in thinking about the nature of emotion in learning. Research now counters the common conception that cognition and emotion operate in opposition, advancing the understanding that they operate together as two sides of the same coin and providing the basis for engagement, perception and comprehension, as well as action and expression in learning (Frijda, 1986; Lazarus, 1991; Russell & Barrett, 1999).

Affective scientist Mary Helen Immordino-Yang notes that:

> Quite literally, it is neurobiologically impossible to think deeply about or remember information about which one has had no emotion because the healthy brain does not waste energy processing information that does not matter to the individual (Immordino-Yang, 2015). Emotions help learners set goals during learning. They tell the individual experiencing them when to keep working and when to stop, when she is on the right path to solve a problem and when she needs to change course, and what she should remember and what is not important. (National Academies of Sciences, Engineering and Medicine, 2018)

So where is emotion in the UDL guidelines? Most obviously emotion is explicitly represented within the *Engagement* principle (the "why" of learning). The guidelines highlighted therein can help practitioners think about: the multiple ways in which people engage and are motivated to learn; lowering barriers to interest; effortful engagement; and self-regulation in designed experiences. In recognizing the shift in the learning sciences described above, CAST adjusted the graphic representation of the UDL guidelines in its second iteration and moved the *Engagement* principle into the first position so as to keep emotion front of mind in design (CAST, 2018).

However, deep engagement is only one goal practitioners might hold for visitors. UDL also provides guidelines for the creation of designed learning experiences that support the many varied ways in which people perceive and comprehend information, as well as the ways that they navigate the learning environment and express what they know. These are the two other UDL principles: *Provide Multiple Means of Representation* (the "what of learning"), and *Provide Multiple Means of Action and Expression* (the "how" of learning).

Emotion is, of course, also represented in these guidelines because emotion and cognition are always at play in every aspect of human life — engaging, comprehending, acting and expressing are all, at once, both cognitive and emotional. Thus, if you frame goals such as, "visitors will explore the perspectives of Native American people," or "visitors will analyze engineering design solutions," or "visitors will discuss scenarios for the mitigation of climate change," for various learning experiences, the UDL guidelines can help you think about how to support and scaffold visitors' diverse cognitive and emotional needs through design.

For example, when you provide background information (the UDL Guidelines: *Provide multiple means of representation — Activate or supply background knowledge)* you are supporting cognition in that you provide context to inform understanding of the current scenario. You are also supporting emotion regulation by lowering the demands of the task and helping visitors be more resourceful. Likewise, providing alternative representations of text labels will support the emotion and cognition of visitors who have difficulty with text (e.g., those who are blind, dyslexic or second language learners) by improving perception and comprehension, as well as by providing for a more positive core affective experience: "I believe I can do this," "I feel like I belong here." These strategies, in conjunction with supporting approach behavior, improve emotional accessibility.

Universal Design for Emotion in Learning (UDEL): Two Case Studies

Though the formal extension of the UDL framework to support emotional inclusion is a relatively new concept, we have developed several models of the approach through our work at the Museum of Science in Boston (MOS) that illustrate what it means to design digital interactives for emotional accessibility. These are by no means meant to be exhaustive — they are a set of examples to provide fodder for practitioners who we hope will be expansive in adopting this frame to develop emotionally accessible and inclusive experiences for visitors.

Our first example draws on prior work leveraging UDL in two scenarios: the design of the *Hall of Human Life* exhibition at the MOS, and a new project we are currently engaged in called APPRAISE (Exhibit Appraisal and Diverse Populations: Pilot Research about Intersectional and Science Identities in Science Exhibits; DRL-1906688). The APPRAISE project is funded by The National Science Foundation (NSF) and is focused on exploring and describing strategies for emotionally inclusive design that reduce barriers to deep learning and facilitate pathways to engagement for a wide range of diverse audiences.

The second example is focused on strategies for supporting, applying and developing emotional intelligence. We draw from work completed under our NSF-funded project, "Developing Guidelines for Designing Challenging and Rewarding Interactive Science Exhibits" (DRL-1612577), where we developed exhibits that strategically leverage emotions to improve performance on specific tasks, support learners' regulation of negative emotions, and promote emotional awareness.

Exploring and Supporting Core Affect and Subjective Feeling in the Hall of Human Life

Within museums, learners select which exhibits they will visit. From our perspective, this decision point is the first moment at which design can be rendered emotionally accessible. The UDL guidelines describe "recruitment of interest" as vital to engagement because, "information that is not attended to, that does not engage learners' cognition [and emotion] is in fact inaccessible" (CAST, 2018). Museum professionals have long studied behavioral patterns in exhibit use through methods like observation and timing and tracking (Serrell, 1997, 2010; Yalowitz & Bronnenkant, 2009). The APPRAISE project pushes beyond this to explore *why* people choose to approach or bypass an exhibit. It studies the ways in which museum professionals can use emotional experience as an information-rich indicator of barriers to visitor engagement or learning, and thereby facilitate pathways to engagement. The project measures visitors' conscious and subconscious bodily responses to designed learning experiences to tease out the emotional mechanisms of the approach and avoidance behaviors that shape museum experiences.

The APPRAISE research study is set in the *Hall of Human Life* exhibition at the MOS. This 9,700 square foot exhibition hosts over 70 exhibits — including many digital interactives — about human biology and human health (Barth, et al., 2018). Below, we explore the emotional consequences of design strategies in the *Hall of Human Life*, focusing on the three UDL strategies for recruiting interest:

1. Optimizing individual choice and autonomy;
2. Optimizing relevance, value, and authenticity; and
3. Minimizing threats and distractions.

Although this project is just beginning, the following sections illustrate the ways in which developers of digital interactives can apply the UDL guidelines in emotionally accessible design, inviting a wide range of learners to feel comfortable initiating a learning experience.

UDEL Strategy: Provide meaningful choice for visitors to create positive and energized emotional experiences.

Offering visitors meaningful choices can lead to emotional experiences that support them to approach exhibits and engage deeply. Reflecting the UDL guidelines for engagement (the UDL Guidelines: *Provide multiple means of engagement — Provide options for recruiting interest; Optimize individual choice and autonomy),* the *Hall of Human Life* provides visitors with a wide range of choices that can bolster feelings of autonomy in the learning experience. Visitors can choose between different types of engagement: at one exhibit, learners navigate through screen-based prompts using a button box similar to a simple keyboard; another exhibit involves taking off your shoes and walking across a platform that measures the arch of your foot; one asks learners to hold their hand still on a metal plate as it reads temperature and provides an interactive data visualization. Additionally, visitors can navigate through the exhibition in any order, allowing learners the choice to drive the agenda of their learning experiences.

Research suggests that these kinds of meaningful choices will have direct affective consequences; feeling like you have control over a learning situation and are able to define your experience on your own terms supports a sense of belonging and comfort. This can result in positive and energized core affect and subjective feelings like happiness, calm and excitement (Barrett, Mesquita, Ochsner, & Gross, 2007; Clore & Ortony, 2000; Scherer, 2001). In turn, the feeling that they are in control of a situation, as well as feeling energized and positive, increases the likelihood that visitors will approach an exhibit, and can lead to their investing more effort into the activity at hand and therefore developing higher levels of mastery (Immordino-Yang & Singh, 2011).

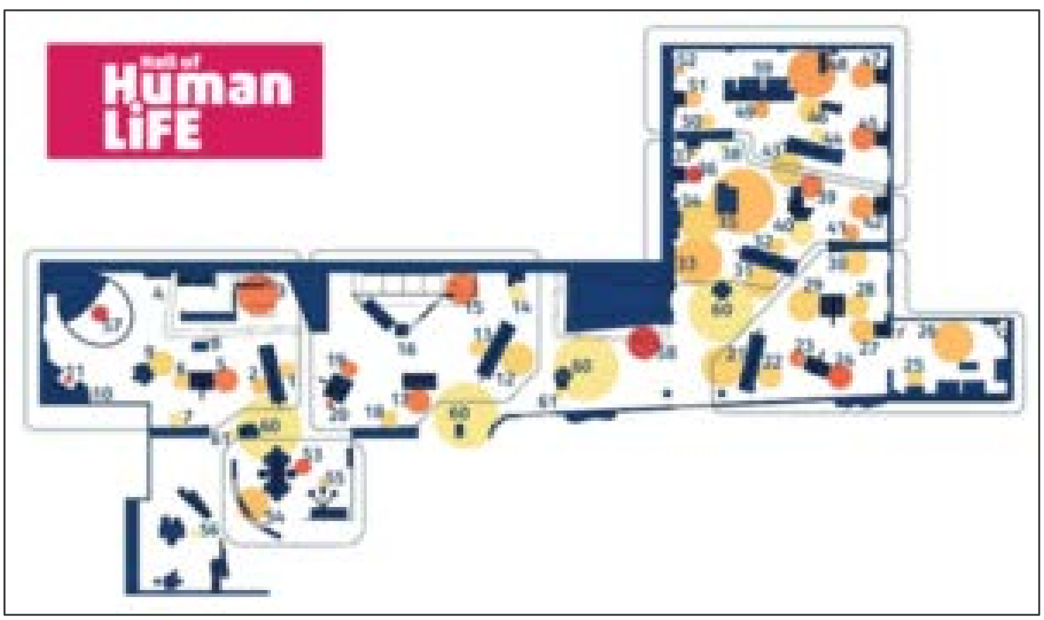

Figure 1: With over 60 exhibit components, the *Hall of Human Life* offers visitors with many choices about how to navigate its non-linear layout.

UDEL Strategy: Provide opportunities for visitors to personally connect, to boost feelings of relevance.

Helping visitors learn about themselves can boost feelings of relevance, contributing to deeper learning. One of the most prominent strategies to optimize relevance, value, and authenticity in the *Hall of Human Life* is a series of Link Station activities at which learners gather data about themselves and compare it with other visitors' data (the UDL Guidelines: *Provide multiple means of engagement — Provide options for recruiting interest; Optimize relevance, value, and authenticity).* This provides a personalized learning context and the opportunity to reflect on oneself within a larger context. The summative evaluation report for the *Hall of Human Life* demonstrates that the Link Stations enhanced relevance for many visitors. For example, "Maddison," a 13-year-old student who visited the exhibition on a field trip, described one of the stations as the most interesting part of her visit. She described the exhibition as "a place where you can interact with many things and learn more about your body and mind, and compare it with other people," and added that the Link Stations helped her "think about what I eat and how much my calorie intake is…[I] learned what my data was compared to other [people]" (Barth, et al., 2018).

As is the case with choice, feelings of relevance strongly relate to emotional experience. From an emotional perspective our bodies are constantly reviewing information about our environments. There is too much environmental data for us to attend to all of it, and doing so would be maladaptive, as much of it does not demand our attention. Instead, our bodies direct resources and attention based on our judgements about what is relevant to us; we attend to, and devote processing power to, what we judge as relevant (Scherer, 2001). This has clear implications for learning, especially within an exhibition with so many choices for interactives. Given limited time, people are more likely to feel positively, energized about, and ultimately choose the interactives that seem immediately relevant to them.

UDEL Strategy: Provide consistency in design and opportunities for visitors to reflect, to boost feelings comfort, safety and calm.

The *Hall of Human Life* provides quiet places for reflection and offers predictability through consistent design across the gallery (the UDL Guidelines: *Provide multiple means of engagement — Provide options for* *recruiting interest; Minimize threats and distractions).* Benches offer a space to relax amid the hectic exhibition environment, and The Human Body Theater is a quiet, enclosed spot to watch film clips in a more passive learning mode than the surrounding interactive activities. Emotionally, spaces for reflection may provide a different kind of learning than the rest of the gallery. Providing benches in the theater is a design that intends to support visitors to feel less energized than in other spaces in the gallery. Emotions that are less energized like feeling thoughtful, peaceful, hopeful and focused may be particularly powerful for learning goals such as building empathy and consensus with others (Brackett, 2019), which can be a particular challenge for digital learning experiences (Immordino-Yang & Singh, 2011).

Figure 2: Benches and quiet spaces in the gallery provide opportunities for reflection. Here, visitors can quietly observe cottontop tamarins and compare them to humans.

With regard to consistency, the *Hall of Human Life* is designed with five main themes — physical forces, food, communities, organisms, and time. Each theme is located in its own physical area in the exhibition, and within that area each theme has the same key elements, including an Introductory Wall, a DNA Wall, a Health Condition Wall, Link Stations, and additional interactives. This consistency helps learners know what to expect after they have visited the first area. The emotional consequences of consistent design elements can help learners devote full attention to the designed learning experiences. Each of us has a limited physiological capacity for deep learning, and we often see that our biological resources are most engaged at the beginning of an activity (Cruz-Garza et al., 2017; Dilenschneider, 2018). Consistent design means learners spend less effort figuring out what to do, so they can dedicate more attention to deep engagement within the designed exhibit challenge.

Figure 3: To reduce the burden of orientation and allow learners to focus their attention on deeper learning, each section of the gallery includes the same elements: an Introductory Wall (pictured here), a DNA Wall, a Health Condition Wall, Link Stations, and additional interactives.

Designing with and for Emotional Intelligence in Skull Mystery

Our second example is focused on applying strategies that support and develop emotional intelligence through design. We present the work of one of our most recent projects which is focused on promoting emotional intelligence through the lens of “productive struggle.” Productive struggle is an emotional experience that occurs when a learner engages with disequilibrium in order to navigate a challenging task and achieve a satisfying resolution. The team defines “disequilibrium” as a sense of imbalance (which can be experienced as confusion, frustration, surprise, or unease) brought on by a social, physical, or cognitive challenge. In this project, we developed an interactive, digitally-enhanced exhibit called *Skull Mystery,* which supports visitors to have emotionally accessible and rewarding experiences. We applied insights about emotional intelligence so as to support visitors to deepen their emotional skills. This exhibit invites learners to select one of multiple physical skulls which they can manipulate and investigate. A digital interface guides visitors through an exploration of different skull features — such as teeth and eye sockets — which provide clues about the animal’s diet, habitat, and other characteristics. At the end, visitors piece together what they learned to identify which animal the skull is from.

UDEL Strategy: Define emotional goals to support the strategic design of exhibits that foster emotions which enhance visitor experience.
In designing this exhibit, the team worked to create a supportive environment that helped diverse visitors leverage emotions for the purpose of facilitating thought — a critical aspect of emotional intelligence. In defining emotional goals for the exhibit, developers applied insight from the emotion sciences to align the exhibit task with emotional states that enhance performance for deep problem solving. This strategic goal-setting sought to create a supportive environment that would allow learners to access deep and rich emotional experiences that might have otherwise been unattainable. In this case, the exhibit activity asks visitors to develop an argument about the skull they are investigating. They gather evidence about their skull and then make a claim about the animal's

identity. Research about emotional intelligences suggests that performance for tasks like this — where you need to engage in problem solving to develop and defend your position — can be enhanced when participants experience active and negative emotions such as confusion and frustration (Brackett, 2019).

To encourage visitors to experience these emotions, the team made the activity intentionally difficult. Visitors learn rules and then find out that there are exceptions to the rules. To heighten activation, visitors are asked to make a guess at the beginning of the activity so their investigation serves to confirm their initial idea or prove it wrong. Preliminary analysis of our summative data collection effort shows that our attempts to support the emergence of feelings of disequilibrium were successful; all 35 participants of the *Skull Mystery* activity indicated that they felt frustrated, challenged, surprised, disappointed, nervous, or confused at some point during the activity.

UDEL Strategy: Strategically support visitors and provide opportunities for them to practice regulating their emotions during exhibit experiences.
To ensure that "struggle" emotions are manageable and inclusive for a wide range of learners, we applied insight from another key aspect of emotional intelligence: emotion regulation. Emotional intelligence research shows that effective strategies for regulating disequilibrium emotions include taking breaks and offering positive encouragement (Brackett, 2019). At *Skull Mystery*, timely feedback encourages a sense of mastery over the task (the UDL Guidelines: *Provide options for sustaining effort and persistence; Increase mastery-oriented feedback)* and learners are empowered to pace themselves through the activity as they make choices about which tasks to do and in which order (the UDL Guidelines: *Provide multiple means of engagement — Provide options for self-regulation; Facilitate personal coping skills and strategies).* These strategies also support visitors to monitor their progress on the task which supports emotion regulation as visitors can better foresee a way through the difficulty (he UDL Guidelines: *Provide multiple means of action and expression — Provide options for executive functions; Enhance capacity for monitoring progress).* The design allows visitors to take on more difficult challenges when they are prepared to embrace disequilibrium, or to step back and work on simpler tasks when the levels of disequilibrium become too high (the UDL Guidelines: *Provide multiple means of engagement — Provide options for*

sustaining effort and persistence; Vary demands and resources to optimize challenge). To support persistence, learners can draw on a range of hints and scaffolds that highlight patterns and prompt attention to key features. In the language of UDL, this structure provides graduated levels of support that build fluency, modulate task demands, and facilitate comprehension (the UDL Guidelines: *Provide multiple means of action and expression — Build fluencies with graduated levels of support for practice and performance) (*Â the UDL Guidelines: *Provide multiple means of representation — Highlight patterns, critical features, big ideas, and relationships).*

In the *Hall of Human Life* example, we described how choice and autonomy can be leveraged in design across an exhibition space to support visitors' core affect and subjective feeling, and encourage approach and engagement with exhibit interactives. Here, we illustrate how autonomy within a designed experience can offer visitors a platform for practicing and performing emotional intelligence at a digital interactive. In this way we worked to leverage strategies that created a sense of autonomy so that visitors would feel safe and in control of their experience, thereby increasing the likelihood that they will feel comfortable persisting through new ideas in a difficult task. Although this was a new way of looking at exhibit design for the MOS, the results were encouraging. Of the 35 participants who used the *Skull Mystery* activity in our final study, all but two people reported that they had felt focused, determined, motivated, and persistent at the activity, and 64% indicated that the ability to make choices about how to use the activity contributed to these feelings.

UDEL Strategy: Provide opportunities for active reflection on emotional experience to support visitors' self and social-awareness.
Although significant thought about emotional intelligence informed the design of the *Skull Mystery* exhibit, most visitors are likely unaware of this intentionality. However, our research into visitors' experiences of the design invited learners to engage with another key aspect of emotional intelligence: as visitors described their experience with the exhibit, they were supported to practice the skill of emotional awareness. Data collectors exercised empathy and welcomed social connection as they interviewed youth participants. This research approach was an intervention in itself, applying UDL strategies to enhance value by inviting active participation in meaning-making about the exhibit and prompting deeper

exploration about the learning experience (the UDL Guidelines: *Provide multiple means of engagement — Develop self-assessment and reflection).* The following vignette shares such emotionally-aware reflections from a 17-year-old visitor whom we will call "Jared," who described himself as having high-functioning autism, attention-deficit/hyperactivity disorder (ADHD), sensory integration disorder, and anxiety disorder. Engaging with disequilibrium could have been threatening for Jared, but he described how the ability to choose his own path through the learning experience helped him ultimately reach a satisfying resolution.

Case Study

Jared sat down in front of the *Skull Mystery* exhibit with his service dog, Nemo. He began the activity at skull 1, where he learned about the eyes, teeth, and crest. Jared had been clicking through the exhibit questions quickly but as he proceeded to the next skull, he slowed down. Jared recalled, "I couldn't tell… if they were flatter teeth or pointier teeth." He reached out and ran his hands along the skulls' teeth. "I was a little bit concerned that I was going to get it wrong because I can't exactly tell which one it is."

This moment could have been critical for someone with Jared's disabilities. However, Jared noted that the ability to make choices about how to do the activity, and the ability to try multiple times contributed to his decision to keep going. He indicated that he was, "focused, determined, persistent, and motivated." Jared gathered all the information he could and then made a guess based on skull 3's teeth. He was correct. "I was a little bit relieved," he remembers.

Jared then re-engaged with disequilibrium as he explored the next skull's ridge. "That one was interesting because of the thing with the ridge," he recalled, "I got it wrong I think because I didn't notice it was a crest. I was just like, 'there's no ridge' and instantly selected that." When the exhibit suggested that there was a better answer, Jared looked back and forth, comparing the skulls and the images on the screen. Reflecting on the experience, Jared explained:

> I didn't understand what they meant by the crest at first. I found the crest, but at skull 3 the crest is a different shape [than skulls 1 and 2] …I was like, oh, wow, that's something that I didn't expect, that it would be a different shape. That's something I'm going to remember.

He revised his answer and tried again, this time selecting the correct response, and said, "I felt good that I got it right."

Summarizing his experience afterwards, Jared reported that he felt confused and surprised when he didn't know the answers to the questions, but that overall the activity was satisfying. He was motivated to learn about the different skulls, and he felt like he achieved that goal, making him feel "proud."

We have found that when you ask someone how they feel, an unprompted explanation almost always follows: "I feel_____ because…" And, when asked about their emotional experience, visitors are often open and excited to share rich details about their experience on the whole. This practice of reflection and social connection around exhibit experiences supports visitors' feelings of personal relevance, value and authenticity, and fosters a sense of community and connection around informal and museum learning experiences. Though we leveraged the strategy as a part of our approach to research, design strategies that support self-awareness and an understanding of self and others could be levied within the exhibit experience itself.

Conclusion

Core affect, subjective feelings and emotional intelligence are central to thriving in learning and life (Elbertson, Brackett & Weissberg, 2010; Durlak et al., 2011). They provide us with content-rich information about our assessment of the social, physical and intellectual environments. They are also critical to motivated behavior, as well as the overall well-being of visitors as they make decisions about their experiences, self-regulate in the face of meaningful challenges, and adapt and grow in response to museum experiences (Lopes & Salovey, 2004). From this point of view, visitors' emotional experience can and should be supported and, perhaps even be the subject of scaffolding to support the further development of emotional concepts and skills critical to learning. Indeed, if we do not actively support core affect, subjective feelings and emotional intelligence in design, then we leave the overall well-being of our visitors to chance.

Within this context, digital technology is paving and will continue to pave new paths towards the creation of emotionally accessible and inclusive learning experiences. In the work we have described in this chapter, the use of digital interfaces allowed us to more nimbly implement UDEL-based solutions to support emotional experiences. Visitors can receive dynamic feedback based on their progress and choices. Interfaces can be implemented in more customizable ways so that we are better able to meet the needs of diverse audiences, and support positive judgements of the museum environment without having to make choices that remain static, thus, narrowing the range of needs and preferences we might otherwise be able to address by design. It is worth noting that we have also been experimenting with biosensors and affect-detection technologies to explore potential design strategies for affect-responsive support within exhibit experiences. Though not specific to the museum field, others are exploring the use of virtual avatars and robots to assess affective experience and support emotion regulation (e.g., Breazeal, 2002; Chang & Breazeal, 2011; Klein, Moon, & Picard, 2002; Picard & Klein, 2002; Ring, Barry, Totzke & Bickmore, 2013).

This kind of work, focused on affective responsivity via dynamic and digitally-designed experiences, is in its infancy but rapidly advancing, raising ethical concerns especially with regard to the limitations of technology to detect and analyze visitors' emotional experiences. The public’s understanding of and trust in affective technology is still limited due to its relative absence in daily life. Concerns around the consequences of algorithmic bias built into affectively-intelligent systems are growing (Heger, Kampling, & Niehaves, 2016). Leaders in fields within and related to affective computing and the advancement of affect-responsive technologies have called for further research, evaluation and development of systems to address the limitations of current approaches. We are venturing towards a time when such systems could reliably detect a multiplicity of naturally occurring emotional states for people in real-world situations, and could do so in ways that are ethically sound and empowering for those involved (Calvo, D’Mello, Gratch, & Kappas, 2015; Picard, 2010).

Certainly, we need to proceed thoughtfully and with caution around the use of advanced affect-detection technologies, but the potential is thrilling. Consider the *Skull Mystery* exhibit described above: while enhanced digitally, our design approach was limited in that we could only assume visitors' emotional experiences and attempt to proactively provide support. We were, in a sense, placing burdens on visitors to access the support they needed, when they needed it, even when it was provided dynamically in response to performance and choices. What if designers had digital tools to implement that could empower more museum visitors to navigate confusion and frustration in ways that foster deeper learning and engagement? What if an exhibit could tune into visitors' affect, sharing the burden of identifying confusion awareness, and leveraging support to encourage persistence in the moment when a visitor needs it most?

Whether or not the integration of affect-responsive technology becomes a reality, UDEL can provide practitioners a framework to think systematically about the affective and emotional variability visitors bring to designed museum spaces. But, to render design emotionally accessible and create emotionally inclusive environments we need to leverage the framework in ways that may feel atypical to current use in the field.

First, we need to get comfortable with and consistent about setting emotional goals. Because emotions and cognition are always at play, setting a cognitive goal without an emotional goal will leave emotion to chance and may bias exhibits to the majority experience or view. Second, all emotions and emotion experiences have utility — there are no “good” or “bad” emotions. Museum designers often have a bias towards supporting happy, positive experiences. What we would suggest is that designers focus on well-being and thriving instead. Confusion feels like a negative, but keeping it out of our spaces actually creates barriers to deeper learning because it is a natural and useful consequence of effortful information processing in the face of new and surprising evidence. It’s good to feel confused as long as visitors are supported through problem solving to resolve those feelings. We have found on the "productive struggle" project that visitors have deeply satisfying experiences and even report feeling pride. By creating emotionally accessible exhibits and inclusive museum experiences we aim to support the proliferation of outcomes that are cognitively, socially and emotionally more meaningful by design.

Finally, it is important to note that while we have found the UDL framework incredibly useful in thinking about design for emotion, in some ways, it is also emotionally wanting. This shouldn't be a surprise per se because the creators were learning scientists who had a cognitive focus; they were also focused on formal education settings which tend to prioritize cognition and achievement. Though the framework addresses engagement explicitly and can be used to maneuver emotional goals there are some aspects which could be enhanced if viewed through an emotion lens. For example, the UDL guidelines deal implicitly with support for emotional intelligence skills but attention to their explicit accessibility would improve the utility of the framework and support practitioners to be more mindful to issues of emotional inclusion.

At its core, Universal Design for Emotion in Learning is about a shift toward embracing the "whole visitor" — social, cognitive, corporeal *and* emotional. In supporting practitioners to start thinking more holistically and about emotional accessibility specifically, we have framed a kind of *emotion-as-information* approach where visitors' core affect and emotion confer value on their thoughts and experiences in museums (Clore, Gasper & Garvin, 2001; Schwartz & Clore, 2007). When design is rendered so as to support visitors' core affect, emotion and emotional intelligence, other aspects of visitor engagement, including approach/avoidance, attention, decision-making and overall well-being, are supported. When emotion is supported and museums are rendered to be emotionally accessible, visitors will be better able to engage in museum experiences with their whole selves in adaptive and constructive ways. Taking this approach will support designers to create more equitable, resourceful and meaningful museum experiences.

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Inclusive Digital Interactives

Best Practices + Research

Chapter 7

Opening Our Doors Wider: Transforming Our Approach to Inclusion via Digital Exhibition Elements at the Smithsonian's National Air and Space Museum

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September 2020

Introduction

Around our 40th birthday in 2016, the Smithsonian's National Air and Space Museum (NASM) faced the inevitable need to update and modernize our building from top to bottom. The disruption this would cause made it a natural time to reimagine just about everything from our exhibitions, public spaces, and programming, to our staff spaces and ways of working. We named the building work Revitalization, and it includes efforts such as, "refacing of the exterior cladding, replacement of outdated mechanical systems, and other repairs and improvements" (NASM 2017). We named the revamping of our exhibitions, public spaces, and ways of working Transformation, and it is being undertaken as three projects, which can be thought of as roughly the West half of the building, the East half of the building, and the Commons spaces. These interconnected initiatives — Revitalization and Transformation — are being undertaken simultaneously, with completion estimated for 2025, and present us with a once-in-a-lifetime opportunity for change.

The opportunity to reimagine ourselves has led to introspection in several areas, and we keep coming back to two key questions:

1. What does it mean to be a transformed museum?
2. How will we better serve and inspire our visitors?

Digital exhibition elements — computer interactives, videos, soundscapes, and projections — emerged early in these conversations as some of the ways to answer these questions, and the need to design them to be more inclusive was clear. Simply adding more digital elements would not accomplish our goal. We also needed to examine the process by which we create them and the tactics we employ in order to make experiences that are inviting to and usable by visitors of various backgrounds and abilities.

What follows is our process to date to create a transformed set of standards for inclusivity through our digital exhibition elements. First, I will share our pre-Transformation baseline and the gaps we identified. Second, I will discuss two places we look to for inspiration on how we want to improve. Third, I will talk about how we involve stakeholders and detail how we have decided to standardize our approach. Given that we are in the middle of Transformation and Revitalization and that technology continues to change rapidly, this chapter will capture a snapshot in time that concludes with gaps we aim to address in the future. It therefore reflects a set of standards in development as we seek to open our doors wider to all visitors.

Step 1: Determine Our Pre-Transformation Baseline

Prior to commencing Transformation, NASM's baseline grew as we created new exhibitions one at a time. Each exhibition was a chance to try something different, but only within that exhibition. With a few exceptions, older exhibitions were neither revisited nor updated, and their digital elements remained examples of an evolving approach to inclusivity. Together, these exhibitions span nearly 40 years and set a baseline serving primarily people with mobility, hearing, and vision disabilities, with the *Smithsonian Guidelines for Accessible Exhibition Design (SGAED)* (Smithsonian Access, 2010) serving as a guidepost. The remainder of this section outlines our baseline and points out places where we feel we can be more inclusive.

Our pre-Transformation approach to serving visitors with mobility disabilities focused on the physical design of the housing around our digital interactive kiosks. For guidance, we referenced the 2010 ADA standards as well as the following language from the "Audiovisuals and Interactives" section of the *SGAED*: "F. Use of interactives must be from a location accessible to people using wheelchairs or other assistive devices (e.g. canes, crutches); interactives must not be blocked by furniture or other obstacles." This translated into computer kiosks being constructed so that wheelchair users can approach them straight on and interactive content being placed within reach of wheelchair users. An area for improvement was in serving visitors with limited dexterity who could not comfortably navigate a touchscreen, or visitors with artificial limbs who could not use some types of touchscreens.

Our pre-Transformation approach to serving visitors with hearing disabilities focused on the inclusion of open captioning on our linear media pieces and in our most recent exhibitions, indicating when a video does not have sound. These tactics align with guidelines A and B from the *SGAED's* section on "Audiovisuals and Interactives," and best serve visitors who are deaf and have little or no usable residual hearing. There was room for improvement in our approach to serving visitors who are hard of hearing who could be served better in two ways:

1. by providing access to a version of the video's audio with the background noise reduced, so that speech is easier to hear; and
2. by adding induction loops to digital exhibition elements for which hearing the audio is key to experiencing the content. For example, hearing the engine on the 1903 Wright Flyer or President Kennedy delivering his iconic speech at Rice University.

Our pre-Transformation approach to serving visitors with vision disabilities was the most limited, and it centered around serving visitors with low vision and various types of colorblindness. As with mobility and hearing disabilities, we looked to the *SGAED*, but found that guidelines for websites provided a greater level of specificity. The Web Content Accessibility Guidelines (WCAG) — issued by the Web Accessibility Initiative of the World Wide Web Consortium (https://www.w3.org/WAI/standards-guidelines/wcag/) — has been and continues to be the source we find most valuable. These standards guided us toward making our digital exhibition elements more inclusive. For example, providing sufficiently high contrast between text and backgrounds, and presenting clear and clean layouts that let users know where they are within our interactives. While helpful to some visitors, these tactics provided little to no benefit to our visitors who are blind or have low vision, and thus, our digital exhibition elements were largely closed off to them.

Step 2: Look for Inspiration

With our pre-Transformation baseline examined, an environmental scan was an important next step in figuring out how we wanted to raise our set of standards. Two places emerged in our research as having practices and tactics that we wanted to examine more closely and consider emulating: the Canadian Museum for Human Rights (CMHR) in Winnipeg, and the Museum of Science (MOS) in Boston. Both museums made an impact on our thinking with their commitment to involving external stakeholders in the development process and to designing experiences that are usable by and meaningful for a variety of audiences.

My site visit to CMHR in May 2017 and a paper written for the Museums and the Web (MuseWeb) conference a year prior (Wyman, Gillam, and Bahram, 2016) illuminated two practices for potential adoption by NASM. First, CMHR made an ongoing commitment to improving their inclusive practices by involving internal and external stakeholders via monthly meetings that began during the development of the museum. This practice underscored the importance of engaging with stakeholders and continuing to engage them beyond opening. Second, their custom accessible keypads set a high standard for access and consistency. I was impressed to find these keypads across the museum and in two forms — one for digital interactives and one for audiovisual-based experiences. They appear consistently in the same locations in relation to the digital experiences they support, which means that visitors don't have to keep learning new systems and configurations. These two practices seemed like ones that NASM could and should incorporate.

An article written by staff at the MOS also provided inspiration for tactics to try at NASM. In *Developing Accessible Touchscreen Interactives*, (O'Hara, Reich, and Lindgren-Streicher, 2015), staff describe their prioritization of audiences during the design process for touchscreen interactives:

> …we prioritized the needs of visitors with limited mobility who have difficulty reaching all active areas of most touchscreen designs, and visitors who are blind or have low vision who are unable to detect the visual cues used to denote active areas.

This approach gave us an idea on where we could focus our tactics for touchscreen interactives, which were likely to be an important component of our overall approach, and their emphasis on visitor testing highlighted the importance of involving people with disabilities throughout development. It was also helpful to learn about how the museum experimented with ways for visitors to engage with data. For their *Catching the Winds* exhibition, the museum tested sonification of data, as well as haptic feedback. Both are ideas we are currently investigating.

Step 3: Involve Stakeholders and Standardize a Set of Tactics

Setting a transformed set of standards has been and continues to be an exciting but also daunting opportunity as we investigate ways to fill the gaps in our pre-Transformation baseline. Unlike in the past when we created one exhibition at a time, this time we can create an updated approach and standardize much of it across the museum. As with CMHR and MOS, we see involvement of stakeholders from the outset as being central to this effort — both in the selection of tactics and the buy-in needed to make them happen. We also see the value in standardization and experimentation, wrestling with the following questions and unique challenges in the context of our initiatives:

- How do we involve external stakeholders in meaningful ways and incorporate their expertise?
- How do we keep internal stakeholders apprised and involved when there are many other efforts happening at the same time?
- How can we standardize tactics to fill the gaps in our pre-Transformation baseline?

The remainder of this chapter will address these questions by sharing what we have learned and decided upon to date.

Involving External and Internal Stakeholders

Involving external stakeholders is not a new approach, but one that is proving especially important during the Transformation project. Two categories of external stakeholders that are key to our efforts are user/experts, who are people with disabilities, and groups who specialize in helping institutions like ours make experiences that better serve all people.

User/experts are vital stakeholders because they bring their day-to-day experiences living with disabilities and raise critically important questions that could go overlooked. NASM connects with user/experts via Access Smithsonian, an entity at the Smithsonian that, "…strives to provide consistent, effortless access to the Institution's programs, collections, and facilities (https://www.si.edu/access)." At NASM, we do so throughout the exhibition development process in order to identify areas where we can improve our process and end products, as well as develop empathy for and awareness of how people with disabilities experience museums. In one such session in 2018, we learned about some of the technologies that visitors with various disabilities might bring with them, such as an app on their phone called "Be My Eyes" that connects users to people who describe what is around the user through the phone's camera, and heard about the challenges involved in making a solo visit to the museum. The latter posed an interesting challenge for us at the intersection of our physical exhibition development and our digital exhibition elements' development — how would someone who is blind or has low vision and visiting us by themselves find our digital exhibition elements? We continue to search for the best solution — looking to examples like the CMHR's cane detection strips — and plan to consult user/experts again once we have potential solutions.

We also regularly consult organizations that specialize in helping institutions like ours develop inclusive experiences. For Transformation, these organization have so far included the Institute for Human Centered Design (IHCD), Access Smithsonian, and the Trace Research and Development Center at the University of Maryland. IHCD is an example of how valuable it is to hire a consultant to work through challenges that cut across the museum, as well as difficulties specific to certain digital exhibition elements. Whenever we or our media contractors hit a stumbling block or want to check we are on the right track, IHCD reviews our in-progress work and offers guidance. Access Smithsonian serves as another resource for insights and potential solutions, bringing museums and research centers across the Smithsonian together to share tactics and talk about what's working. The Trace Research and Development Center has contributed their expertise by engaging our staff and media producers in deep dives into the tactics and best practices involved when incorporating accessible keypads into our computer interactives — particularly related to supporting the experiences of visitors with vision disabilities.

Incorporating accessible keypads is largely a new endeavor for many on this project, and is an area where we have brought in all of our external stakeholders to assist in two primary areas: the selection of a keypad model, and how to program it to make our computer interactives more inclusive. Selecting a keypad happened over the course of nearly three years and involved three steps. First was my site visit to CMHR to see their custom keypads. Second, we tested a selection of off-the-shelf models with user/experts. Finally, we talked with the Trace Center and learned about how the programming of the keypad was as, if not more, vital than the model itself.

While all three steps proved invaluable, the feedback from user/experts was the deciding factor and our search for a keypad model continued with a sketch from the user/experts' testing report that suggested a diamond shaped configuration of buttons for navigation with a button in the middle to make selections.

We kept this sketch in mind and decided on an off-the-shelf model with that configuration of buttons, as well as pairs of buttons to control screen reader volume and speed.

Programming these keypads to make them effective tools for more inclusive computer interactives has benefitted from deep dives with staff at the Trace Center, along with their partner Assistra. Early on in our consultations with them, our staff and media producers were shown a sample program for a train fare machine. Seeing how the keypad worked in conjunction with the program sparked productive conversations which led directly to the refinement of our standards. For example, visitors who are blind or have low vision are going to be relying on the screen reader that is coupled with the accessible keypad in order to navigate our computer interactives and therefore, will not only access the content in a linear fashion but also not necessarily be aware of how many options there are when presented with more than one. Programming is therefore critical to ensure that content is read in an optimal order and that visitors know if they have one option, or three, or twenty.

Developing our transformed standard for more inclusive digital exhibition elements would also not be possible without the involvement of key internal stakeholders. At NASM, our key internal stakeholders are members of our senior leadership team, the curatorial departments, the exhibition department, the exhibition technology department, the education department, and the visitor services department. While each group needs to be briefed throughout the project, we have tailored our approach so that not everyone is involved in the day-to-day decision making.

We brief the senior leadership team at a high level in order to secure buy-in and to help them talk to outside entities about the work we are doing. This is not dissimilar to other areas of the Transformation project and consists of answering questions such as what our previous standard was, what our new set of standards is to date, and how our visitors are better served as a result. Their briefings thus focus on changes and the impacts we hope these changes will have.

The exhibits department, along with our exhibits technology department, is at the other end of the spectrum by being involved in the daily details. As the Exhibits Media Manager in the exhibits department, I lead all aspects of the creative side of the process, acting as a liaison to external and internal stakeholders and ensuring that we keep inclusivity in mind throughout development.

The exhibits technology department leads decision making on the technical side, ensuring any software and hardware solutions proposed are ones that not only provide a more inclusive experience but are also ones that we can maintain over the life of our exhibitions.

As for the education, curatorial, and visitor services departments, we decided early on not to involve the them in the day-to-day work unless their support and/or expertise was needed to make a tactic work. On a smaller project, we would involve these departments more often, however, with more than twenty exhibitions to develop, this was a decision that came out of consideration for the sheer volume of information coming at staff members every day.

In cases where creating a more inclusive digital exhibition element has had a significant impact on the development of the piece, we do involve curators and educators. We are in the middle of one such instance at present, which involves creating an experience that encourages our visitors to build their own solar system. Our media producer for this digital exhibition element identified it as needing special attention in order to create a dynamic, inclusive experience that works for visitors with various disabilities. Their idea for a solution focuses on sound as part of the way to convey what is happening visually on the screen. Rather than confining this sound to an accessibility mode, we have decided to incorporate it into the experience for all visitors. This change was a significant departure from the original concept, so getting the exhibition team’s buy-in was critical, as was working with IHCD to ensure that the idea is, pun intended, a sound one.

Finally, working more closely with our visitor services department is part of supporting our new set of standards, and we keep them updated on a regular basis with a focus around tactics for which their support is crucial. For example, we do not want to assume that all visitors who will use the accessible keypads on our computer kiosks to access screen reader functionality will have headphones with them that work with the keypads’ input. Serving these visitors means having disposable headphones available at our welcome desk, and, with space at the welcome desk at a premium, we will need the buy-in of the visitor services department to support that.

Our Transformed Standard — to Date

Based upon our pre-Transformation baseline and what we have seen across the museum field, we feel we can make the biggest strides toward more inclusive digital exhibition elements by focusing on serving visitors with brain-based, vision, hearing, and mobility disabilities. The following text is taken from the most recent version of our standards document, which was developed with our exhibition contractor for the West End exhibitions. It captures what our thinking is at present and points to solutions we have decided to standardize across NASM.

Tactics for Vision Disabilities

1. Accessible Keypad
   Accessible keypads provide access at two levels: interaction and audio.
   - Interaction:
     - Visitors have the keypad and touchscreen available at the same time.
     - Visitors can move through text and images using the keypad buttons, with their current position shown onscreen by a focus indicator (a rectangle around the current position).
     - Visitors get audio feedback for keypresses in addition to screen reading.
     - Visitors can access alternative (alt) text for images via a screen reader, which gives them an understanding of what the image is and why it is on the page.
     - Visitors access content that has been reordered for improved readability.
     - Visitors can access basic instructions about the interactive at any point via text read to them using screen reader technology.
     - Visitor have access to contextual information — for example: "group of buttons, 1 of 3."
     - Visitors with low vision will be able to see the keypad buttons better in dark galleries because these buttons can be backlit.
   - Audio:
     - Visitors have access to volume control using keypad buttons.
     - Visitors have access to the text and alt text for images via a screen reader.
     - When the keypad is activated, the audio switches to the headphone jack. Audio is delivered through either speakers or headphones.

2. Screen Reader
   Screen readers are a type of assistive technology most helpful for people who are blind or have low vision but also benefit those who have learning disabilities or who cannot read. It reads out the text on the screen, as well as any alt text provided for images. The speed of the screen reader will be adjustable via the accessible keypad.

3. Audio Instructions
   SGAED details that instructions for use of all computer interactives must be included in both an audio and text format. Audio instructions will be accessible to users as text that is read by a screen reader. These instructions will be minimal and only include what is necessary in addition to the instructions on the main screen for all visitors.

4. Audio Description
   The provision of audio description for videos within computer interactives and linear media requires a two-fold solution.
   - Videos within Computer Interactives
     Videos within computer interactives will need to be audio described, and the audio described versions of the videos should be delivered when visitors plug headphones into the headphone jack on the accessible keypad.
   - Linear Media
     While the accessible keypad is a viable solution for delivering audio described videos as part of computer interactive displays, it is not feasible for large immersive projection areas or video displays. In most cases, there is not an obvious point that a visitor can approach in order to plug in their headset to receive the audio description. Therefore, an alternate approach will be developed — likely one that utilizes a mobile device — and audio descriptive tracks should be produced for these pieces. Since not every person will come into the museum with a mobile device, we would like to make a limited number of mobile devices available to borrow at our welcome desk.
   - Gallery-Wide Audio Description
     Each gallery will be audio described to give a basic overview of the gallery. A method for delivering these descriptions is being determined but will require a mobile device.

5. Alt Text
   Alt text is text that is inserted into code to be displayed if the image does not render and to give people who are blind or have low vision an understanding of why the image is on the page. This text is read by a screen reader. According to experts at the University of Maryland’s Trace Research &

Development Center and WebAIM (https://webaim.org/techniques/alttext/), the best practice for alt text is to use it to describe the image's content and function rather than describe exactly what is in the image.

6. Consistent Locations for Navigation Elements
   While each is different, the user interfaces for our exhibition media pieces have common elements that should be located in the same places on the screens. These include the home button, the information/help button, and others.

7. Typographic Legibility
   To ensure legibility, typographic layouts will be designed for type size and viewing distance. To ensure maximum legibility for the largest segment of visitors, fonts will be selected with legibility in mind (proportion, contrast, x-height, etc.) and type sizes will be set at minimums based on viewing distance.

8. Contrast and Focus
   Designs will be tested to make sure that there is sufficient contrast between background and foreground colors for people with low vision or color-blindness. Particular attention will be paid to text and background elements to ensure readability.

Tactics for Hearing Disabilities

1. Narrative Audio Edits
   A narrative audio edit is a version of the audio track with the background noise reduced so that visitors can hear the dialogue more easily. Induction loops (detailed below) will deliver the narrative audio edits.

2. Induction Loops
   An induction loop requires a visitor to be wearing a hearing aid with a t-coil or an induction loop receiver and to be standing in the electromagnetic field created by the induction loop. This technology also depends on the electromagnetic field having the appropriate strength to ensure the visitor's hearing air or receiver gets enough power to hear intelligible audio. NASM is

exploring the option of having a small number of induction loop receivers available to visitors who do not come to the museum with the necessary technology.

3. Open Captions
   Open captions are text that is on the screen whenever the video is playing and include descriptions of sounds in addition to what is being said. Open captions will be provided for any linear or interactive media pieces which contain narrative audio. Any interactives or linear media pieces which do not contain audio will have text on-screen to assure visitors who are deaf or hard of hearing that they are not missing information.

4. Visitor-Operated Volume Controls
   Visitor-operated volume controls are present on many of the accessible keypads that were under consideration so that visitors who are hard of hearing can hear audio at above-average volume via headphones. NASM is exploring the option of having a small number of headphones available to visitors who do not visit with their own headphones.

Tactics for Mobility Disabilities

1. Position and Sizing of Touchable Elements
   Media producers, exhibition designers, and fabricators will work together to ensure that controls and display surfaces will be at a height and angle that will be within easy reach for children and adults including visitors in wheelchairs.

2. Accessible Keypads
   Accessible keypads serve people with limited mobility and/or strength by making available buttons that are easier to use and in a closer and more consistent location. Unless the computer interactive screens are pressure sensitive, the keypads also help people with artificial hands.

3. Single-Touch Buttons
   Single-touch buttons will accompany complex user controls (i.e., swiping, dragging) on the screen for computer interactives whenever possible so that the same task can be accomplished in two ways.

4. Recovery Methods
   Whenever possible, we will implement methods to undo or recover easily from user actions. For example, we may provide "back" buttons in order to undo a selection.

Tactics for Brain-Based Disabilities:

We will use the following set of strategies to address the broad range of brain-based disabilities:

- Avoid unnecessary complexity in content, design or user interface.
- Reduce the amount of text where possible and break it into chunks.
- Write text for clarity and avoid abstraction where possible.
- Provide supporting imagery where appropriate.
- Avoid distracting animation effects while content is being displayed.
- Locate navigation elements in consistent places.
- Provide information in multiple formats.

Conclusion

While the transformed set of standards in the previous section indicates progress made, there are still decisions to make and details to confirm as the project evolves and as new methods arise that have the potential to open our digital exhibition elements to more visitors. As shown by CMHR and MOS, this is a process that never stops and one that must be underpinned by stakeholder involvement at every stage. Our work-in-progress transformed set of standards therefore must continue to grow through stakeholder involvement and internal reflection — even as we are in the middle of implementing it across the west half of our reimagined National Air and Space Museum. In this spirit of continual reflection upon and redefinition of our approach, this chapter ends much as it began — by sharing one of the key gaps in our current approach and how we are thinking about addressing it.

As mentioned in our transformed set of standards, we do not currently have a method identified for delivering the audio described versions of our linear media pieces. Our linear media pieces will be presented as either looping videos on video players or looping projections on surfaces such as gallery walls and, unlike our computer interactives, neither presentation format will have an accompanying accessible keypad. The reasoning behind this is that these are not visitor-controlled experiences. One option to address this gap is to make the audio-described version of our linear videos the version that gets played in the gallery for all visitors. Another is to present the audio-described versions on a website or mobile app that visitors can access from either their own mobile device or from one that they borrow from the welcome desk. We are leaning toward the latter option, although it is likely that there are also other options that we have yet to discover. As with the transformed set of standards we have decided upon to date, this one will also benefit from scanning the field for inspiration and working with our external and internal stakeholders to see what works best. We look forward to their input and the process of getting to a solution that opens our doors a little wider to all.

Acknowledgements

I would like to thank Jan Majewski at the Institute for Human Centered Design, Beth Ziebarth at Access Smithsonian, and Beatrice Mowry at the Smithsonian's National Air and Space Museum for their guidance, support, and edits.

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Inclusive Digital Interactives

Best Practices + Research

Chapter 8

Wise Stones: An Interactive Accessible Circuit Designed to Enhance the Experiences of Visitors with Disabilities

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September 2020

Overview

Museums, now more than ever before, are committed to the inclusion of all members of society, aiming to promote similar visitor experiences for their various patrons. With the challenging mission of exhibiting and communicating humanity's common heritage, while also preserving it, the creation of an inclusive museum experience is a complex task with multiple dimensions.

This article aims to contribute to the field of accessibility in museums by discussing the three main stages of designing the *Wise Stones Accessible Circuit*, a five-year project which aimed to enhance access at the MM Gerdau Museum in Brazil by creating an interactive tactile exhibit displaying original artifacts from the museum's collection.

A participatory methodology was adopted throughout the project in which 37 professionals from multidisciplinary fields at various institutions, and 151 visitors, who performed a formal evaluation of the digital interactives, were involved. Conclusions and implications of designing accessible digital interactives, with feedback from as wide range a of visitors as possible, are presented. Although the project's main goal was to enhance the museum experience for persons with disabilities, it ended up benefitting all visitors.

Introduction

According to the International Council of Museums (ICOM), museums' social functions are at the very core of their existence — being nonprofit institutions at the service of society, and committed to social development (Desvallées & Mairesse, 2010).

In that sense, it becomes critical to have issues related to social inclusion and accessibility treated as priorities, not only because there are more than one billion people living with disabilities worldwide, but also because everyone may experience temporary impairments or age-related sensory, physical or cognitive changes in the course of their life (World Health Organization & World Bank, 2011).

In Brazil, where this project was developed, the last census (IBGE, 2012), estimated that about 45.6 million citizens self-reported at least one of the surveyed disabilities: vision, hearing, physical, mental and cognitive. This number represents almost 23.9% of the country's population.

Assistive technologies are highlighted by Freeman et al. (2016) as having the potential to increase access and enable more inclusive opportunities and experiences for disabled patrons at museums. They are one aspect of inclusive experiences and can help museums serve a wider audience while diminishing some barriers to full access (Pillow, Banks, & Reeves, 2015; Vaz, Fernandes, & Veiga, 2018a). In addition, Andrade et al. (2016) argue that the implementation of inclusive technologies in museum exhibitions foster positive economic impacts.

The *Wise Stones Accessible Circuit* project was designed to enhance access for all visitors — disabled and non-disabled — of the MM Gerdau Mines and Metal Museum in Belo Horizonte using interactive tactile presentations of original artifacts from the museum's main collection. The exhibit uses a visitor's tactile interaction as the trigger for the presentation of multimedia content, which includes different sensory perceptual strategies such as audio descriptions, enlarged images, sign language, and text labels/descriptions.

This project was based, from the beginning, on the social model of disability, which argues that people are not disabled by their conditions but rather by the external barriers they face, many of which are created by the environment (Disabled World, 2017; Oliver & Barnes, 2010). The goal was to make visits — spontaneous and planned — to the museum accessible for as many patrons as possible. Special attention was paid to the experiences of visitors with visual impairments, considering the industry consensus that museum exhibitions remain primarily visual and therefore contribute to marginalizing this group of visitors (Cachia, 2013; Candlin, 2003; Classen, 2007; Ginley, 2013; Hayhoe, 2017; Johnson, 2018; Morgan, 2012).

This five-year project began in 2014 with an international research agreement involving the MM Gerdau, the Federal University of Minas Gerais (LavMUSEU/UFMG, Brazil), the Polytechnic Institute of Bragança (Portugal) and the University of Aveiro (Portugal), and received an award from the Ibermuseums Program in 2016. The practices of design for all (Abascal et al., 2011; Andrade et al., 2016; Smithsonian Institution, n.d.; Wyman, Timpson, Gillam, & Bahram, 2016) and participatory design methodologies (Preece, Rogers, & Sharp, 2002; Sanders, 2002; van Dijk et al., 2016), were employed through the course of the project.

In this chapter, we will present the three main stages of the project, focusing on the process of designing the interactive exhibitions; discuss the implementation of the *Wise Stones Accessible Circuit;* describe the technological approaches followed; and share some results obtained during the evaluations at each stage. The three main stages are as follows:

1. From the foundations of the project to high-fidelity prototype implementation;
2. The first iteration of the participatory design methodology, with a discussion of the re-design of a pilot exhibit;
3. The presentation of the *Wise Stones Accessible Circuit,* which comprises three new modes of access — accessibility for visitors who are visually impaired, hard of hearing and/or use wheelchairs. It also includes a website with detailed information for visitors and museum professionals.

This is followed by a discussion of the project's repercussions and the changes it has introduced to museum policy concerning inclusion for all, and the chapter ends with recommendations for the museum community and other researchers who also aim to create accessible museum experiences.

The *Wise Stones Accessible Circuit* Project

From Scratch to a High-Fidelity Prototype

The first stage of the project consisted of brainstorming sessions with museum's exhibit design, technology and education teams, as well as the administration. From those sessions, we gained in-depth knowledge about the whole collection, the multiple permanent exhibitions, and the museum's previous experience with visitors with disabilities.

Given the pervasive use of digital media in almost every exhibition, a total of 44 digital interactives in the museum were evaluated. They were classified by those that were accessible for people with visual impairments; those accessible for people who are hard of hearing; and those that were completely inaccessible.

It was noted that most pieces in the collection — even those that did not have any restrictions based on preventive conservation — were off-limits to visitor interaction. To create a high-fidelity prototype with tactile samples that would function as interaction triggers, four geological samples from the museum's collection — petrified wood, aquamarine, muscovite and flint — were made available. The intention was that the direct handling of the samples would trigger the interactive experience so that visitors could physically sense the objects while receiving information about them.

An interaction design study followed, in collaboration with various professionals in geosciences, education, and communication design, as well as some museum visitors, which facilitated the creation of a usable interaction model that would be implemented. Usability principles and human-computer interaction guidelines from Dix, Finlay, Abowd and Beale (2004), Norman (2002), and Preece et al. (2002) were employed in this process.

The implemented interaction model defined that:

- The act of picking up a sample identifies an interest in finding out more about it, while putting it back down signifies a loss of interest or lack of intention to continue accessing associated content. The adoption of this interaction language was expected to provide an instinctive mapping, where each action was associated with a specific event.

- Visitors have the opportunity to access information about one of the four samples at a time, and to find out the differences between any two of the samples, simultaneously. Whenever two geological elements are handled at the same time, contents related to both are presented, focusing on a comparison between their scientific, historical, and everyday applications.

- The samples can be handled freely, even though concerns regarding the possibility of permanent loss, by accident, for example, were broadly discussed. To prevent damage and loss, it would be necessary to ensure that the samples were correctly returned to the surface whenever a visitor leaves the exhibit. To make that easier to achieve, the regions on the surface were designed to have dimensions and shapes similar to the samples.

- Graphics and audio were both used to communicate information in the exhibits. For users with low vision, enlarged images of the pieces and accompanying text were projected on a wall. The inclusion of audio descriptions was intended to provide visually impaired visitors, elderly visitors, and people who cannot read, with the same information that was presented graphically. The audio included a detailed description of the shapes, textures, and other relevant features of the tactile samples, along with general information for identification.

- Additionally, it was designed to provide visual feedback to indicate the success of visitors' actions. Each time a sample was lifted from the surface, a light in the area corresponding to that particular geographical specimen, lit up. However, this feature was not accessible to visitors who had visual impairments including color blindness.

The system architecture that was eventually implemented resulted from a technical viability study based on the interaction model for the exhibit. It used an Arduino Leonardo microcontroller, four force-sensitive resistors, four bright actuators, and a computer to run the processing software, as well as a projector and two sound columns for the multimedia presentation (Vaz, 2014; Vaz, Fernandes, & Veiga, 2016).

The exhibit, designed based on guidelines for accessible exhibition design from the Smithsonian Institution (n.d.), consisted of the physical structure to house the interactive samples, with provisions to embed the necessary hardware. The structure was kept as simple as possible since the primary goal at this stage was experimentation and ideation to prompt feedback that would be necessary for an improved design.

Figure 1 presents a photograph of the high-fidelity prototype in operation in the main exhibition space of the MM Gerdau. The four geological samples are placed on the surface of the *Wise Stones* prototype with the images of the samples on the projected wall ahead with the phrase 'choose one sample,' written in Portuguese, below.

Figure 1: The *Wise Stones* prototype installed at MM Gerdau, with the four geological samples arranged on the surface, separated by black lines. Photo by Leonardo Miranda.

In Figure 2, a visitor is handling the aquamarine and flint samples at the same time. On the projection, the text in Portuguese informs him about their chemical compositions, places of origin, core characteristics of each and everyday uses. Only the areas of the prototype's surface corresponding to those two samples are illuminated, each with a similar color to of the object.

Figure 2: A visitor interacting with the *Wise Stones* prototype interface. Photo by Leonardo Miranda.

The objectives of the prototype evaluation were, on the one hand, to assess the positive and negative aspects of the interaction with the samples, and, on the other, trying to understand if visitors thought their museum visit was enhanced by this interactive exhibit. Other aspects of the exhibit, such as the multimedia components (images, audio and text), number of samples available to touch, and overall satisfaction (to determine whether this exhibit should be retained in the permanent exhibition), were also evaluated. During a four-month period (April to August 2015), a total of 138 people evaluated the prototype. Of them, 9 were people who are blind, 17 were employees of the museum who had not previously participated in any phase of the project, and the remainder were visitors who happened to visit MM Gerdau during that period. The complete results of the evaluation were published in Vaz et al. (2016).

In general, the results showed that the use of the prototype pleased visitors — those who were blind and those who were sighted — all of whom rated the tactile aspects of the interaction very positively. The participants who were blind reported that their access to the collection was enhanced by the additional sensory stimuli. The majority of the participants mentioned that it was their first opportunity to handle collection objects in a museum and that this approach was very simple, pleasant, and motivating.

The duration, speed, content and presentation of the audio description proved to work well, but the graphic design and visual content needed to be reviewed, prioritizing images instead of text. All participants who were blind and half of the sighted participants suggested increasing the number of tactile geological samples available. Based on the results, we were able to conclude that interactive exhibits, like this one, are received well in the museum context, and the decision was made to proceed with a pilot study.

Exhibit Re-Design and Pilot Implementation

The pilot phase of the project aimed to develop a final version of the *Wise Stones* prototype to permanently integrate into the MM Gerdau's exhibition space. It took into account data collected from the evaluation, and also new insights generated during additional testing with visually impaired people.

Features Supported by the Pilot

The main characteristics of the re-designed exhibit are the following:

- The interaction model of the prototype would be maintained but expanded to include five samples rather than four.

- An improved interaction system was created for safety reasons — the geological samples would remain connected to the surface via a steel cable. When a sample is picked up, the movement of the cable triggers the sensor, playing the corresponding audio description and showing the associated content on the projected wall. The allowance for simultaneous interaction with two samples and obtaining comparative information side-by-side remained.

- Visitors are informed through audio and visual cues how to use the interactive system with prompts (Preece et al., 2002), and about the existence of the comparison mode. The system also provides audio feedback to alert visitors any time more than two samples are “active” at the same time (this proved beneficial when samples were not correctly placed on the surface and the interaction then didn't work as intended, which confused some visitors during prototype testing). In order to enhance the whole experience, the sound fades out smoothly between the different events.

- Even though feedback about the audio descriptions during evaluation was very positive, additional details about the physical characteristics of the samples and educational information, like forming processes, industrial uses, and surprising facts, were added.

- Several visually impaired visitors who used the prototype after its formal evaluation reported that they benefited from the enlargement of images on the screen since they could better view the colors and discern geological details. It is important to note that the World Health Organization (WHO) reports that not every visually impaired person has complete loss of vision. In fact, people with some visual perception comprise the largest percentage of people with visual impairments, so it was imperative that the revised graphic design take that into account.

Figure 3 shows the TV screen with content corresponding to the petrified wood sample. The image displayed showed intricate details that were difficult to see on the sample itself so the on-screen content also helped sighted visitors obtain more information. The updated, enlarged text provides a label with the sample's name and a brief description. This information was also presented through the audio description — the text and audio complement each other as some visitors benefit more from one or the other, while other visitors appreciate the reminder.

Figure 3: Screen view of the petrified wood sample, with the text: "Petrified wood: it is formed when the original wood's organic remains have been replaced by mineral substances". Graphic design by Roberto Vaz.

- A flat-screen TV replaced the projector, presenting a better cost-benefit in terms of the acquisition, maintenance, and quality of content. Previously, the projection was sometimes impacted due to light sources in the room. This solution also allowed better results by allowing for customized lighting sources like directional lighting.

- Although the interaction model didn't change significantly, it was necessary to re-design the system architecture to accommodate for the changes that were made. Detailed information about this was published in Vaz, Fernandes and Veiga (2018b).

The Interactive Process of Re-Designing the Pilot Program Setup

The physical setup of the exhibit was entirely re-designed as well, in partnership with a product designer. During that phase, the Smithsonian Institution's guidelines for accessibility were followed strictly with three core goals in mind: making it accessible to the broadest range of visitors possible, completely embedding the hardware inside it, and guaranteeing an accurate operation of the triggering system with the samples attached to the surface by a steel cable. We ensured that the furniture was accessible to all visitors; that objects were displayed within viewing distance for persons of short stature, seated and standing visitors; and that the setup was cane-detectable.

Given its complexity, this stage involved multiple iterations, during which various options for the furniture were prototyped and tested with real users, before selecting the final version. Figure 4 shows photos of one of the last prototypes.

Figure 4: A low-cost prototype of the pilot setup made of cardboard, glue, and adhesive tape (left) and MM Gerdau staff and Roberto Vaz presenting it (right). Photos by Roberto Vaz (left) and Ana Cecília Rocha Veiga (right).

Since it had been decided that the exhibit would be integrated permanently within the exhibition space, the setup was designed to fit aesthetically with the other elements already in the exhibition. The focus was meant to be on the samples, so the furniture setup was built to be neutral and dark, using lacquered, black, medium-density fiberboard. The surface was coated with durable velvet to create a pleasant tactile experience where the hardness of the samples contrasted with the surface they were on. Another factor was to ensure that the exhibit was movable and could be relocated to other museum spaces as needed.

A photograph of the final product is shown in Figure 5, where the phrase 'pick up a sample,' is written in Portuguese on the screen, inviting visitors to start interacting with the exhibit and the five geological samples displayed on the velvet surface.

Figure 5: The *Wise Stones* exhibit from the pilot phase, at MM Gerdau museum. Photos by Leonardo Miranda.

Evaluating the Pilot with Real Users

A formal evaluation of the pilot was conducted in March and April 2018 with 13 visually impaired participants — five of whom were blind while eight had low vision — who had not used the prototype before. The main goals were to study the differences, if any, in users' interaction and satisfaction with this solution; if the audio descriptions were clear and accurate in the context of what they were sensing as they were interacting with the samples; as well as understanding how to provide an enhanced visitor experience using more exhibits like this one during future visits to the museum. The complete results of the pilot evaluation can be found in Vaz et al.(2018b).

In general, participants reacted very positively and enthusiastically to the exhibit experience. The audio descriptions helped them conceptualize the five geological samples, but two of the blind participants noted that the description of the petrified wood sample confused them because what they sensed was different — a cold mineral with the texture of a piece of wood along the edges. Based on this feedback, the audio description was revised to clarify the transformation process of wood into mineral. The participants also added that the integration of Braille labels could help them remember the names of the samples more easily without having to listen to the descriptions again, although they noted that Braille labels are not always an ideal solution given that not all blind people can read them and, if implemented, their location would need to be indicated clearly.

Regarding their expectations of more exhibits like this one for future museum visits, the majority of the participants specified that they would prefer the accessible exhibits be distributed across all three floors of the MM Gerdau so that they felt a sense of inclusion throughout the museum and would have the opportunity to visit all the exhibition spaces as sighted visitors do.

Complementary evaluations were conducted with other visitors, museum staff, and accessibility professionals, which revealed the need to expand the exhibit's accessibility for deaf visitors and visitors in wheelchairs. Figure 6 shows some photos from the pilot evaluations.

Figure 6: Visitors using the *Wise Stones* pilot exhibit at the MM Gerdau. Photos by Ana Cecília Rocha Veiga (left and right) and Leonardo Miranda (center).

Wise Stones Circuit: Ibermuseums Award and the Interactive Accessible Circuit's Consolidation

Ibermuseums is "an intergovernmental body for the promotion and articulation of public policies to support the museums of the Ibero-American Cultural Space and also provides support for different projects that help integrate, modernize and develop these institutions" (http://www.ibermuseos.org/en/about/our-role-in-the-sector/). It is supported by, among others, the Organization of Ibero-American States (OIE).

The *Interactive Interface Accessible Circuit,* consisting of the *Wise Stones Accessible Circuit*, and other accessible museum collections, won fourth place at the 7th Ibermuseums Education Award — Category II (projects in the development phase) in 2016 (https://webmuseu.org/mmgerdau-wise-stones/visitors-guide/). That year the award had, in consideration, 167 projects from 18 different countries, and the *Interactive Interface Accessible Circuit* was the only Brazilian project to receive an award. The museum was awarded $10,000 to be reinvested in the project.

With the Ibermuseums Education Award, as well as wide acceptance from people who are physically and/or visually impaired, the project was able to continue and consolidate into an *Interactive Accessible Circuit*. The project's goal, therefore, was to be part of the museum’s permanent museography, i.e., its long-term exhibition.

The first step toward the circuit’s implementation was the analysis of the usability tests and interviews, in addition to the team’s feedback. We then verified what had to be implemented, given that there was no longer one single exhibit, but various exhibits throughout the museum.

In the pilot exhibit, supervision by museum staff was more significant. In this new phase, the exhibits have to assure both, the user’s autonomy, and the collection samples’ safety. The alterations were made with that expectation in mind. Those decisions were difficult to make because when one aspect was enhanced, another was weakened. It was therefore up to the team to analyze the pros and cons and to set priorities according to the resources available at the museum, as discussed below.

The New *Wise Stones* Exhibit

The pilot exhibit’s structure was maintained for the new exhibits, with the following alterations:

- Adaptation of the furniture’s lower section, now hollow (shown in figure 7), to ensure access for people in wheelchairs, who can pull up directly to view the content on the surface rather than have to approach parallel to the structure.

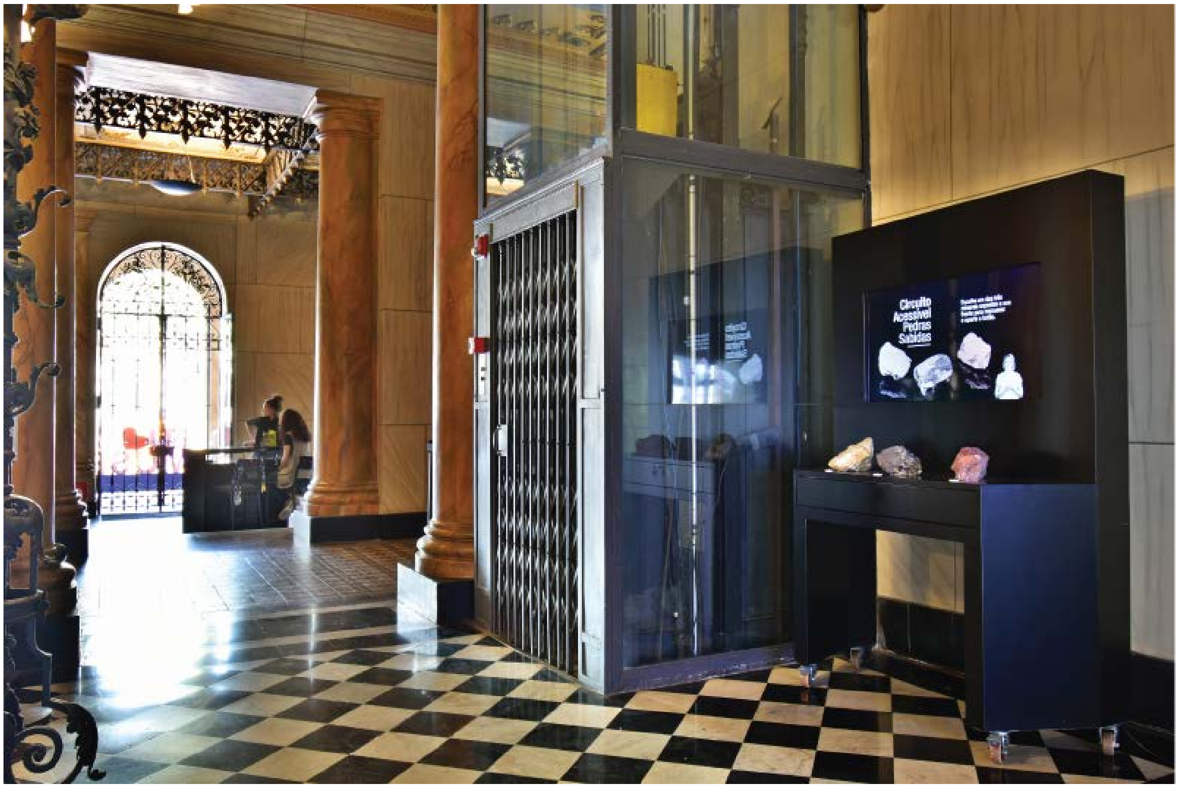

Figure 7: *Wise Stones* exhibit at the MM Gerdau Mines and Metal Museum's first floor. Photo by Leonardo Miranda.

- Minerals (samples) fixed on the exhibit, allowing the use of bigger and heavier samples than previously possible. This setup is better for the safety of visitors, who can now experience heavier samples without the risk of dropping them, and it also prevents theft. Bigger minerals discourage their removal from the surface, and their fixation also mitigates the maintenance required for the triggering system implemented in the previous version. Braille labels were also added, as presented in Figure 8.

Figure 8: Talc sample with button to start multimedia experience and Braille label. Photo by Ana Cecília Rocha Veiga.

- Buttons near each mineral start to play their respective videos on the screen. The videos contain enlarged images to show intricate details of the sample that may not otherwise be clear to all visitors, especially visitors with low vision; audio descriptions for visitors who are blind or cannot read; text on-screen for visitors who are deaf and can read in the vernacular; and sign language interpretation for visitors who are deaf and understand it. A screenshot from the video is presented in Figure 9. Although the focus for the accessible exhibits is still on serving visitors who are visually impaired, we tried, wherever possible, to meet the requirements of universal design.

Figure 9: Screenshot of the video at the *Wise Stones* digital interactive — *Quartz'* exhibit, which features enlarged images, audio descriptions, sign language interpretation, and text descriptions in Portuguese that translate to "Quartz: Huge variety of shapes and colors" and "When it is pink, it is known as Love Stone." Video from the *Wise Stones — Quartz'* exhibit.

With those alterations, part of the dynamism experienced with the pilot version was lost — previously, the media experiences were triggered automatically as soon as users picked the samples up, and comparisons between samples were possible. Now, a button press is required to start the experience. On the other hand, with those alterations, the exhibit's maintenance was made easier, human supervision (for theft prevention) is no longer necessary, and the samples can be larger. Figure 10 presents two photographs of the new *Wise Stones* exhibits. The pilot version continues to be available for mediated activities and is located in the museum's educative section.

Figure 10: *Wise Stones — Quartz* final exhibit (left) and Gibbsite (right), where text on-screen reads: "*Wise Stones Accessible Circuit* — Choose one of the three minerals in front of you to handle and press the button." Photos by Ana Cecília Rocha Veiga.

The MM Gerdau Accessible Circuit

In addition to the *Wise Stones* interactive interfaces (comprising three new exhibits and the pilot), eight new features, which were already part of the museum, were included in the development of the MM Gerdau accessible circuit. To undertake this selection, we used the survey mentioned in the *From Scratch to High-Fidelity Prototype* section earlier, which meticulously classified the museum's digital interactives according to their accessibility features.

Examples of items featured in the circuit include: minerals that can be touched, notably a 508 kg (1120 lbs) quartz druse and a meteorite; a famous Brazilian poem recited as part of the ambient sound in the *Miragens* (Mirage) gallery; and some videos/audio tracks that are not specific to certain exhibits but provide general information useful to all visitors. The circuit also features two touchable scale models — one of the large sculptures, *Língua Afiada* (Sharp Tongue), which occupies almost the entirety of one of the museum's halls (Figure 11), and another of the Liberty Square, Belo Horizonte's most famous square, where the *Circuito Liberdade* (Liberty Circuit, of which MM Gerdau is a part) is located.

Figure 11: Sculpture (left): *Língua Afiada* (Sharp Tongue) and its touchable scale model (right). Photos by Leonardo Miranda (left) and Ana Cecília Rocha Veiga (right).

The Liberty Circuit consists of a network of museums and cultural spaces at and near the Liberty Square. Operating in an integrated manner, the Liberty Circuit acts collectively through committees, one of which is the "Accessibility and Inclusion" project (Circuito Liberdade, 2017).

Considering the context in which it exists, MM Gerdau has the potential to impact the various museums that are part of its network, as well as its many visitors. As of August 2019, the number of visitors for the year was as high as 160,000 and, in the same year, the museum passed the mark of one million visitors since its opening in 2010. With the goal of widening the impact of the *Wise Stones Accessible Circuit*, sharing the knowledge obtained in the process, and encouraging similar experiences at other institutions, the team published a guidebook and website about the project.

Wise Stones Guidebook and Website

A *Visitor's Guide* is available on the *Wise Stones* website, and contains a description of each of the accessible circuit's features, classifying them according to their accessibility; it also contains information about visits, which are free and can be made during the museum's opening hours. In our survey, people with physical impairments heavily criticized the seasonality and temporariness of the museum's accessible activities. Consequently, none of the features in the accessible circuit, are temporary.

The website contains not only visitor information, but also an online, bilingual guidebook (Portuguese/English, also available in PDF format as well as in print in Portuguese), aimed at museum professionals who want to replicate the project at their institutions. In addition to the information about *Wise Stones*, clippings, scientific articles, handbooks, website links and useful tools about the project's themes, such as accessibility, management, web, technology for museums, etc., are also available.

The *Wise Stones* website, therefore, opens, a new avenue for research involving the production of digital content for museums, digital accessibility, web-based writing, search engine optimization, schema and web semantics, just to name a few. The first results were published by Veiga, Vaz, & Fernandes (2019), in which they proposed a new model for web-based writing for culture and the impacts, positive and negative, that digital marketing techniques have were discussed.

The End is the Beginning: What Changed with the *Wise Stones* Project

The *Wise Stones* project contributed to the consolidation of a new, permanent accessibility policy at the MM Gerdau museum. A specific sector was structured to deal with inclusion at the museum. General improvements are being implemented gradually and specific actions, such as a course that discussed the issue of accessibility in the context of museums; an exhibition of episodes of the first Brazilian animated cartoon in sign language (with the director there); and guided visits for people with physical and sensory impairments, among other inclusive and free scheduled activities, are being promoted.

Special importance must be given to the temporary exhibition, *Fossils: From the Sea to the Conquest of Land*, which took place in 2019. The exhibition, pictured in Figure 12, had accessibility at the very core of its design, which included: a podotactile floor (also known as tactile floor markers or textured ground surface indicators), Braille brochures and labels, tablets with audio guides, videos in sign language, and a rich collection of original fossils and replicas, both available for visitors to touch and experience.

Figure 12*: Fossils*, a temporary accessible exhibition at MM Gerdau. Photos by Ana Cecília Rocha Veiga.

Another relevant aspect of this process was the strengthening of connections between MM Gerdau and LavMUSEU/UFMG, with the museum's space used for research, internships and other integration activities. The accessible circuit forms the instructive content for many disciplines at UFMG, especially for undergraduate museology students, who go to the museum every semester for technical visits and activities. Thus, each future museologist becomes a disseminator of the knowledge gathered over the five years of the *Wise Stones* project, which continues to bear fruit toward a more inclusive and fair society.

Conclusions and Implications

Designing accessible digital interactives in museums with the aim of including all members of society is challenging, given the adaptations required to serve a diverse range of visitors with varied needs. With the opportunities to provide tactile samples of original museum objects come restrictions, often based in conservation issues, which contribute to perpetuating the highly visual culture inherent to these institutions.

Despite the availability of assistive technologies to enhance the visitor experience (Vaz, Freitas & Coelho, 2020), like 3D (Buonamici, Furferi, Governi, & Volpe, 2015; Cantoni et al., 2018; D'Agnano, Balletti, Guerra, & Vernier, 2015; Reichinger, Fuhrmann, Maierhofer, & Purgathofer, 2016) and haptic solutions (Carrozzino & Bergamasco, 2010; Comes, 2016; Romeo, Chottin, Ancet, Lecomte, & Pissaloux, 2018), the intent of this project was to promote sensory and intellectual access to original museum pieces, rather than to their replicas.

This chapter presented the different stages involved in the creation and development of the *Wise Stones Accessible Circuit*, which aims to promote accessibility and inclusion in spontaneous visits (rather than pre-planned, scheduled ones) to the MM Gerdau for the broadest number of patrons possible, especially prioritizing visitors with visual impairments. A multisensory strategy was adopted, combining touch and sound in addition to the existing visual cues.

During the five years of this project, many lessons were learned, and some procedures that proved to work well can benefit other professionals and researchers in their own accessibility projects. These include:

- Working with a multidisciplinary team of curators, technologists, designers, educators, academics and other professionals from the museum and also from other institutions that deal with accessibility concerns, was crucial to broadening the concepts and creating integrative visions for this project. It was also important to establish a collaborative network.

- Organizing guided visits and performing formal and informal evaluations with real users during all stages allowed us to generate the most critical insights of the project. People commented on the positive and negative aspects of their experiences, what should be improved, and what their expectations were, among other aspects. Some visitors expressed to the researchers that their participation also made them feel a greater sense of inclusion and helpfulness, and that their life experience gave them something to teach others.

- Testing embryonic ideas with colleagues through simple tools like paper prototypes and simulations, like the Wizard of Oz technique (Dix et al., 2004; Preece et al., 2002), enabled the team to experiment with potential scenarios and understand some interaction errors, without expending too much time.

- Promoting seminars and staff meetings, where iconographic records and reports of the process were brought to the discussion, was vital to guaranteeing that everybody was updated with the most important stages of the project, providing each museum sector additional time to think about the changes that will need to be introduced to their future day-to-day work and to developing internal procedures.

- Making the pilot version available to be used by all visitors, as if it was the definitive version, allowed the team to observe their adherence to the exhibit; their reactions and behavior; the time they spent using it, and so on. It also allowed perception of the museum staff's engagement with it in their everyday work.

As far as limitations go, the *Wise Stones Accessible Circuit* is not fully accessible from a technological point of view, since it does not support a completely independent visit for visually impaired visitors: digital tools for visitors' orientation and mobility inside the MM Gerdau had not been contemplated. The physical accessibility of the exhibition space has to be ensured by museum staff or by visitors’ companions. This limitation reveals new opportunities for research in this field.

Although the main purpose of the project was to enhance the museum experience for patrons with disabilities, it can be concluded that the result ended up benefiting all visitors.

Acknowledgments

This project was funded by *Associação Mantenedora do Museu das Minas e do Metal* (Maintaining Association of the Mines and Metal Museum), *Lei Rouanet de Incentivo à Cultura* (Rouanet Act for Culture Incentive) and Ibermuseums Program. The authors thank the MM Gerdau team, all external collaborators and visitors who contributed to this project, the LavMUSEU/UFMG laboratory, the State Public Library of Minas Gerais, and the São Rafael Institute.

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Inclusive Digital Interactives

Best Practices + Research

Chapter 9

Pushing Forward Together: From Failures to Feats Through Increasingly Inclusive Design

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September 2020

Introduction

The first time I tried to test audio description in our research team's prototype mobile app, I couldn't figure out how to get the app to work in my phone's VoiceOver-like mode. I then spent about a half-hour frantically just trying to get *out* of that accessibility setting, which seemed to have turned my device into an unusable brick. I eventually found a way back from this dark and mysterious audio-oriented interface, with the help of internet searches and guides, but I did not return from the experience unchanged.

The type of frustration I struggled with — for just a moment — is an everyday, all-the-time, and enduring part of life for people who are blind or visually impaired. Only there is no simple online hack for it. When roles are reversed, and a blind person tries to explore a sight-oriented environment such as a museum, an exhibition hall, or a visitor center, through its ocularcentric interfaces, the media ecosystem can turn hostile quickly and in surprising ways, too. All types of media (videos, photographs, illustrations, timelines, charts, tables, maps, etc.) require significant audible augmentation to speak to this audience. Best practices for doing such work are scarce. Not surprisingly, audio versions of visual media often aren't readily available.

What can be done about that? This paper, aligned with the theme of this publication, argues for an inclusive design approach.

Certain stakeholders rarely get seats at the design table. Therefore, their perspectives on design choices don't get heard, sometimes ever, sometimes not loudly enough, or sometimes just too late to do anything about it.

A remedy for that is a dedication to more inclusive design processes that provide agency early and often to key stakeholders of all types. Working together provided, for our research team, many benefits at few costs. In addition, an emphasis on this approach has raised innovative ideas and extended communicative possibilities for media accessibility beyond any individual team member's abilities, expertise, and experiences.

When I left my comfort zone of visual smartphone interfaces, for example, I was shocked to discover how unprepared I was for working within an audio interface. The sooner I had learned this lesson, the better, because I already had been making important design decisions about a media ecosystem based on unfounded assumptions (and some of these decisions then had to be redone at significant cost).

This misstep was probably the most fundamental mistake I could have made in starting any design project, but here I was, making that focus-group-of-one mistake again.

This time, though, the product wouldn't work for anyone, let alone intended users. In turn, I recommend that you begin any design process by thoroughly investigating your assumptions and biases, acknowledging them openly as contested knowledge before getting to know your audience, in-depth, which includes understanding the rich diversity of your audience's abilities, needs, motivations, obstacles to participation, and possible contexts, especially those involving inflexible communication infrastructure. Then, remove the clutter and noise and make your design process truly reflective of the findings of that investigation.

These are not added complications to your design. These are not problems to overcome. These are proven approaches to improving design. Team members, collaborators, and reviewers from your intended audience are a source of diversity and strength that will elevate your designs above those without such active and engaged participation. Such openness and outreach are not a divergence from your design plans. This is the plan, providing the best path forward.

The insights you identify in an inclusive design process can become novel opportunities to serve people in ways that they might never have been served before. I came to many of the ideas shared here only after missing them in the beginning and by being abruptly grounded by them later. This is an easy mistake not to make. Be inclusive from the beginning.

To further set the stage for this discussion, though, some necessary background: audio description for interactive exhibits, when in place, generally focuses on video, with descriptions stuffed into slight pauses in soundtracks and delivered through special equipment. Inaccessible visual media of other kinds, though, is rampant as well throughout these same museums and public spaces, including some of the most basic orientation materials, such as signage, wall texts, and brochures. Audio description is needed for those, too. Picking up a brochure and getting oriented to a place through that silent piece of paper, for example, is the most common activity at U.S. National Park Service (NPS) visitor centers and exhibition spaces (NPS, 2011). Yet, when we started our research project in this particular vein, only a few of the more than 400 NPS sites offered such a fundamental accessibility option. We should also acknowledge that all sorts of accessibility issues appear throughout public-learning environments, indiscriminately and pervasively, from inaudible panoramic views of presentation spaces to the silence of gift shop offerings, such as t-shirts and keychains, to inaudible aesthetic flourishes on interactive exhibits.

From a Box of Brochures to The Descriptathon Way

For scope, and structure, I start this account at the inception of the project in the Fall of 2014 and unfold its findings roughly in chronological order through the completion of our fifth Descriptathon in the Fall of 2019. My perspective comes as a sighted technical communication researcher and designer of digital tools who typically addresses information-gathering challenges at place-oriented public attractions. In this case, my primary audiences were people who are blind or visually impaired, but this work also clearly could benefit learners of all types. Our cross-disciplinary research team, of which I serve as the Principal Investigator (PI), included scholars and consultants in the fields of disability studies, education, and computer science. This work was intended to foster and support inclusive and interactive discourse in museum and museum-like contexts, but it also inherently illustrates systemic problems that routinely arise in the development of assistive technologies, and systems for creating assistive technologies, offering other potential insights for this larger area of study as well.

As an autoethnographic case study, it documents some of the factors that led us astray in the beginning and also key adaptations we made that allowed us to gain traction, establish a footing, and improve media accessibility. Since that initial setback, The UniDescription Project (https://www.unidescription.org/) increased its inclusionary tactics and correspondingly improved accessibility at a sizable scale, including through partnerships with American Council of the Blind (ACB) chapters in about 20 states and through producing audio-described orientation media at more than 75 U.S. NPS sites across the country. By detailing these lessons learned, we will recap and help readers cogitate about key moments in the processes of building webtools, mobile apps, training programs, and an audio description network, guided by an audio description research agenda.

As a part of the many twists and turns during this project and during this time period, like the nonfunctional-prototype surprise, The UniDescription Project spawned a spin-off idea called a Descriptathon, which is like a hackathon for making more inclusive media. The Descriptathon concept, which also will be described in more depth later in this paper, was born as a way to address a multitude of overlapping and foundational issues.

From an academic perspective, audio description generally lacks best-practices guidelines that have been put to any sort of stringent empirical tests, leaving practitioners and scholars to debate anecdotes and preferences without much scientific study about the topic.

There are no vetted professional certification programs for audio description in the United States. Before we began our project, there also was no easy (and cost-free) way to make and distribute audio description. As researchers, we did not just want to engage in one-off service work, producing limited effects by crafting and testing model descriptions for a few NPS sites and then leaving it at that. So we started building something bigger.

We decided to first construct the critical communication infrastructure we needed, supporting the processes of making and sharing audio description. The Descriptathon way of doing that — inspired by the intensity, enthusiasm, and playfulness typical of hackathons — grew out of those efforts. It was designed as a pop-up training program that connects people — across the spectrum of sight, and throughout the country — via conference calls, desktop computers, and smartphones. A Descriptathon complements our other free and open-source resources, such as our online training programs, through verbal training over conference calls as well as verbal and mediated forms of encouragement (such as feedback from listeners posted to participants' online projects). A Descriptathon also has clear research objectives, such as determining best practices for describing a map (Conway, Oppegaard, & Hayes, in press). A Descriptathon integrates description games and contests — staged like a sports tournament and fueled by fun Hawaiian-themed prizes — with practical goals of completing useful pieces of public description, ready for use. For a larger and more abstract goal, it also intends to bring people together at all levels (administrators, patrons, staff, volunteers, academics, advocates, etc.) in common cause to improve and audio-describe the world.

Our most-recent Descriptathon, for example, attracted teams (of one to five people) from 28 NPS sites, mostly in the Southeast region, spanning Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Alabama, and Florida. In addition to those NPS staff members, providing in-kind labor, we welcomed about 20 volunteer judges from the ACB to the mix for the three-day virtual event, all of whom generously shared insights and provided important quality-control functions, plus another half-dozen consultants who also contributed significantly to elevating the event's discourse and energy. Combined with our research team, based in Hawaii, this dispersed but united group, numbering about 100, both learned about and produced professional-quality audio description, much of which quickly then became available for public use. At this point, all of these critical parts of the project work intricately in unison (the Descriptathon, the field tests, the ACB partnership, the grant support, the mobile apps, the webtools, and the website). They are an interlinked operation. The vibrancy of these activities around the recent Descriptathon provides a dramatic contrast to where we began, five years earlier, with just a cardboard box filled with several hundred printed NPS brochures. The latest Descriptathon showed just how far we had come but also illuminated the key steps that were necessary to get here, fueled primarily by increasingly inclusionary design practices.

The Origin Story

I had worked with the NPS on several complex mobile-media projects before, including my dissertation, various studies in non-visual and interactive mediation, and even on a temporal recalibration experiment at the world's first national park, Yellowstone, in which we used mobile devices to reconceptualize time for users around geyser eruptions, rather than through relations to Greenwich Mean Time (GMT). Those experiences in mobile media, and the trust the NPS developed in my work with them, therefore, had been built over many years before the box of brochures even arrived.

So for this new media accessibility project, I was asked if I could help to develop a system for converting visual media into audible media through digital means, mobile technologies, and the translation technique of audio description. My source material was the UniGrid brochures offered in visitor centers, as a fundamental way to orient a visitor to a site. I somehow had to transform the information in those silent brochures into information that could be efficiently and effectively accessed through listening.

Intrigued by this technical-communication challenge, I recruited a couple of colleagues in the Center on Disability Studies at the University of Hawaii, who were experts in creating media accessible to people who are blind or visually impaired. I also brought on board a scholar at another university who specialized in the development of closed captioning. Then the box arrived. It was a plain cardboard box, about a foot wide and two feet long; maybe six inches tall. I opened it to find hundreds of brochures inside, spanning the country, from Acadia National Park in Maine to Zion National Park in Utah. At that point, I think I realized how monumental the task ahead of us was.

On the positive side, the layout of these brochures was orderly, based on the UniGrid system, created in the late 1970s by Massimo Vignelli, who was renowned for his design of the New York City Subway map. The UniGrid system standardized these brochures in ways that improved production and printing efficiencies. With that heralded system as an inspiration and a guiding force, we named our project UniDescription, with a goal of bringing unity (or, as we started calling it, UniD) to the small and relatively fragmented audio description community.

From Literature Review to Laws

As academics tend to do, we started this process by determining what is already known about this field, with a thorough literature review of audio description in general, including best practices, and any label variants, such as verbal description. We found paltry amounts of established scholarship. There is no academic journal devoted to it. Many books that include research on audio description also include other types of media-accessibility issues, such as captioning, sign language, braille, etc. (Cintas, Orero, & Remael, 2007; Cintas, Neves, & Matamala, 2010; Meloncon, 2014). So we didn't have much to start with.

Audio description originated as a formal translation technique in the 1970s, decades earlier than the debut of the smartphone, as a way to augment television, movies, and theater (Snyder, 2014). The few best-practices guidelines available, usually from advocacy associations around the world, mostly focus on standards for live events and pay little attention to static media, including illustrations, tables, and graphics. They generally offer tips on tried-and-true writing techniques (such as using active voice, subject-verb-object construction, short sentences, etc.) but offer little guidance about what to say when, for example, one is describing a map, which has no central focus, no clear use-case, and thousands of details of relatively equal importance.

Besides digging into the foundations of audio description, we also had to deconstruct the particular media artifact that we were translating at first (a brochure), as a way to determine what exactly a "brochure" was, in essence, and then also to provide quality-control measures for its output after the translation. We especially needed to ensure equivalence in richness and scope.

In quick summary of that work, which we conducted over about a year, our content analysis determined that the brochure was a communicative act that operated both in holistic and in modular manners. In a holistic sense, the brochure was an introduction and orientation to the park site, including its justification for existence, its highlights, and its boundaries in terms of characters, settings, and timelines. In modular ways, though, the brochure also communicated useful information outside of the larger narrative, such as what activities people might undertake at this place (hiking, biking, boating, etc.), where the restrooms are located, and even what the mailing address is. Our mandate, from the NPS staff, was to not edit the material but to convert every part of that brochure, from the most complex — including collages that show a site's ecosystem, complete with all plants, animals, and geology — to the smallest of details, such as a gray-screened signature overlaid on a background image. In the end, all of it needed to be heard.

For more than 40 years, since the passage of such legislation as Sections 504 and 508 of the Rehabilitation Act, the NPS has been grappling with how to realistically address federal mandates that require such availability of equivalent learning media. While NPS sites offer much visual media, in many forms — including videos, visitor-center exhibits, and wayside signs — this research project focused on the interactions that visitors had with the foundational media provided in the brochure. How did it help them to navigate and experience the site? We initially thought we could use a third-party system to build, test, and deliver our descriptions. Instead, like with the scant academic literature and best-practices guidelines, few options existed, and the ones that did could not meet our needs.

With grant support from the NPS, and later Google, to cover programming and research costs, we started to develop our webtools and app prototypes based on earlier experiences of how this process likely should go, rather than collaborating immediately with end users and fostering organic solutions arising from those interactions. That was a crucial mistake. Creating audio description, we learned, really was not like our other projects, despite how similar these seemed on the surface. And delivering audio description to a listener also was more foreign than expected, from content creation demands to device controls. Audio description is not just a variant of audio books, audio tours, radio theater, play-by-play sports broadcasts, using wireless earbuds to listen to music, etc. We found that audio description — due to the specific needs of its audiences — instead is a unique media ecosystem that demands solutions tailored to its particular quirks and audiences, many of which have not been addressed or even explored in existing academic or industry literature. That assertion is especially evident in static media in public settings, such as at museums and parks. For our part, we therefore had to quickly acclimate to this ecosystem, build tools for production and dissemination within it, and test our assumptions as they developed. We iterated often, sometimes radically. We identified various practical and technical communication issues at play. But we also began to conceptualize this type of inclusive design work as a form of establishing, reclaiming, and extending social justice. From that critical cultural perspective, the label of disability is just a social construct that masks deeper problems in design practices that privilege some people and disenfranchise others.

From that critical cultural perspective, the label of disability is just a social construct that masks deeper problems in design practices that privilege some people and disenfranchise others.

Starting a Training Program, Finding the Descriptathon Way

After the initial UniDescription webtool was built through an admittedly insular design process — primarily based on our team's collective ideas about what it should be, and how it should work — we collaborated with park staff at three NPS sites (one in Hawaii, one in California, and one in the Washington, D.C., area) in February 2016 to try these ideas for the first time in the wild. For this initial pilot, we offered just a one-hour introductory phone call with the park staff, a call that had to cover all of the orientation about the project, and everything we wanted the person to know about audio description, plus training on the software. Yes, you read that right, in one hour. Without any additional guidance about audio description best practices, we then let the park staff loose to work on the webtool and describe at will, for roughly a day (we asked them to spend about eight hours of work on it, but we did not track the actual effort), before bringing everyone back together for another one-hour phone call. There was no real synergy among the participants. They worked mostly independently. The time frame, in hindsight, was absurdly short. Most of that second call was spent on tallying technical glitches with the webtool and sharing basic information we realized should have been in our orientation, such as explaining simple best practice guidelines for common audio description tasks, including how to describe images of people, places, and artifacts. The staff worked for another half of a workday (about four hours), then we wrapped up the pilot with what we had completed at that point. The results were better than nothing but with much room for improvement.

Aside from webtool usability issues, which were many, we also realized we still had a lot of work to do to prepare sighted people for the craft of audio description. It was sort of like teaching and learning a new writing genre, only in hyper-speed. While these park staff members already knew a tremendous amount about their parks and knew how to interact with visitors in clear ways, and some were good writers, they were mostly unpracticed and generally unaware of the nuances of translating visual knowledge into acoustic knowledge for this purpose. So we generated as a product from this initial process mostly a reflection of existing skills, in which a California park staff member, seasoned by earlier audio description projects at the site, produced a solid final version, ready to share with the public. The park staff at the other sites, who had no experience in audio description before this project, struggled to understand the genre, including the translation process and technologies affording it. Some of the problems in the process could be attributed to the rough state of the webtool and its glitches, which at times took a high degree of technical skill (and patience) to overcome. But the California park's staff member could do it, and do it well, forcing us to look beyond just technological obstacles as excuses for the uneven results.

At a national park in Hawaii, the one person working on this project immediately became overwhelmed by the process and essentially dropped out (only to return to it months later via one-on-one tutoring). At a national monument in Washington, D.C., we had asked three different staff members to independently work on the same brochure, in separate project files, as a way to compare how this process worked with the same content, in the same artifact, within the same organizational culture, with people of three different skillsets, in different types of positions. We found that these variables, such as organizational position, really didn't affect the experiment much, though, because none of the three ended up understanding (likely due to our thin orientation) what we were asking them to do and why. Instead of describing visual elements of the brochure, for example, the three spent most of their time engaged in just retyping text on the brochure and writing a few alt-text-like descriptions, akin to “This photo shows the (monument) on a sunny day.”

If we would have thought about all of the low-hanging transcription tasks beforehand, we could have copied and pasted the texts into the webtool and eliminated that straightforward but time-consuming part of the job (which we have done since). From that lesson, we also became determined in future collaborations to do everything we possibly could to prep our project files with whatever rote production work could be done beforehand. Ideally, we wanted new audio describers to have nothing to do to take their focus away from describing visual elements. So we created a new type of prepping system in response, including a template and transcription checklist, to put the focus of the Descriptathon on only the audio description. That said, even with the focus on descriptions, we realized that doing this work was not an innate ability in most people. We needed a more robust training system as well.

The Descriptathon: Blending a Hackathon, Conference Call, and Online Training

As mobile, web, and other digital technologies converged in the mid-2000s, people were trying to figure out how to harness these emerging powers in various situations, transcending education and business (Bogost, 2016; McGonigal, 2011; Nacke & Deterding, 2016; Walz & Deterding, 2015). Gameplay could drive intriguing behaviors in many situations, even in serious contexts, through increased engagement and efficiency, which also could spur innovation (Rauch, 2013). Hackathons, Irani (2015) found,

> manufacture urgency and an optimism that bursts of doing, and making can change the world. Participants in hackathons imagine themselves as agents of social progress through software, and these middle-class efforts to remake culture draw legitimacy from the global prestige of technology industry work practices.

Such gamification also overlaps with iterative design processes, making gameplay and user experience studies sometimes difficult to tell apart, when they both incorporate forms of iterative design, rapid prototyping, and user testing in real life situations (deWinter & Vie, 2016; Porras, et al., 2018). Few argue anymore that gamification techniques can work, and work well, in the right circumstances. More interesting discussions exist now around precisely which ones work and how (Deterding, et al., 2013; Deterding, 2014; Nacke & Deterding, 2016). Some people have tried issue-oriented structuration, born from the immediate needs of a particular public to confront a particular concern (Ladato & DiSalvo, 2016). Hackathons also have morphed from their origins of strictly technical activities oriented toward programming prototypes into more expansive systems of issue response and support, including subject-matter training, extensions of services, and social networking (Porter, et al., 2017). They have especially been helpful as systems for bringing volunteers together quickly around an important societal design problem, for articulating the most pertinent issues, and then for immediately starting work on solving core problems (Easterday, et al., 2018; Lodato, & DiSalvo, 2016).

Our research team gravitated toward these more expansive hackathon ideas as a way to make media accessibility more aligned with a community of practice in which people came together to do this type of work in a fun and engaging environment as a societal calling of the masses rather than as a checklist task to complete. Technical communication as a field also has taken a turn toward social justice issues, particularly at the intersection of disability studies (Meloncon, 2013; Moore 2017). The timing, therefore, was right to try this approach, as motivating factors converged in terms of societal interest and technological capabilities.

At the debut of this new Descriptathon approach — which we launched from the national design hub for the NPS, at the Harpers Ferry Center Interpretive Center, in September 2016 — staff members from eight NPS sites across the country participated via an online and web-based conferencing system and a conference call (including Yellowstone, as well as sites in Alaska, California, Florida, Hawaii, New Jersey, and Washington state). They were invited via correspondence that contained, among other information, such aspirational rhetoric as:

> By participating, we hope you will become an advocate for audio description and help to spread it and the importance of accessible media to the rest of the world. … We also have higher goals, hoping to kickstart a national conversation about media accessibility and the value of including more people in our societal conversations.

At that point, our research team included six people (me, two co-PIs in disability studies, two research assistants, and a subcontracted web and mobile app programmer). We also had major logistical help and guidance from our devoted NPS liaison. Park participants, usually volunteers rather than conscripts, were first given an overview of audio description, as a process, as well as introduced to the prototype webtool and then asked to use that tool to create descriptions for their site brochure. We spent much more time on this training activity than before, about nine hours together. But this still turned out to be a lot of new information to share at once, including introducing a new genre of writing and a new piece of software, with a heavy production expectation by the end of two days. The hackathon part of the event was straightforward and utilitarian; basically designed as a way to get together with like-minded others and finish descriptions of your brochure, through discussion and guidance by the group. This event was much more successful than the pilot, in terms of the quality and quantity of the descriptions produced, but it also opened our minds to the potential of expanding these activities even further. We definitely needed to do more. More what, exactly, we weren't quite sure. But definitely more.

Descriptathon 2: Gamification Through a Tournament

For Descriptathon 2, in February 2017, we dramatically increased the size and scope of the event, working with park staff at 28 NPS sites across the country. We cut the online conversation channel and focused on the audio only, via conference call, with captioning. We brought in two prominent external consultants in the industry, to bolster the quality and scope of the audio description training we offered. We increased the event from two days to three days, with more built-in time for independent description, and we made a significant shift in the tone of the proceedings. In short, we thought we were missing the “fun” of a hackathon, and the NCAA “March Madness” basketball tournament was coming up. I had been involved in a couple of unconferences, with a hacker-like vibe, and many thrilling sporting tournaments, and wondered if the excitement of sports and a hackathon could be combined within a bootstrapping and time-constrained, get-the-job-done environment. We asked participants to do more prep than before, including filling out a survey that described their audio description experiences to date and completing exercises to practice description beforehand, such as describing an image on a brochure and calling a friend to read the description over the phone as a way to practice hearing how such description sounds aloud and works without visuals.

Unlike earlier training exercises with other parks, this group was organized by sites into a tournament bracket, in which pairs of parks competed against each other in exercises and semi-competitive games designed to create comparable audio description, around themes such as “the portrait,” “the landscape,” “the cultural artifact,” “the collage,” and “the map.” We gave a bit of orientation and training for each theme, gave the participants a timed exercise to complete, and then judged with the consultants, one of whom is blind while the other has low vision, and our researcher who is blind, serving as the review panel. They determined which description of each pair was better and why. After the judging period, the reviewers talked about what they liked and what they didn’t like in the various descriptions. They gave illustrations of excellent descriptions in the contests and also noted faux pas. There was a prize for the participant who completed the most brochure descriptions on their park project in a day. There was a prize for the description each of our four research assistants liked best, which they read and explained. We had participants self-nominate descriptions they wrote that they liked best and had a competition among those. We tried a lot of different dynamics.

The winners of each round, as determined by the reviewers, advanced to the next round, spurred by promises of Hawaiian-themed prizes at each stage (touristy items that were gathered and mailed to them afterward). The gamification strategy appeared to clearly generate more data, and more research-focused data, in terms of quantity and lengths of descriptions, than the previous training exercises, per user. Several participants also commented about how much fun they were having or how exciting (or stressful) the training was.

But we noticed that this approach also seemed to somehow disenfranchise a few of the participants as well, four of whom dropped out of this voluntary training, which might or might not be attributable to the perception of an “electronic whip.” Everything considered, good and bad, we concluded afterward that this approach was a major improvement from Descripthathon 1, yet it still lacked significant inclusion of the intended audience beyond a few hand-picked representatives. We wondered how a more-inclusive system, from Descriptathon to field test, would affect the process and products. Then, we received some great news.

Descriptathon 3-5: Much More Support, Much More Inclusion

Two interconnected and important developments followed the second Descriptathon. First, Google’s accessibility group decided to invest in this project with a significant grant. In addition, as a part of those grant discussions, our research team was introduced to leaders in the ACB, a leading advocacy group for people who are blind and visually impaired. This is where the mostly disparate parts of the Descriptathon structure and the underlying drive for better integration and evaluation of inclusive design finally came together.

With the new grant support, I was able to hire two student research assistants. One of them was blind, and the other had worked in the Hawaii Library for the Blind, both bringing helpful and diverse experiences directly to our research team. The connection we created with the ACB in this process started strong as well, with commitments from their members to field test our generated descriptions at NPS sites. I have had synergies develop before with research partners in other projects, and this partnership quickly became one of those most precious collaborations, in which what we decided to do at first became quickly dwarfed by our common-ground ambitions that propelled us both to unforeseen benefits, heights, and side projects.

For example, our field research outings also morphed into community-building events, bringing together NPS staff and ACB members living in a localized area, by introducing real people and their accessibility concerns directly to the nearby park, instead of just strictly conducting tests and calling it a day. These events, which included a focus group and a field experiment with new audio description generated through this research project, also featured some important downtime for informal discussion, mingling, and park exploration.

In turn, these events often developed a lasting bond between the federal agency and representatives of the nearby community of people who are blind and visually impaired, who then typically became more active park supporters and patrons.

When we conducted a field test at Morristown National Historical Park in 2018, for example, the New Jersey site of several American Revolutionary War landmarks had some proprietary audio description equipment for its videos. But the staff could not get the equipment to work. We did our focus group and field tests, and during one of the breaks, our group of five ventured into a small and nearby historic structure, the Wick House. Escaping the sun, we went into the house primarily for the shade it offered on the hot day but were greeted by a costumed interpreter inside spinning yarn. She told the group of ACB members about the knitting process, allowed them to touch the yarn and the spinning wheel, and suddenly our group was diverted into a full-blown exploration of the house.

These ACB members circulated throughout the small building in ways that I was unaccustomed to witnessing at national parks. They did not breeze through by glancing around and walking rapidly from room to room. Instead, they took their time and deeply explored every touchable object and architectural feature available, as the costumed interpreter and the Morristown park ranger described verbally what they were encountering. In the entryway, for example, this group found the fireplace and felt around all of the edges on the hearth. They felt the different cooking instruments hanging nearby, item by item, and even knelt down to touch the fireplace rack, where the wood would be placed. We spent well over an hour inside, and a lesson learned from that experience was that quantity of information provided is not necessarily a barrier to interpretation.

As long as the information is of high quality and can be navigated and stopped when interest saturation is reached, the idea to “write short” in audio description seems in conflict with this audience’s potential interest in deep learning.

Instead, we found through various other experiments and discussions with ACB members, listeners want to know what they are getting into before they get into it. They also generally want to have the ability to stop and move on, when they want, similar to scanning a learning environment visually. They do not want to be held captive by a long, winding, and multipronged recording. But they might very well listen to a long audio piece, if it is interesting. In response, we redesigned our audio description products to start with a linked table of contents that allows the user to learn about the information highlights and structure of a set of descriptions before choosing where to dive down into it.

Benefits of Inclusive Design Blossom

The increasingly inclusionary design and evaluation practices that developed out of this partnership involved dozens of ACB members from around the country and led to countless adjustments and adaptations of our technologies, from locating show-stopping bugs in our programming to major oversights in the design that simply weren’t picked up in any other way through our research team’s normal review processes. For example, we exported audio description through our mobile apps in three formats: text only (marked up digitally, for screen readers), audio only (with MP3 files that could be listened to on any device), and a combination format that provided both. We had a three-tab button system for selecting and changing this format at the bottom of the smartphone screen, where it seemed to be out of the way but also easy to find and use. Only, when a blind person listened to this page, those tabs actually were so far down the list and out of the way, from an audio-oriented and linear sense, located after even the park’s contact phone number, that none of the people who used our app in these tests even recognized that it was there and that changing formats was an option. The simple fix was to move the buttons to the top of the page, so they could be found and adjusted easily before listening to the audio description. What seems obvious now as a design choice was veiled then, because we didn't have enough people in our intended audience participating directly in the design and testing process.

As another example of the benefits of this partnership, when we kept uncovering various accessibility issues of different sizes and scopes in our field visits, ACB members volunteered to conduct a Section 508 and Web Content Accessibility Guidelines (WCAG) 2.1 AA comprehensive accessibility evaluation of our website, our webtools, and our mobile apps using the WebAIM's WCAG 2 checklist. Through that review, we were able to meet Level AA conformance. Through our partnership with ACB, we learned exactly what type of compliance was important and valued by this particular audience, which represented our larger intended audience as well, and then we were able to focus our efforts on achieving that specific standard.

For Descriptathon 3, our research team asked ACB for volunteers who could judge and provide feedback about descriptions, and 14 people from ACB chapters around the country jumped into this important information loop. We worked with a dozen park sites in Descriptathon 3 (September 2017), two dozen in Descriptathon 4 (March 2019), and 28 in Descriptathon 5 (August 2019), with dozens of ACB volunteers bolstering this expansion by serving as judges, consultants, and first-draft reviewers of content. In addition to enriching the Descriptathons, these ACB members and others also volunteered to conduct field visits to each of the sites afterward, as another critical form of quality control. Most of these field visits gather five to 10 ACB volunteers, who live near a park site. Our field visit to Yosemite National Park, in November 2017, for example, was so popular that we chartered a bus to transport the dozens of interested ACB members (and four service animals). An ACB Facebook post about the trip afterward attracted more than 100,000 views, setting a record for the organization in terms of social media engagement.

From a curatorial perspective, NPS staff were able to shape, vet, and control all content shared with the public as they deemed appropriate, aligning with their interpretive goals, objectives, and tactics. They had final say in whatever was published, and, through the free and accessible UniD tools, were able to instantaneously update and add content as often as desired. That said, these staff members also had a universal desire to collaborate and learn from their audiences about how to create and deliver better and more useful information. At no point, and in no park so far, has this process turned contentious or devolved into issues of control. Instead, park staff members involved in this project have been eager to adjust their approaches, or make accommodations, to improve the end-user experience. At this point, and with these overwhelmingly positive results, it's become difficult to imagine this project even functioning without the integration of ACB members in it, and without their evaluations of the end products as endorsements. In retrospect, we only wish we had started such collaborations sooner.

Seeking a Connection Between People Rather Than Building a Product

Upon reflection, and aligned with sentiments found throughout this publication, I think my research team and I were too focused at first on making the tool and its products while not being attentive enough to the establishment of our intended audience as a meaningful part of our design processes. On less-than-sound footing, we thereby stretched toward our core research question: in what ways can we improve audio description in America's most precious places, such as at NPS sites? We were operating at times both out of context and balance. We did not consult thoroughly enough at first with important stakeholders in our research area's community, and many of us on the team did not live these experiences daily. For the most part, we were studying these issues from a detached scientific distance. In turn, instead of divining systemic solutions in an efficient manner, with the help of the people most affected, we stumbled into rookie mistakes in predictable places.

How could I have forecast these issues? How would I address these problems? Those were not just straightforward design, production, or programming concerns, so the answer was less technical and more philosophical. When I started this project, my design concepts were entrenched in an ocularcentric paradigm. I didn't realize that, of course, but I was looking for answers, rather than seeking them through all available sensory means. This article outlined some of the crucial developmental steps of a technological system designed for improving inclusion. It extended beyond a report about a particular app, though, or a webtool, into details that can be examined in a variety of ways, such as through the use of the products, and exploring our extensive project website which includes access to the open-source code. In this article I've shared some of the larger lessons learned, essentially what I know now that I wish I knew years ago.

In my effort to efficiently create a successful design, I realized, I inefficiently skipped many of the most important parts of the process. I rushed to *see* the most visible solutions rather than patiently working to discover them. When I realized this misperception, I knew I needed to change my approach. I knew I needed to get more first-hand knowledge. I also needed to enlist more help, well beyond my usual circles of collaborators, including reaching out and developing an extensive partnership with everyday users of audio description through an active national advocacy organization, the American Council of the Blind. So I refocused on applied fieldwork, studying user experiences, and conducting usability experiments, as ways to seek further assistance, guidance, and real-world feedback. I also turned to people who are not just experimenting with acoustic interfaces as an intellectual exercise, but who use them every day, even in quotidian ways, as powerful instruments of social and public engagement. Such use is definitive of expertise. So why wouldn't a design team want to include it?

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Inclusive Digital Interactives

Best Practices + Research

Chapter 10

Warhol for All: Designing an Inclusive Audio Guide and Tactile Exhibition Elements at The Andy Warhol Museum

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September 2020

Introduction

Located in Pittsburgh, Pennsylvania, the place of Andy Warhol's birth, The Andy Warhol Museum is the largest single-artist museum in North America. It holds the world's largest and most comprehensive collection of Warhol's artworks and archival materials, and is dedicated to educating and inspiring through his life, art, and legacy. Now over a dozen tactile reproductions of selected works from the museum's collection help tell the story of Andy Warhol's life and his expansive artistic practice through touch. They are accompanied by audio recordings on the museum's inclusive audio guide, *Out Loud*, a mobile app built on Apple's operating system (iOS) that guides visitors through the experience of feeling the reproductions and visualizing the original artwork. Using Bluetooth beacon technology, the audio guide is location-aware, notifying visitors about content available for works of art nearby. It is fully accessible with VoiceOver, Apple's native screen reader. It includes transcripts for all audio, making the experience accessible to users with vision or hearing loss, as well as those who simply prefer text. Content is delivered in a conversational style in short chapters and includes different voices and perspectives, including detailed visual and guided tactile descriptions of select objects. The app experience and tactile reproductions are most helpful to visitors who are blind or have low vision but enhance the gallery experience for all visitors. This article traces the development, rollout, and evaluation of this inclusive mobile app and the tactile exhibit elements.

Figure 1: A user/expert tests app features in development at The Warhol, 2016. Photo by Desi Gonzalez.

About The Warhol

The Warhol is situated in a seven-story historic industrial building on the Northside of Pittsburgh, a 10-minute walk from the city's downtown cultural district. Organized chronologically from the top floor down, the museum tells the story of Andy Warhol's art and life, highlighting different aspects of his varied artistic practice through rotating displays that draw on the museum's rich holdings.

Warhol's life offers an unlikely example of the American dream. Born in the midst of the Great Depression in the industrial city of Pittsburgh, Andrew Warhola had a childhood neurological disorder, was openly gay, and came from a working-class immigrant family. According to the cultural attitudes of that time, few would have expected him to become one of the most iconic artistic voices and cultural influencers of the 20th century.

As an artist, Warhol was famously appreciative of difference, cultivating diverse social and creative circles around him throughout his career. In keeping with this inclusive spirit and Warhol's roots, The Andy Warhol Museum seeks to be welcoming to all, with a special focus on developing relevant, accessible programs and strategies to engage people who have traditionally been marginalized or excluded from cultural institutions.

Adopting a Universal Design Approach

In their most traditional conception, independent art museum visits are largely visual and highly intellectual experiences that involve quietly looking at objects and artworks and taking in information through reading or listening. For individuals who are blind or have low vision, or people with tracking, attention, and processing disorders, museums can be alienating, inaccessible, and unengaging. Yet, museums have legal, moral, and financial imperatives to make their experiences accessible to a diverse public that includes people of all abilities.

Regular audience surveys at The Warhol reveal that 60% to 70% of the museum's visitors are from out of town. As one of the top cultural destinations in Pittsburgh, The Warhol is a place of pilgrimage for Warhol aficionados from around the globe and a popular spot on tourist itineraries (*Pittsburgh Quarterly* cited the museum as the city's top tourism destination in 2018). While some museums provide visitors who are blind or have low vision with periodic guided tours that offer detailed descriptions of artworks and opportunities to touch reproductions, material samples, and the like, this approach is not sufficient for a museum with such a high percentage of out-of-town guests who have limited flexibility with the timing of their visits.

For The Warhol, adopting inclusive design principles in developing multi-sensory exhibits and an inclusive audio guide fit the museum's audience profile, the characteristics of its collection and exhibition program, as well as the organization's mission, vision, and values. Inclusive design anticipates a diverse user base and aims to compose environments and experiences that can be accessed, understood, and used by all people regardless of age or ability. If done properly, visitors with and without sensory disabilities can enjoy an enriching, accessible experience of the museum's singular collection at any time, with no advance planning necessary.

Ruben Niculcea, a developer at the CMP Innovation Studio who worked on *Out Loud*, reflected on the value of a universal design approach:

> We all go through situations where we experience impairments. Designing something so that it can be accessed without the sense of sight is not just designing for people who are blind or have low vision — it's also designing for someone who is distracted, someone who is aging, someone who has their hands full. It's not designing for accessibility, but designing for all humans. The whole human experience is that we depend on changing, imperfect bodies, and we can make technology and experiences that work better for all humans.

Building on Past Experiences

In 2014 The Warhol made its first attempt at designing an inclusive audio guide in conjunction with the exhibition *Halston and Warhol: Silver and Suede*. In addition to interpretive content featuring the voices of curators, scholars, and friends and family of the artists, the guide included a dozen visual descriptions of key artworks and fashion designs. The app featured transcripts for deaf and hard of hearing users, and relied on low energy Bluetooth beacons to push out location-based content. However, despite their best efforts to design an effective and accessible experience, visitor reviews were mixed. As associate curator Nicole Dezelon wrote in a later reflection about the guide, “While excited by new technologies and motivated with best practices in accessibility, we quickly learned from our user testing that our best practices…weren't the best” (2016). Visitors found the standard format visual descriptions to be boring, and the beacons were imprecise and suffered from interference. Armed with lessons learned in this initial foray into accessible design, The Warhol team was committed to continuing to develop inclusive mobile offerings to enhance the experience of the museum for all visitors. In 2016 they began development on *Out Loud*, a new iOS app designed for users of all abilities.

Designing *Out Loud*

Out Loud was a collaborative effort that involved an array of contributors, consultants, and user/experts. It was developed over the course of approximately seven months beginning in January 2016 by:

- An interdepartmental core project team and advisory team with expertise in digital technology, museum interpretation and content, accessibility and inclusion,
- The Innovation Studio at the Carnegie Museums of Pittsburgh, an in-house design and development laboratory,
- Prime Access Consulting, an agency dedicated to inclusive design technology with a specialty in museums and public spaces,
- Tactile Reproductions LLC, a local design and fabrication company, and
- A team of user/experts who offered feedback and consultation throughout.

Design Philosophy

The production of *Out Loud* was rooted in commitment to agile development and human-centered design. Desi Gonzalez, The Warhol's former manager of digital engagement and the project manager for the development of *Out Loud*, explains this orientation:

> First coined in 2001 in the Manifesto for Agile Software Development (Beck et al., 2001), 'agile' is used in the technology industry to refer to a loose set of principles centered around designing and developing software products in iterative cycles. Agile is often contrasted with the waterfall model of project development, in which stakeholders sequentially define requirements, come up with a concept and design, and finally build the project. Agile methodologies allow for more flexibility and adaptability along the way, with the final product shaped by testing. Unlike with the waterfall method, an agile process might result in a product that is completely different from its initial requirements. (2017)

In addition to a focus on agile development, the museum prioritized a user-centered design approach — all of the choices made in the design and development process would be based on the needs, preferences, and perspectives of users, particularly users with disabilities.

The core team embarked on research that included a review of best practices in accessible mobile design for people who are blind or have low vision, as well as formative conversations with user/experts with visual impairments. Learnings from the research phase were synthesized into five simple design principles:

- Provide a path with a choice;
- Build a social experience;
- Use industry standards for interactions;
- Keep physical interactions to a minimum; and
- Provide a mix of voices and tones

As one of the user/experts interviewed during the research phase explained, a good museum experience would allow her to be “engaged, social, experiencing art in a way that was expressly made for [her]," adding, "it allows me to be independent.” The design principles articulated in the research phase guided decisions large and small throughout the development process.

User Testing

Throughout the process, user testing with individuals who are blind or have low vision was critical. All decisions were shaped by input from user/experts and local disability groups. Three Pittsburgh-area residents with a range of visual impairments — including full blindness, low vision, and colorblindness — served as primary user/experts and co-designers. Each brought their unique perspectives and experiences to bear on the development process, as well varying levels of comfort with technology. Over the course of the process, members of organizations such as the Pittsburgh Accessibility Meetup, Blind and Vision Rehabilitation Services, and the Leadership Exchange in Arts and Disability also conducted user testing to give feedback.

Feedback sessions and user testing took different forms over the life of the project — initially the team created paper prototypes of different possible design directions, and asked advisors to test and respond to them. To test concepts with users who were blind or had low vision, the developers built interactive prototypes. This prototyping approach allowed the team to test different designs for specific project components, like audio player controls, before arriving at the final state. During later stages of the project, users were invited to test a beta version of the app.

Feedback from users not only informed the design of the app itself — it also influenced the kind of headphones the museum offers (many users with visual impairments preferred earbuds), the addition of accessories like lanyards, optional headphone splitters and neck loops, and the way tactile reproductions were mounted and displayed in galleries.

Figure 2 - Visitor Profile Attendees at the 2016 LEAD conference preview The Warhol *Out Loud* and tactile reproductions, 2016. Photo by Sarica Feng.

Designing for Accessibility

Rather than reinventing the wheel, the project team decided to leverage existing inclusive technology. *Out Loud* is designed to use VoiceOver and Dynamic Type, two of the built-in accessibility features on iOS devices. VoiceOver is Apple's screen reader, which verbalizes on-screen content using a synthesized voice and allows users to navigate via gestures such as tapping and swiping. Users without sight can aurally scan and interact with content using VoiceOver, but only when an app has been properly designed using appropriate structure, clear and consistent nomenclature, image descriptions, tags, and other conventions. Dynamic Type allows users to control text sizes, adjusting magnification to improve readability.

In addition, the app features a custom-designed audio player which presents three to six short chapters of audio content per story. The player reorders the chapters based on a user's preferences and behaviors — for example, if VoiceOver is enabled on the device, the player will push visual descriptions to the top of the queue, immediately following the brief introduction to the artwork. This allows users with visual impairments to gain a sense of an artwork before engaging with its historical context or related interpretive content. Over time, the player can also recognize which categories of content a user listens to most (such as archival audio), and offer those chapters up earlier in the queue.

Location Awareness

Out Loud delivers location-based content to users via the app's "Near Me" functionality. Armed with learnings from their 2014 experiments with Bluetooth beacons, the team knew they wanted to use the technology to help users connect content on the app to physical works of art in the galleries. However, their earlier attempts, which paired individual beacons with specific artworks, yielded interference and confusion for visitors. The app would pick up multiple signals at once and switch back and forth between audio tracks, resulting in a frustrating experience for the visitor.

The project team made the decision to incorporate beacons as a key feature of the app, but deprioritized precise wayfinding and location orientation for the app's original release. Visually impaired users involved in testing it said that they most often visit museums with a companion who helps them navigate the space, indicating that independent wayfinding was not their highest priority. Thus, in *Out Loud*, each beacon covers a region of a gallery rather than a single artwork. When a user passes a beacon, for example, by entering a new room, users with VoiceOver enabled will hear an announcement in the "Near Me" section of the app that new stories have been detected. Enhanced location awareness remains a primary goal for future iterations of the app, with the goal of allowing for visitors with visual impairments to navigate the museum independently.

About the Content

The museum's educators, digital producers, and curators came together to develop a new model for content, focused around themes suggested by users who gave feedback in a focus group.

Broad categories for content include brief introductions to the artwork, historical and cultural context, points of view and artist interviews, as well as supporting information like music clips or archival audio. The guide also includes accessible content, such as visual descriptions and guided tactile experiences, which are tailored to the needs of users who are blind or have low vision, but available to all. Rather than expecting all visitors to listen to a single two to three-minute clip corresponding to a particular artwork, content is broken up into small, modular chunks, primarily under one minute in length. Visitors can choose to dive deep and continue exploring a particular artwork with multiple stories, or not, according to their interest and availability. Rather than a single narrator, the guide features an array of voices offering distinct perspectives on the museum experience.

As project manager Desi Gonzalez explained:

> "In designing *Out Loud*, we were determined not to silo accessible content apart from other interpretive content. Instead of creating "a thing about disability," we hoped the audio guide would be a seamless, inclusive educational experience regardless of a user's ability. More generally, our user research demonstrated that all

> visitors — whether they have a visual impairment or not — bring different perspectives to the museum experience and therefore want the ability to learn about Warhol in ways that best fit their interests." (2017)

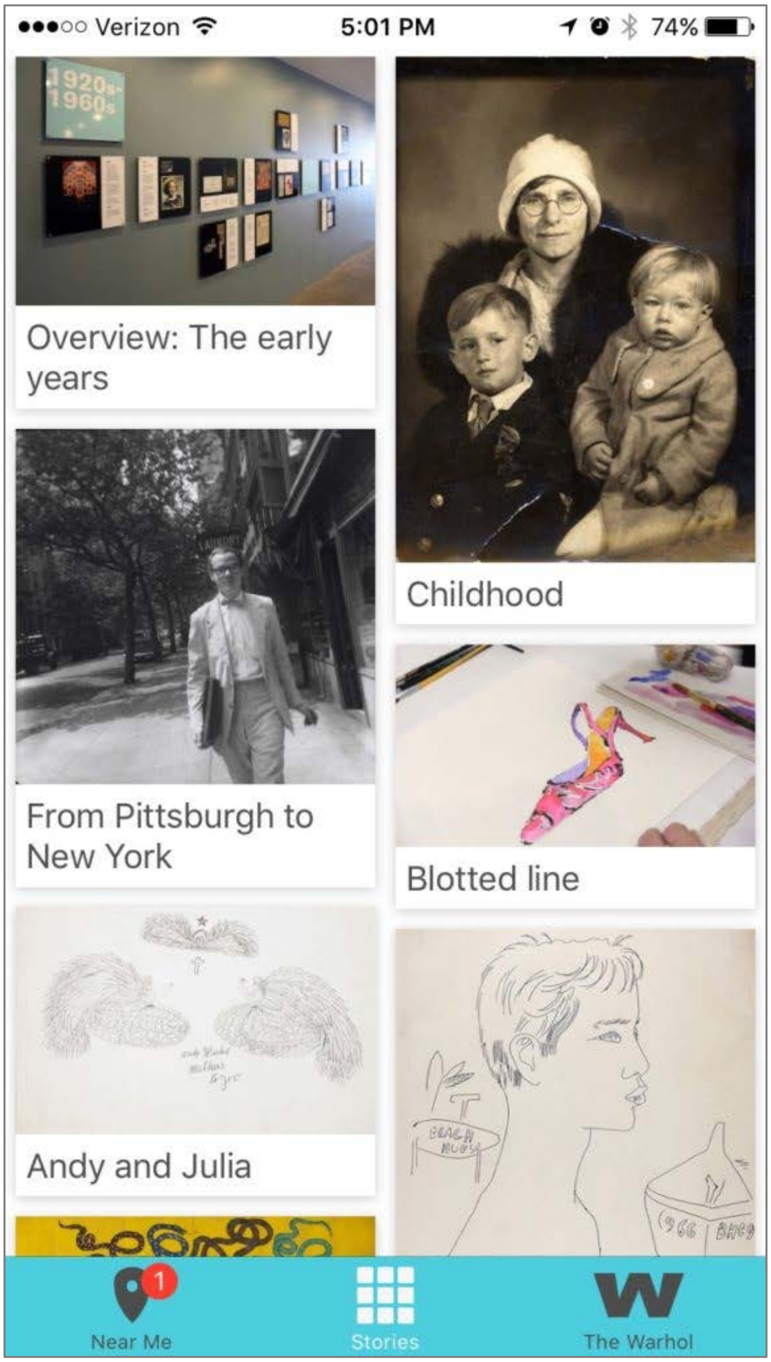

Figure 3 - Screenshot of The Warhol *Out Loud*, showing different content areas.

Tactile Reproductions

Touch is likely the sensory modality that is most underutilized in art museums. However, when storytelling and teaching in various disciplines incorporate different modalities — touch, sound, movement — comprehension and memory retention are enhanced for all. Many visitors to the museum, with and without disabilities, enjoy engaging artwork with their hands and their minds. These embodied, multisensory encounters bring all visitors closer to the art.

Helen Keller wrote in 1932:

> Few people who see realize how many and how great are the marvels of touch. Blinded by their eyes, they never stop to think how vital the sense of touch is in all the processes of their physical development, what a potent ally it is in all the activities of life… All the time I pity those who look at things with their hands in their pockets and do not take the trouble to explore the delights of touch or understand how it ministers to their growth, strength and mental balance.

As part of developing *Out Loud*, The Warhol decided to invest in permanent tactile reproductions of artworks in its collection galleries. The museum now features 14 tactile reproductions of artworks from The Warhol's collection, including adaptations of drawings, paintings, prints, sculpture, film stills, and even wallpaper. The museum collaborated with David Whitewolf of Tactile Reproductions, LLC to create the panels. Each one is based on a high-resolution scan of an artwork in The Warhol's collection. The pieces are made of acetal, a durable and hygienic thermoplastic, using a computer numerical controlled (CNC) router to etch digital files — etching a single piece can require up to 80 hours of machine time.

Educators and curators selected artworks from each floor of the museum's permanent collection galleries. The objects were chosen to represent significant series or stages in Warhol's artistic development — an example of his early commercial illustration, an intimate 1950's portrait of a reclining male, a Campbell's soup can, portraits of icons like Jackie Kennedy, Mick Jagger, Warhol’s mother Julia, and even wallpaper featuring the repeated hand-drawn image of Chairman Mao’s face. Andy Warhol was an artist who famously worked in series, appropriating and repeating iconic images again and again in distinct compositions and color combinations. Even as individual objects in The Warhol’s collection rotate on and off view in the galleries, the tactiles are representative of signature series and bodies of work, making them an evergreen addition to the visitor experience.

Figure 4 - A visitor touches a tactile reproduction of an artwork in The Warhol's collection, 2017. Photo by Shannon Thompson.

Refining the Approach

Like every step of the development process, creating the tactiles also required an iterative, experimental approach. Initially, The Warhol education department experimented with 3D-printed versions of 2D artworks. The lightweight plastic reproductions were useful in the galleries, but they were limited in size and some details were lost or impossible to reproduce well at a small scale. Using a subtractive process in which a CNC router etched away at material to imprint a textured design, it was possible to create larger reproductions. The project team experimented with numerous substrates, from lightweight foam to painted plywood, testing the samples with user/experts with visual impairments and comparing durability, detail, and overall quality of feeling. Finally, they arrived at acetal, a durable thermoplastic used for fabricating items like cutting boards. The dense plastic surface was able to register a high level of information, felt pleasing to the touch, could stand up to significant handling and cleaning without getting damaged, and had antibacterial properties.

In a 2016 interview with educator Leah Morelli, fabricator David Whitewolf of Tactile Reproductions, LLC., described his process:

> The primary purpose of a tactile reproduction is to make the visual information created by the artist accessible to a patron who cannot experience it visually. Because of this, we've taken the approach of providing as much of that information as possible to the patron with limited modification. In other words, it is important to us that our tactile reproductions do not add information to the works. Rather, we make every attempt to provide an accurate experience by simply differentiating one feature from another. After all, no one knows what the back of Mona Lisa's head looks like, so we don't make any claims like that in our reproductions. (Morelli, 2016)

Accessible Content

Many tactile diagrams use simplified forms and a vocabulary of different textures to communicate visual information and make it comprehensible through touch. Ironically, tactile diagrams that look the most impressive visually can be some of the hardest to understand with touch alone. This is because of how the sense of touch is interpreted. The same metaphors, patterns, and idioms that comprise a common visual language do not directly translate when being felt. This is why good tactile diagrams use the aforementioned simplified forms and special patterns to enhance comprehension.

These best practices, though they are highly appropriate for diagrams, do not support an unbiased translation of an artist's aesthetic decisions about size, shape, depth, orientation, and much more. This is why visual descriptions and guided tactile descriptions are so critical when trying to understand the tactile reproductions in this project.

It is important to keep in mind that our approach is not to simplify the art, but rather to augment the visual information as much as possible when it is being transformed into the tactile domain. This way, with appropriate context provided by visual and guided tactile descriptions, the visitor is able to feel as close to an exact reproduction as we could conceive.

Visual Descriptions

In developing *Out Loud*, the project team decided to offer a visual description for every object discussed on the audio guide, ensuring that the entirety of the content would be accessible to a user who is blind or has low vision.

Visual descriptions are rooted in the context that the recipient is unable to see the subject of the description. This could be for a variety of reasons, including a difference in the ability of the recipient to see the subject of the description, the recipient simply being remote, such as via a telephone call and much more. Whatever the impetus for the description, visual descriptions have the singular goal of establishing an accurate representation of whatever is being described in the mind of the recipient based on the description alone.

Visual descriptions are critical in the cultural sector. They can be found in mobile apps, on websites, during in-person tours, as part of audio guides, and much more. A description alone, however, does not often facilitate as deep a connection or as nuanced an understanding as vision does. This is why tactile reproductions were chosen on this project. By being multisensory, they can drastically increase the immersive qualities of the experience for the visitor.

As much as visual descriptions are rooted in the context that the recipient can't see the object being described, guided tactile descriptions are rooted in the context the recipient is actively touching the object of description. Because touching the original works was not an option, nor would it even offer much useful information, we chose to provide tactile reproductions in this project.

The guided tactile descriptions invite the visitor to touch the reproduction, to begin at a common starting point, and to join the describer on a tour of the tactile piece. In fact, in some domains, these guided tactile descriptions are referred to as tactile tours. During the guided tactile description, the mapping of various textures are explained: for example, metaphors like “polished concrete” are used to describe a texture the visitor may be feeling. The guided tactile description also discusses the salient visual details in the region being explored, thereby helping build that mental model of the work and hopefully making it easier for the visitor to map what they are touching to that mental model.

At the end of the guided tactile description, the visitor is equipped to understand the various things they may feel while exploring the piece further. Some visitors may choose not to explore further whereas others may spend far more time with a piece of interest. This is exactly the same for sighted visitors at an art museum who may choose to dwell for an extended period of time with one work, but spend far less time with others. This opportunity to choose is at the very heart of following an inclusive design methodology.

Building a Brillo Box

Working through the process, the team grew excited about the potential of the tactile medium to interpret different artworks for visitors to explore. They decided to create a 3D replica of one of Warhol’s Brillo Box sculptures. In the mid-1960s, Warhol carried his consumer-product imagery into the realm of sculpture. Calling to mind a factory assembly line, Warhol employed carpenters to construct numerous plywood boxes identical in size and shape to supermarket cartons. With his assistants he painted and silkscreened the boxes with different consumer product logos: Kellogg’s corn flakes, Brillo soap pads, Mott’s apple juice, Del Monte peaches, and Heinz ketchup. The finished sculptures were virtually indistinguishable from their cardboard supermarket counterparts. These controversial objects infuriated critics and collectors, and prompted many to question the very nature of art itself.

To create a touchable replica of Warhol's Brillo box sculpture, a high-resolution scan and raised-surface diagram of each face of the original artwork was completed using the CNC router. The resulting tactile reproductions of each surface were assembled into a box using an internal metal armature, and the box was mounted on a rotating platform to give visitors easy access to each of its sides. The accompanying tactile descriptions on the guide describe each surface of the box — as each side of the box was silkscreened by hand, there are subtle variations on every face.

When the tactile replica was introduced, it was immediately popular with visitors of all ages and abilities, who were drawn to it and highly engaged with exploring and manipulating the reproduction. Feeling each unique surface of the piece provides a distinct and more comprehensive experience from simply looking, in which viewers are limited to a single perspective.

Evaluation

In addition to eliciting ongoing feedback from user/experts throughout the development process, after launching *Out Loud* the museum's digital engagement team spearheaded an evaluation that targeted sighted visitors to the museum. They collected data from Google Analytics, pen-and-paper surveys that were administered to museum visitors after they borrowed audio guides at the museum, user interviews, and usability tests.

While *Out Loud* was designed with users who are blind or have low vision in mind, the vast majority of visitors to The Warhol are sighted, so it was also important to gauge their satisfaction with the app. Users surveyed in the evaluation enjoyed the diversity of content — they appreciated hearing from different voices and having a larger number of chapters that were shorter in length. Some comments focused on the potential for improving audio quality and consistency.

Understandably, the visual descriptions and guided tactile experiences were among the content sighted visitors were least likely to listen to in their entirety (most listened to a portion of the clip, but did not continue through to the end).

Participants in user interviews, usability tests, and surveys had mixed feelings about the visual descriptions — the evaluator received approximately as many comments indicating that they found the descriptions interesting and engaging as they did comments indicating that they were boring or unnecessary.

Feedback surrounding the tactiles and guided tactile experiences, however, was more consistently positive. We received a number of comments about the tactile installation being “interesting,” and one participant indicated that she had “never seen anything like [the tactiles] in a museum before.” Most respondents were unaware that content such as the visual descriptions and tactiles were created as a part of an accessibility initiative. When they found out about The Warhol’s accessibility initiative, feedback was overwhelmingly positive, and participants were interested in hearing more information about what the museum was doing to make Warhol’s art more accessible to visitors who are blind or have low vision. One participant said that the tactiles were still interesting to him as a sighted visitor because “it allows you to use another one of your senses to experience the art,” adding another layer of depth to a visitor’s interaction with the works in the galleries (Pallotti, 2017).

As we continue development of the next iteration of *Out Loud*, the focus will be on expanding coverage, improving beacon functionality and precision, producing additional audio content with better quality/consistency, and continuing to make the app’s user interface as intuitive as possible.

Looking to the Future

In 2017 The Warhol received a Gold Muse award from the American Alliance of Museums (AAM) Media and Technology Committee for *Out Loud*. In their comments on the project, the judges praised the app for its inclusive design:

> As a shining example of universal design, *The Warhol: Out Loud* is a beacon in the museum technology sector and beyond... In order to support multiple modes of engagement, the app presents verbal descriptions of artworks and content, and while these features provide accessibility to visitors who are blind or have low vision, they also provide a deeper level of guided interaction for visitors with full sight, providing a strong example of universal design. (AAM, 2017)

In addition, the app's open source code has been adopted by other museums internationally, and the project has been featured in numerous media platforms, from the *New York Times* and *Smithsonian Magazine* to *Geekwire* and *Lonely Planet*. Our commitment to accessibility has sparked new collaborations and has helped raise the bar for universal design in cultural institutions in Pittsburgh and beyond.

The Andy Warhol Museum has engaged in an iterative process to create welcoming museum experiences for audiences with a range of abilities, and will continue to expand and build on these efforts. Like Warhol himself was, their process has been collaborative, engaged with new technology, inclusive, and experimental. And, like Warhol, the museum staff are committed to continuing to innovate, push boundaries, and challenge conventions to reimagine the ways we experience art.

Acknowledgements

The development of *Out Loud* at The Andy Warhol Museum was generously supported by Allegheny Regional Asset District, The Edith L. Trees Charitable Trust, and the FISA Foundation in honor of Dr. Mary Margaret Kimmel.

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Inclusive Digital Interactives

Best Practices + Research

Chapter 11

Work in Progress: A Case Study from the Tenement Museum on Personalization for Staff Accessibility and Its Wider Effect

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Smithsonian | Institute for Human Centered Design | MuseWeb

September 2020

Introduction

Much of the literature on museum interactives and access focuses on the visitor experience. Yet museum staff, too, are part of the equation. This article details one specific technology used at the Tenement Museum to tell the stories of immigrants, migrants, and refugees, and describes the process of making this technology easy to operate for staff with disabilities. Through this process, the museum learned from staff experiences and experimentation, and developed best practices for this work. The insights gained through this work benefited the museum as a whole, improving interpretation for both staff and audiences.

The Tenement Museum was founded in 1988 by Ruth Abram and Anita Jacobson in a building that had been untouched since 1935. They turned it into an historic site highlighting the stories of immigrants to New York. Over its 30 years in operation, the Tenement Museum has grown in the stories it tells as well as the tools that it uses to tell those stories. The Tenement Museum operates differently than a majority of institutions where people can explore on their own. The only way to visit the museum is by taking a guided tour, led by a member of the museum's paid staff, referred to as an educator. Each educator shapes their tour using museum resources to tell the stories of the real people who lived in our two preserved historic buildings, 97 and 103 Orchard Street, New York City.

Over the past 10 years, the museum has developed and incorporated technological tools to help tell these stories. While a few of these interactives offer opportunities for visitors to engage in self-directed learning, most of this technology is operated by educators in the course of their tour. Therefore, the process of finding solutions that fit our unique structure includes ensuring that these are easily operable by our diverse educator corps of approximately seventy.

Accessibility for Staff Using Digital Tools

The Tenement Museum strives to forge connections between its visitors, the stories of the immigrants, migrants, and refugees that lived in the building, and the creation of an American identity. This work is primarily done through tours led by the educators. Their storytelling work is what allows visitors to forge the connections between their experience and the experiences of the former residents of Orchard Street. Each tour is centered around a different theme and tells the stories of real families who lived in our buildings. Educators are given content about each family — their lives as well as historical context. They are then tasked with creating a story to relay to visitors in the apartment. In the recreated family apartment, they also have at their disposal relevant primary source documents, oral history clips, period-appropriate handling objects, and historical photographs, all of which they can use to construct their narrative. An educator will use different tools depending on the group they are leading. Crafting these tours, as well as managing and responding to a group of visitors, is a delicate task, and there are many scenarios that can make it complicated. In our conversation-based approach, educators walk a fine line to maintain their authority during a tour. Being comfortable in their surroundings, with everything at their disposal to tell the story, is an important part of that balance.

The education department often works collaboratively with other departments in creating and refining the resources that are used on tours, including the technological aspects. In my role as Education Specialist for Access at the museum I oversee accessibility efforts for both visitors and staff. While a lot of this work is general, I also work with specific educators to ensure that they have the tools and support to do their jobs. One of the educators I work with is Daryl Hamilton. When Hamilton joined the museum staff in 2009, he was the first educator with an apparent disability. Hamilton lives with glaucoma, which has a large impact on his vision. Hamilton is a well-respected educator. His long tenure at the museum and his singular skill for fostering conversation and dialogue on his tours means that he is often sought out for advice from both his fellow educators and full-time staff at the education department. His skill, professionalism, and passion for the work make him an invaluable member of the team. He and I collaborate to create reasonable accommodations that ensure he is able to work comfortably and to the best of his ability. This often revolves around printed material and visual details involved with the job. As the amount and type of technology used on tours at the museum has expanded, our efforts now frequently include the successful operation of technology. After many years of working together we have some tried-and-true methods of effectively brainstorming reasonable accommodations when it comes to technology. Hamilton and I first review the technology in question. Together we operate it and Hamilton identifies barriers. We then discuss possible solutions. From that conversation Hamilton indicates which solution is the most ideal and I work to execute it. We reconvene when the solution is operational to practice and refine it.

We applied this method to create an accessible system for playing oral history recordings. The creation of a workable and reliable system of operation for Hamilton took effort as well as experiments with technology but ultimately resulted in a system that benefited all staff. The process also produced a set of best practices that were applied to more recently installed technologies and quickly resulted in accessible solutions.

Process

The Tenement Museum has been using oral history recordings in our *Hard Times* tour for most of the time the tour has been in existence. These evocative clips feature former resident Josephine Baldizzi recalling her childhood home at 97 Orchard Street — one of the few oral histories the Tenement Museum has from 97 Orchard Street residents. Over the past five years, the delivery method for this oral history has changed many times as technology has evolved. With each change the museum worked with Hamilton to create reasonable accommodations.

When Hamilton first started working at the Tenement Museum, Baldizzi's audio was played for visitors using a CD player. A remote control was added as an accommodation so that educators did not have to crouch down to press play on the CD player. Colored stickers were also placed on the remote and the CD player to make the small buttons easier to identify. When this technology was first put in the space, it was the only solution available. The system itself was not ideal. As the technology aged it became less reliable and more difficult to fix. It was not an ideal set up for Hamilton, who remembers: “I was never able to develop a confidence in it that that would work for me every time” (2019). The system did not leave room for creative alternative possibilities.

In 2013, the IT and education departments at our museum began looking for alternatives to the CD player because it was no longer consistently reliable. To update the system, they decided to install an iPod Touch and speaker. The museum has often used re-purposed and enhanced low-budget technology options to present media. From the beginning, Hamilton and I worked with the IT department to ensure that making this new technology accessible was part of the process. Due to his vision, Hamilton encounters difficulties with touchscreen because they require precision. When looking at a lit screen, Hamilton’s vision distorts, causing things to bleed together. Hamilton and I were able to work with the iPod before it became part of the exhibit to identify solutions. We brainstormed and tried a number of methods to make it accessible for him and feasible for the space both before and after it was installed in the Baldizzi apartment. We used “guided access,” an option in the iOS operating system which restricts what can be activated on the screen. We also implemented bump dots, which are raised stickers created for wayfinding. There are countless uses for bump dots that can make life easier for people who are blind or have low vision. The San Francisco LightHouse’s website describes them in the following way:

> Bump dots are a low-profile, low-cost way to strategically make your home or office space more accessible and increase your effectiveness and independence. What is a bump dot, you ask? These small, raised dots come in all shapes, sizes and textures and can be put on everything from home appliances to school work. It may seem simple, but it’ll save you from selecting the wrong wash cycle or always playing the squint-and-guess game, so you can spend more time and energy on the important stuff. (https://lighthouse-sf.org/2017/07/26/better-living-through-stickers-7-ways-to-use-bump-dots-in-daily-life/)

For this project we placed bump dots on the screen and sides of the device (Figure 1). We chose to use bump dots in this context because they had been used in other places in the museum with great success. Before using them for this project we placed them on adjustable light switches to indicate the appropriate level of light needed in the room. Placing bump dots in these specific locations on and near the screen made it so that Hamilton could use a tactile indicator to navigate to a specific area on the touchscreen. This significantly increased his chances of selecting the correct area to trigger the recording. Without the bump dots this would have been much less accurate. Lastly, we tried to circumvent the touchscreen entirely with a remote. To make this option accessible we replaced the buttons which had small, low-contrast markings with enlarged color-coded versions (Figure 2). However, none of these solutions provided reliable access and did not consistently function when used by 13 or more educators during the course of daily museum operation. The CD player acted as a backup method throughout the process. Having a backup gave Hamilton a sense of security and confidence as we experimented, and also provided an alternative when the iPod malfunctioned. The most reliable iteration of the iPod setup was created with a mobile app called QuikTracks that was created so users can easily select tracks at the touch of a large button, used in concert with bump dots, guided access, and a longer cord (Figure 3). This made the technology both workable for Hamilton and more robust for a full schedule of tours and educators with varying technological experience.

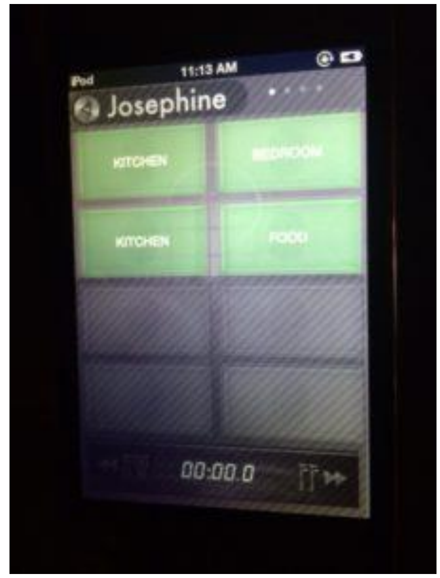

Figure 1 (left): iPod Touch with bump dots and guided access. Courtesy of Ellysheva Bunge-Zeira
Figure 2 (center): Bose speaker remote with enhanced buttons. Courtesy of Ellysheva Bunge-Zeira.
Figure 3 (right): QuikTraks playlist for Josephine's oral history. Courtesy of Ellysheva Bunge-Zeira

From start to finish, finding a reliable iPod solution that worked dependably for all staff and specifically for Hamilton took a year of trial and error. This iterative process is a core approach to new content and installations at the museum. Miriam Bader documented this in *Exhibition* (2015) regarding our Shop Life exhibit that opened in 2012. While the iterative process of improving the technology to present Josephine Baldizzi's oral history is on a much smaller scale than the process of creating a new tour, the method still applied. This process included not just us but other representatives from the education and the IT departments. This approach to the work helped build a case for better options. Another part of this process that proved crucial was practice. With each new iteration, Hamilton was able to have dedicated time to practice and acclimate as a facet of his reasonable accommodation. This approach was important to Hamilton: "That trial and error helped to build my confidence. If something didn't work, I still felt we would find a solution."

The method described above proved to be the most successful and was in place for three years. During that time there were still issues but it was reliable enough that we removed the CD player and brought the same system to other apartments that also included oral histories.

In 2016 the Tenement Museum was in the process of both creating a new exhibit with a digital component and revising our Irish Outsiders tour, which also included many digital sources. Learning about new technologies available for the upcoming exhibit prompted us to include a technology upgrade in the revision of Irish Outsiders to improve the system in place and increase opportunities to share a variety of sources with visitors. Before the upgrade, we used a DVD with captioned videos of songs and images that helped educators tell the story of the Irish immigrant experience. Educators would use a remote to navigate between the different songs. At first, this system, like the iPod in other apartments, was unreliable, often malfunctioning. Additionally, it did not allow us to include sources that were not videos. Lastly, the system was challenging for Hamilton to operate: the remote had small buttons that were difficult to see even with modifications; the indicator that communicated what had been selected was too far away and there was no way to bring it closer because it was projected onto a screen. Due to these challenges Hamilton adapted his tour to be able to work any one of the available videos into his narrative.

The main change in the upgrade was, instead of playing a DVD using a PC as the driving mechanism the museum installed a Raspberry Pi, a tiny computer created by the Raspberry Pi Foundation. The Raspberry Pi is primarily an educational coding tool for students. They describe the Pi on their website in the following way:

> The Raspberry Pi is a low cost, credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. […] It's capable of doing everything you'd expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games. What's more, the Raspberry Pi has the ability to interact with the outside world, and has been used in a wide array of digital maker projects, from music machines and parent detectors to weather stations and tweeting birdhouses with infra-red cameras.
> (https://www.raspberrypi.org/help/what-%20is-a-raspberry-pi/)

A Raspberry Pi alone was not enough to create a solution that was reliable, with opportunities for diverse content, and accessible for staff. Because it was created to teach students how to code, the device itself doesn’t have a traditional operating system. While the Raspberry Pi can be used in myriad ways, you have to be able to write the code to do those things, making it complicated to program for individuals without a coding background. Part of the process was finding a program which let us create a solution that was uniquely tailored to our needs. Nick Capodice, our colleague in the education department, recommended this system for our purposes and found a program to execute what we needed.

> We wanted a program that could tie keystrokes on a keyboard to either a photograph or a movie. Most museums do this in 'kiosks.' […] But kiosks are very expensive and take companies to create. However, some generous soul in the Raspberry Pi community created an open source program called "Pi Presents” (https://pipresents.wordpress.com/) which allows just that.

Once the team had this program it took Capodice and the IT Department at the museum a month to get it working. To tailor it specifically to our needs not only did they have to load Pi Presents and our particular media files onto the Raspberry Pi, they also had to code the Raspberry Pi to ensure that its only function was to launch Pi Presents when turned on. While the coding process was complicated, it came with many benefits. Because there is no operating system, the Raspberry Pi will only do what you request. Other digital interactives in the museum run on desktop computers that update when they are connected to the internet but sometimes the updates cause problems with the underlying programming of the digital interactives. With the Raspberry Pi we were able to program it to do only what we needed. We connected our Raspberry Pi to a projector and a wireless keyboard. This allowed us to connect selected primary sources like pictures and songs (with captions) to specific keystrokes. During that portion of the tour an educator can call up whichever primary source best fits with their story and the interests of the visitors, allowing for personalization. This was extremely low cost, durable, and very easy to modify. Hamilton and many others on staff benefit from the high contrast and enlarged text we added to the keyboard. The use of a Raspberry Pi in this exhibit was so successful that the museum has since incorporated the same technology in many other exhibits.

Hamilton and I were part of the technology upgrade process for this exhibit as well. Once again, we were able to work and practice with the new technology before it was installed in the space. Compared to the other technological solutions employed, the practice process for the Raspberry Pi setup was extremely easy. Capodice had witnessed all of the work that went into making the iPod system accessible so when searching for a better alternative, he considered accessibility upfront. As he saw how simple this system was to make accessible for Hamilton he shared his plans with us. Reflecting on the process, Capodice summarized it in the following way:

> Museums often hire tech companies to create things, but if you have flexible IT staff in-house, you can take the time and save money by figuring out what your individual institution really truly needs and make that thing. […] You need two things: a person on staff who advocates for employees who need access support, and a tech-savvy person who will be flexible and listen to that person to come up with a solution.

Around a year later, when the iPod in the Baldizzi apartment ran into technical problems, it was replaced with a Raspberry Pi. Given our previous experience with the system it took a matter of minutes for Hamilton to practice, acclimate to, and feel comfortable using the new system. Finding an easy-to-use and universally accessible system was a cause for celebration for Hamilton:

> I was overwhelmed. As soon as I saw the Raspberry Pi, I knew that this was our solution. We finally reached a point in our journey where we were seeing the successful fruit of all of those labors. This is what we had been working towards.

Almost all audio sources shared within the museum's exhibits today are driven by Raspberry Pis. The entire process to find an ideal accessible solution to sharing audio sources was challenging but it produced best practices that have been valuable in guiding technological change at the museum.

Best Practices

The three practices that have had the most impact and continue to support creating usable technology for educators to operate include tactile wayfinding, practice, and using an iterative process in the development of digital technologies.

Tactile Wayfinding

One of our most useful strategies was to create tactile wayfinding clues with bump dots. Long before our experiments with emerging technology, the Tenement Museum used bump dots and other customizable forms of raised features to create accessible experiences for both visitors and staff. They had not, however, been used previously with digital technology. Bump dots proved to be crucial to making the iPod Touch accessible for staff. In different iterations we placed bump dots both on the sides and screen of the device next to areas that Hamilton needed to touch in order to operate the iPod. These tools created tactile frames of reference, giving Hamilton more concrete support in finding a specific area on the screen. In 2017 the museum created *Under One Roof*, a new exhibit that used more oral history and digital technology than any other tour in the museum's history. Including bump dots and other tactile cues we already had experience with ensured that the overall process and acclimation to these new systems happened efficiently and rapidly.

Practice and the Iterative Process

The complicated reality of operating a touchscreen for someone who has low vision demonstrated that taking time to practice and evaluate the method of operating the digital technology is key to finding both success and comfort. Practicing with another stakeholder and working together in an iterative process to develop the best method is crucial. It also ensures that staff will be comfortable operating the technology for visitors. Since working with the iPod Touch, each time a new iteration of digital technology has been introduced into the museum, Hamilton and I schedule time to make alterations as a team and practice using it in advance of his first time operating it for the public. This has exponentially increased Hamilton's level of comfort with digital technology both within the working environment and in everyday life. Understanding that space must be set aside for practice and the iterative process has made each new integration more seamless.

Conclusions

Beyond illuminating best practices, the process of creating accessible digital interactives for staff has highlighted two crucial and connected ideas that allowed for the success of our project. We believe that these two tenets are essential:

Personalized Solutions

In the world of accessibility, efforts are most often made to accommodate majorities. Considerations for individuals with unique and/or multiple needs are not frequently included in design processes. However, when these unique needs are incorporated, solutions can provide greater access across the board. In Rothberg and Reich's 2014 article "Making Museum Exhibits Accessible for All: Approaches to Multi-Modal Exhibit Personalization" they outline this idea of personalization:

> Personalization for accessibility creates another alternative, beyond the application of universal design principles, to enable more inclusivity while enhancing the quality of exhibition design. This new design paradigm will allow engagement with multiple modalities, encourage visitors to explore exhibits, and take advantage of new ways of imagining flexible, accessible exhibits. Personalization can be thought of as taking Universal Design for Learning (UDL) ideas one step further. If visitors communicate their specific needs for interacting with a museum exhibit, a digital exhibit can respond flexibly to provide an experience tuned to each visitor.

While this idea of personalization was developed with visitors in mind, the personalization principle was also crucial to our success in implementing new tour experiences for staff. Taking Hamilton's personal accessibility needs into account and finding tools and supports to ensure those needs were met eventually resulted in the creation of a durable staff-operated interactive that worked across a wide spectrum of needs.

Inclusion of People with Disabilities in the Museum Workforce

If Hamilton had not been working at the Tenement Museum our creative and sustainable solution might never have come to fruition. Ensuring a diverse employee population and ensuring the input of those employees in the creation of any project is essential. As communicated on a much larger scale in Ginley (2013), including people with disabilities in the museum workforce creates impactful and lasting change. Within this audio project, Hamilton and I experienced a similar impact. The results of our work have been employed museum-wide in nine different iterations across all audio-related content, improving ease of operation, stability, reliability, and access to multimedia content for all staff and visitors.

Since Hamilton was hired, the Tenement Museum has continued to employ more individuals with disabilities. We are now using the approach outlined above to investigate and expand the accessibility of our internal digital learning environment and wider staff experience. Hamilton sees this impact beyond the digital space: "Conversations about access are now part of the museum norm" (2019). This audio project was part of a culture shift at the museum which set the foundation for further growth.

Acknowledgements

This case study was supported by the Tenement Museum. We thank our colleagues at the museum who supported us, made the process and results possible, and fostered lasting solutions.

We are grateful to Nick Capodice for his ideas and creativity in creating these digital solutions as well as his comments on this essay. We would also like to thank Michelle Moon, Chief Programs Officer and Alisa Martin, Vice President Educational Operations, at the Tenement Museum, and Miriam Bader for their comments which improved this essay.

Lastly, we would like to acknowledge present and future Tenement Museum employees who we know will continue to improve accessibility at the Museum.

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Inclusive Digital Interactives

Best Practices + Research

Chapter 12

Accessibility First: Universal Design and the Freer Thinking App

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September 2020

Introduction

In March 2016, with 18 months until the grand reopening of the Smithsonian's Freer Gallery of Art and Arthur M. Sackler Gallery (now known as the National Museum of Asian Art), Scott Brewer, co-founder of Art Processors, and Courtney O'Callaghan, Chief Digital Officer at the Freer and Sackler, met to discuss a mobile app. The result, when the doors reopened with a fanfare of Asian drummers and dancers, was a multilingual, inclusive digital experience framed by the principles of universal design (UD), crafted with the invaluable guidance of an enthusiastic community of museum-lovers and usability testers with disabilities.

In this essay, we will cover three main topics:

- We will provide an overview of the basics of design theory with a focus on both universal and accessible design, demonstrating how these practices informed every aspect of ideation, design, development, and implementation of the Freer Thinking app.
- We will explore the greatest challenge we encountered while forging our accessible application; the alignment of internal stakeholders, while providing a blueprint of our strategy to gain support for making accessible philosophy core to the content and software design, rather than a token feature tacked on at the end.
- We will share resources that illuminate a wide range of design theory and are useful for encouraging internal staff alignment; creating an appreciation of the importance of design that respects the needs of a wide range of users, including ones your collaborators may never have considered.

Rethinking Accessibility and Inclusion

Developers and designers of visitor-centered interactives are too often faced with well-intentioned clients who share an honest objective to provide audience-wide inclusion and general accessibility, without understanding what reaching those ambitious goals truly entails. The mantra of inclusion can quickly devolve into merely a mandate to cram every piece of available audience-appropriate content into a single, cluttered experience. Accessibility simply becomes a final legal hurdle to be overcome; a list of minimal quality assurance standards to check off at the end.

What happens if we instead infuse all the elements of design, development, and implementation of our vision of inclusion with the guiding principle of *users first*? What if we (re)define accessibility as providing equitable access while enabling active participation by the widest array of people? What if we harvest the tools and concepts cultivated by paradigms like universal design, design theory, accessible design, design for all, and human-centered design? If we embrace all these things with care and dedication, accessibility and inclusion become inevitable.

We must, as a community, strive to build experiences based on the belief that every human has the right to access environments, products, and services to the greatest extent possible. As creators, we have an obligation to respect and promote the application of these rights (Global, 2012).

In developing the Freer Thinking App, we defined accessibility as maximizing access to the content, “democratizing the experience," by anticipating the variety of desires and challenges users brings to our content.

We Need an App

“Framing the right problem is the only way to create the right solution” (Stanford, 2010).

Before the Freer Thinking app was a definable project, even before Courtney’s tenure as the museum’s first Chief Digital Officer began, the staff had an idea. It could be summed up in the ambitious yet misguided dream that “an app will solve all of our problems.” Those of you who have been in this sector for a while will assuredly have participated in a variant of this conversation with your institution’s management. It starts with decision-makers seeing an app as a magical instrument that will increase visitorship, foster engagement, replace printed visitor materials, share multimedia content, gather emails, collect donations, make us appear future-focused, and more than likely, all of the above (Grobart, 2011).

By the time the Freer closed for renovations in January 2016, an app was at the top of everyone's mind for the reopening. It was decided that four groups of museum staff would revisit the various ideas that had been floating around for years and present a revised concept to the entire staff. Not surprisingly, each group had vastly different ideas of what the app should offer, how it should function, who should create content, and how it would increase visitor satisfaction. It rapidly became apparent that the decision-makers would never agree on a single app idea.

The process clearly put the cart before the horse; the museum was focused on a bewildering array of specific solutions but had failed to define the specific problem the app was to solve. It was clear we needed to back up and get agreement around that problem and ensure everyone was aligned with the bedrock principles of empathy for the visitor and true inclusivity. We then just had to reconfigure our cart/horse paradigm and develop a consensus about our ultimate destination. And we had to do this with an agreed-upon framework that limited second-guessing and constant backtracking. We needed a solid methodology to guide our interactions.

Design Tools and Usage

The design methods movement has been evolving and growing in influence for more than half a century, since its introduction at the *Conference on Design Methods* held in 1962 (Jones and Thornley, 1963). From that seminal point forward, we have been provided with countless methodologies, frameworks, and equations, all designed to help allay the headache of defining rules by which our projects can be shaped. While methodologies and frameworks have many benefits, we will focus on their ability to draw disparate teams together while enabling confident decision-making on project processes that offer the greatest impact. By reinforcing a shared sense of confidence in the decisions made at the macro view of the project, design tools free teams to spend their precious time on the micro view.

But which methodology do you follow? The challenge for designers and developers is not simply to implement an existing methodology but to customize the implementation to the unique problems at hand in the most effective and efficient manner. This requires a constantly switching from macro to micro project views, from known to unknown technological states, all while under the pressures of time and budget. Given the unique constraints of each project, it is almost impossible to stick to one defined methodology. We must borrow from known examples: applying the right cure for the ailment being faced (or, when required, coming up with our own treatment and applying that)! In the case of Freer Thinking, before choosing the project methodology, we first had to solve the problem of alignments; we had to arrive on a consensus on the project as a whole.

Finding Common Ground with a Design Thinking-Centered Workshop

The challenges at this stage were clearly a misalignment of the stakeholders and lack of buy-in to a single creative vision that could potentially achieve all their respective desires (while fulfilling our underlying vision of centering accessibility in any solution). To overcome this challenge, we prescribed a structured workshop designed to create alignment and empathy among the stakeholders with the ultimate goal of organizing them around a singular cause.

We approached this with an open mind, accepting that it was even possible that an app was not in fact what the museum needed at all. To find out, we had to bring all the stakeholders together to share their cherished-and-resolute ideas in a safe space, using proven tools and an impartial moderator in order to emerge on the other side as a cohesive and effective team.

While the workshop format was customized to suit the museum's needs, it leaned heavily on the approach offered by design thinking. As defined by the Stanford d. School (2010), the methodology (or macro view) of design thinking consists of five stages: **empathize, define, ideate, prototype, and test.** The workshop was split into four key blocks spread over two days. Day One focused on empathy and creating empathy through alignment. Day Two primarily focused on ideation with time set aside for prototyping and testing. We hoped the workshops would lead to alignment around a central cause that would be used to drive all future decision-making.

The first step was drawing up a roster of those whose opinions and skills were necessary for signoff (the director), content (curators and educators), and implementation (editors and the digital team), with the understanding that these were the people who could derail a project they did not believe in. We settled on a group of 12 people. To minimize distractions and clearly define the project as a museum-wide priority, we blocked off two consecutive eight-hour days and brought in lunch.

Day One - Alignment and Empathy

The first day we used two-way knowledge sharing to build alignment between workshop participants and empathy between the needs of the museum and the visitor. Because of the group's varied experience with digital projects, we started with a series of case studies to introduce a broader understanding of museum-based mobile projects. In each study, we described the key phases of a project, some of the benefits, and many of the potential pitfalls. These concrete examples created a shared baseline of knowledge of how digital projects can fit or fail their audience. Diving into the key phases of a completed project gave each workshop member a better understanding of how important their participation was to overall success in a project of this scale, as each of their skills or positions were integral to a successful project.

We then moved on to creating visitor personas, our first deep dive into empathizing with the visitor. Using existing visitor data gathered in the year-long survey conducted before we closed for renovations, attendees each created a persona, giving a face to the statistics. We encouraged participants to create personas that actually matched our visitor profiles, including people of different races and nationalities than their own, people who spoke a language other than English, people with challenges such as mobility, hearing, and vision.

Next, each person wrote down all of their goals for the app and for the visitor, keeping the profiles in mind. We ended the day looking at the 60+ goals and each tried to sum them up in a single mission statement. By encouraging attendees to understand the app users, to voice their own goals for the project, and to craft a mission statement that incorporates the goals and personas, we began to align our ideas with our actual audience. This final exercise was designed to create a greater understanding of what the project meant to each participant. The goals would be used extensively in evaluating concepts on Day Two.

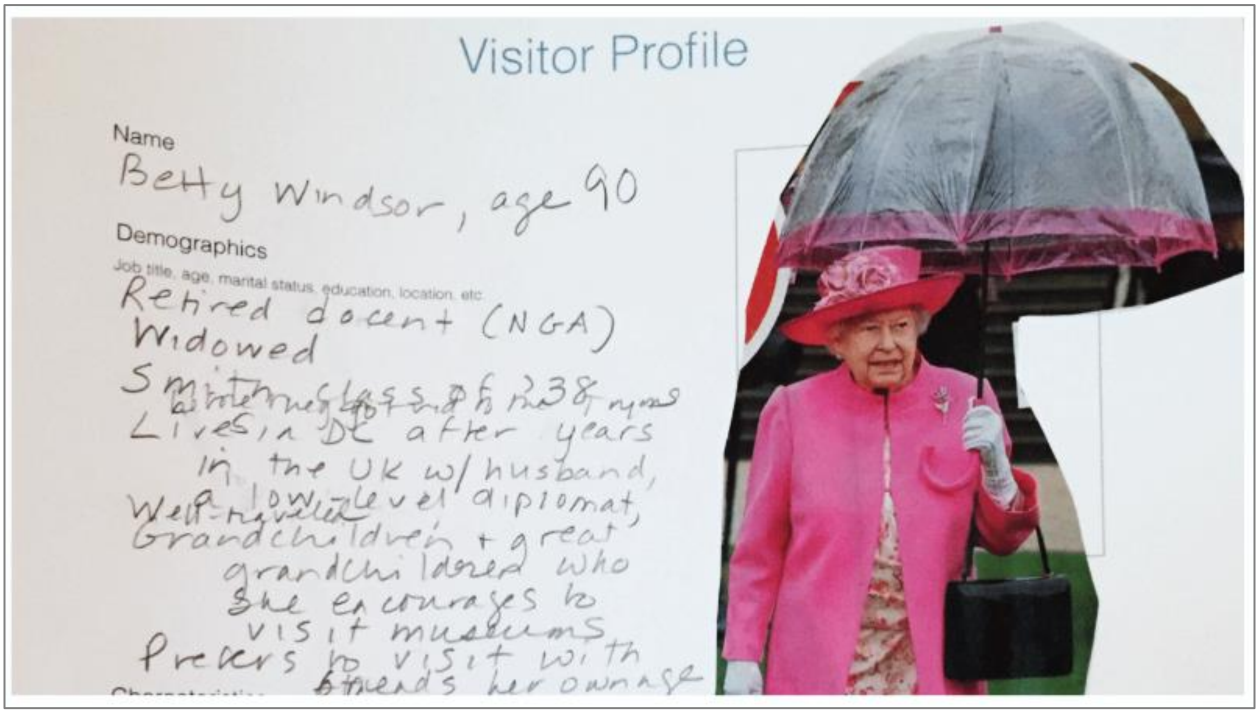

Figure 1 - Visitor Profile

Day One provided the group with an understanding of the importance of designing an experience that speaks directly to the visitor in a way that encompasses the voice of the institution and illuminates the expansive work involved in projects of this size. Getting attendees to write goals in their own words prior to working collaboratively (which would be undertaken on Day Two) was important to get a handle on where each person stood on their own before we attempted to align everyone behind a common concept.

Language about accessibility and inclusion was scattered throughout personas, goals and a few mission statements. One mission statement read, "The app's job is to make the museum (more) accessible through language, diversity of opinion, and depth." Goals included welcoming perspective, multiple (diverse) perspectives, languages, and sign language. Though the first day did not see accessibility or inclusion at the center, the seeds of it were there for us to work with on the second day.

Day Two - Ideation, Prototyping, and Testing

The goal for the second day of the workshop was to create an actual product. Though this seemed an impossible task before the workshop began, using design thinking we now had a shared understanding of and empathy towards our audience, a list of our goals, and a possible mission statement.

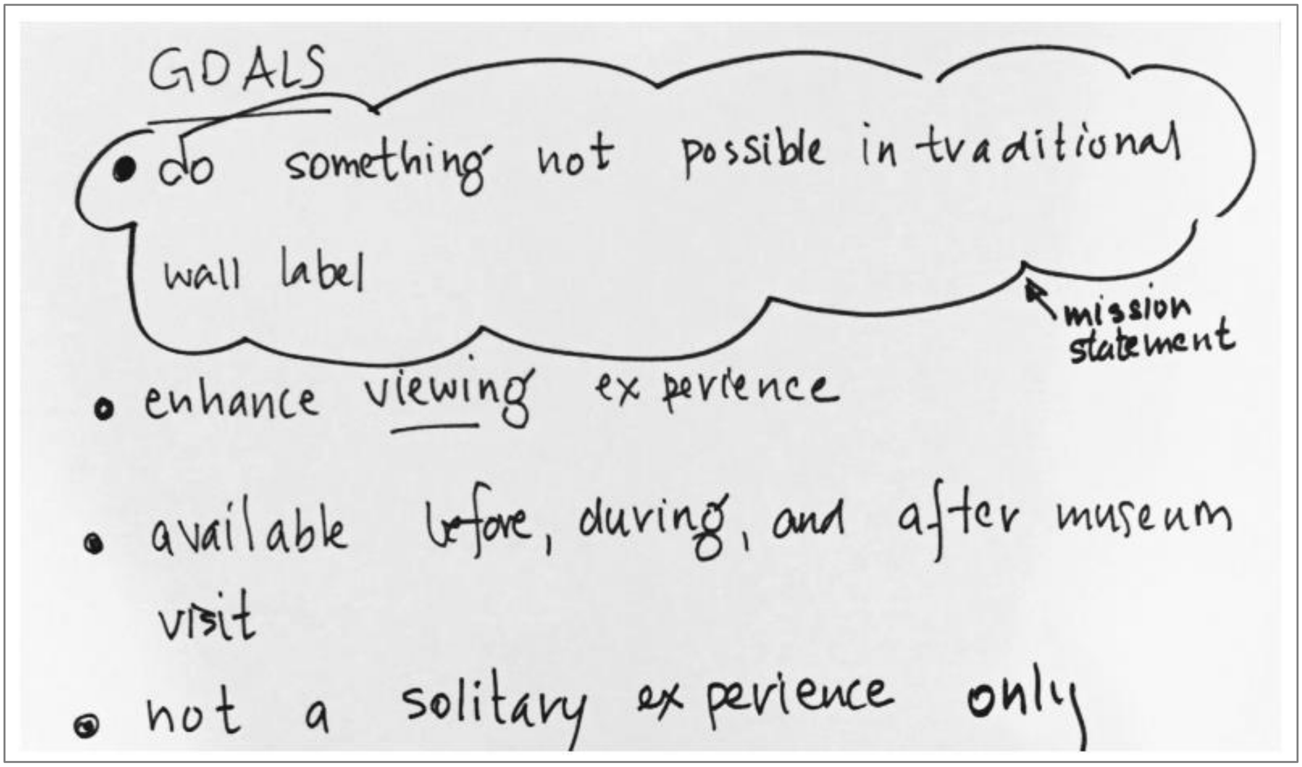

Figure 2 - Goals and Mission Statements

The first task of the day required attendees to ideate the experiences available within the app. The group was encouraged to pull as many ideas and experiences as they wanted from both the previous internal app workshops and the materials produced during Day One and write them on post-it notes. It was important to encourage participants to share ideas ranging from the traditional to outlandish, and remind everyone to *separate the generation of ideas from the evaluation of ideas* if they want to step beyond the obvious and inspire innovation (Stanford, 2010).

As a group, we then evaluated each of the 30+ notes and placed them on a value/feasibility matrix; together discussing why some ideas that sound great at first perhaps aren't the right fit for a mobile application experience. Using the ideas that fell into the high feasibility, high-value quadrant, we created a list of conceptual products and necessary functionalities. The group agreed on four possible concepts, and then, after discussing each, one rose up as a clear winner, with enthusiastic backing from the entire group.

Figure 3 - Value-Feasibility Matrix

Going into this workshop, no one had faith we would find common ground but at the end of Day Two, we had a roomful of believers. A design thinking methodology had saved the day. We had not only defined a product, we had also created alignment around accessibility as a central cause or vision to drive the project. Pulling out the matrix ideas of "multiple languages, sign language (or transcripts), children's content, personal and engaging, welcoming and inclusive, multiple perspectives, tailored experience," we had as a group agreed upon several definitions of what we meant by access (physical location, ability, language, age level, and visit style). We had also co-designed a high-level creative concept that took into account the concerns of staff and aligned with everyone's thinking.

We left the workshop with a mission to create greater access to the collection, the museum, and the stories it contained. To do this we had a product plan based around the central idea of a connected narrative, a themed tour that could be experienced in-house or as a podcast. These themed narratives would help illuminate the stories and connections that wove like invisible threads across the collection, that were currently only known to the curators, and our format would allow us to tell these stories to both onsite and offsite (digital) visitors. For those visitors who may not have the time, patience, or ability to follow these longer-form narratives through the galleries, we would create a set of more traditional, self-contained audio stops that could be accessed in an ad-hoc manner. The goals and ideas ranked highest by the group were clearly centered around a broad concept of accessibility: with the object and gallery highlights presented in multiple languages, as text, as highly polished podcast audio, and in a way that made both text and images accessible to people who are blind or visually impaired through the use of accessibility features on modern mobile phones. All of this, wrapped in a location-aware package that could automatically deliver content in the right location and a format amenable to the individual user.

Universal Design Interlude

In order to help us choose a project methodology around which to organize our development process, we reviewed our experiences during the workshop. We were looking for a methodology that we believed would provide us with speed and confidence in decision making. Universal design has served continually as a high-level guiding principle and met the criteria of forming excellent, well-thought-out guidelines with which we could assess our decisions in the project design. The seven guiding principles of universal design are both, broad enough to allow for high-level guidance on decision-making and narrow enough to make sure the focus remains on access and the inclusive nature of the project. The principles as defined by the *10 advocates* (the members of the team that defined the principles refer to themselves as advocates rather than authors) in the Center for Universal Design, The Principles of Universal Design, Version 2.0 (Connell, et al., 1997) can be stated as intended to create:

1. Equitable Use: The design is useful and marketable to people with diverse abilities.
2. Flexibility in Use: The design accommodates a wide range of individual preferences and abilities.

3. Simple and Intuitive Use: Use of the design is easy to understand regardless of the user's experience, knowledge, language skills or current concentration level.
4. Perceptible Information: The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.
5. Tolerance for Error: The design minimizes hazards and the adverse consequences of accidental or unintended actions.
6. Low Physical Effort: The design can be used efficiently and comfortably and with a minimum of fatigue.
7. Size and Space for Approach and Use: Appropriate size and space is provided for approach, reach, manipulation and use regardless of user's body size, posture, or mobility.

With these guidelines in place, we believed we could ensure any additional work would always be in support of creating an experience with the greatest possible accessibility. Of course, we did still have concerns around the speed of the project when faced with the need to launch the app in time for the firmly scheduled grand reopening ceremonies.

To prepare ourselves to overcome any impasses, we discussed how we could make rapid progress without negatively impacting the accessibility of the content. Every decision had to align itself with our broad definition of accessibility and inclusion, enabling active participation by the widest array of people. By combining project constraints (time, budget, technologies) with goals (access, leaving no one behind), we were able to craft a series of rules that took both into account in the design process. As a result of our continued desire for frameworks, we put together a decision workflow (also referred to as a decision tree) that gave us confidence in our decision-making with respect to both access and project success as defined by time and budget.

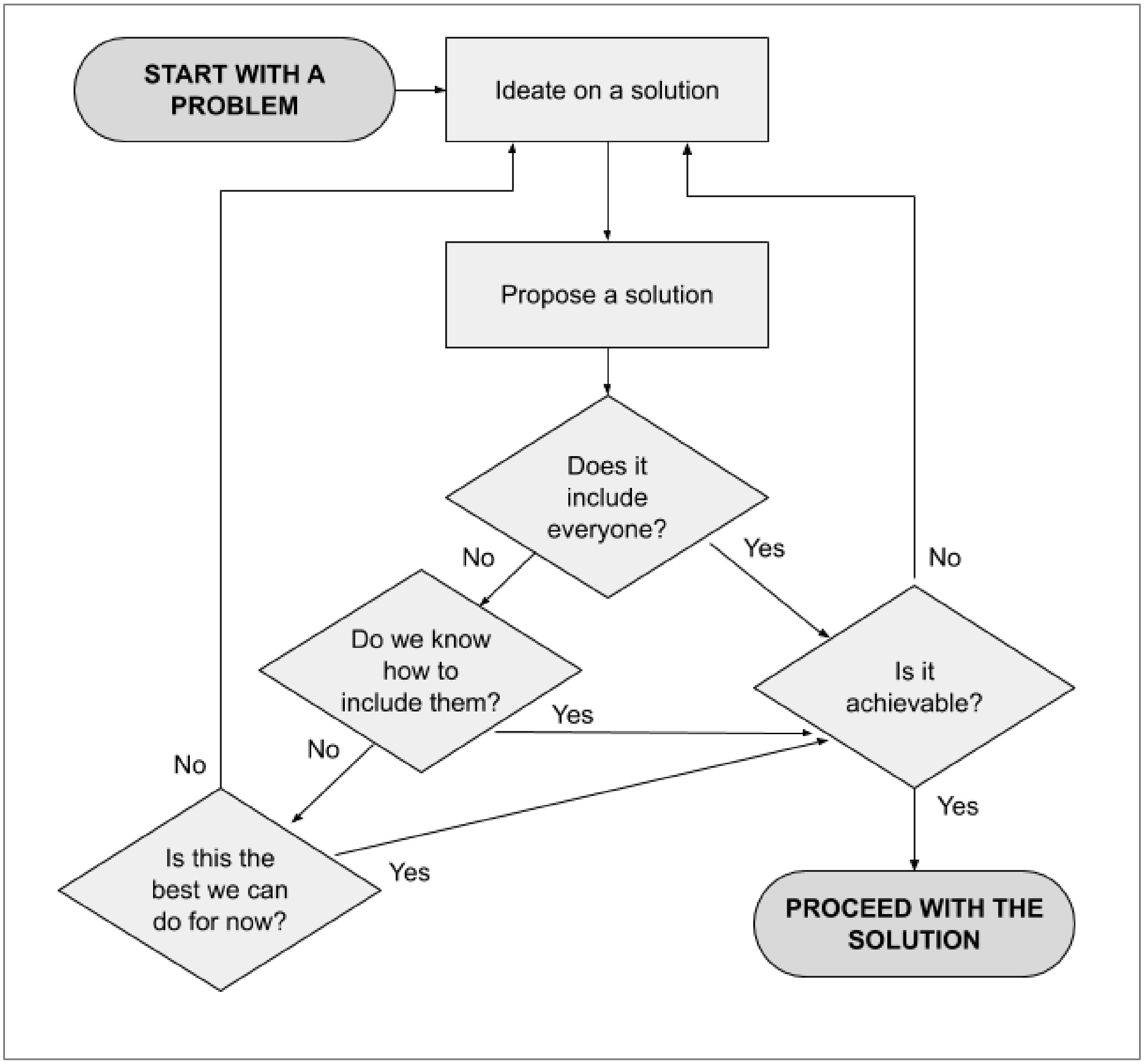

Figure 4 - Decision Workflow/Decision Tree

Whenever we found ourselves facing a design problem, we would always run any potential solution through a decision workflow consisting of the four following questions:

1. Are we including everyone? If we were going for as much access as possible, the goal was to include as many people as possible.
2. If we are including everyone, is it achievable? Will it fit within time frames and budgets and technical feasibility? If so, proceed. If not, keep searching for a solution!

3. If we aren't including everyone, do we know how to include them? Maybe we can solve this quickly by rethinking it!
4. If we are excluding someone and don't know how to include them, is it the best we can do for now? If we truly believe that, and it is achievable, we might find ways to include them later. Maybe we just need more money, or time, or both.

Building a Solution

The Freer and Sackler already had a reputation for making art and knowledge open and accessible to all, from working with Google to become one of the first museums to allow Google Street View cameras inside in 2011, to releasing the entire collection for non-commercial use in 2015. This app would be an ideal continuation of the museum's tradition of access and accessibility (Voon, 2015). Revisiting our broad definition of accessibility as providing as many means as possible for the consumer of the content to access it in a manner that felt right for them, we wanted to ensure that those who wanted to listen to a podcast could find it on SoundCloud or their favorite podcast app, and those who wished to read it in text form could do so through the Freer Sackler website. To address different modalities, we wanted to facilitate flexible access for those who face a time constraint or prefer to wander, and provide intensively guided experiences for those who wish to dig deep or have the luxury of multiple visits. We were purposefully driven to accommodate as many "native" experiences as we could, to begin to break down the walls that many apps have been accused of building up.

When we combined the workshop elements into an experience, the concept of using the "podcast" as a narrative tool morphed into an experience that could be of value both to visitors on-site, by navigating people through the physical space via indoor-location technologies, and to visitors off-site, by providing a more traditional podcast presentation. By overlaying the visitor demographics, we were testing for inclusion upon the value-feasibility matrix, we defined five key factors integral to the experience that had to be addressed: location, abilities, language, age level, and experience. This combination of defined product, key elements, and the decision tree allowed us to shape decisions in a simple framework that aligned with the vision of the organization.

Location	Onsite	Offsite
Abilities	Non-Disabled	Disabled
Language	English	Non-English
Age Level	Adult	Family
Experience	Instant	Involved

Figure 5 - Key Project Elements

These decisions made the initial *planning + requirements* stage of the project cycle efficient. For instance, when looking at users who were hoping for an instant, or more flexible experience, we could look at the long-form podcast tour across galleries and note that we would need an alternative experience. So, the first decision was to include not just the podcast content but also a standard audio tour of highlights that could be dipped in and out of at a user's leisure.

For the handling of language concerns, we were able to look at the design of the application itself and focus on making it icon rather than text-driven. This decision also made the design more usable to those with limited app experience.

This framework performed well when working across our five factors, particularly abilities, language and age level. We were able to make a lot of decisions by knowing in advance that we were going to build these features.

We decided on a video for app on-boarding, allowing us to embed closed captions and handle multiple languages with relative ease.

The themed podcasts needed to include audio referencing clear physical landmarks that would help users navigate between points of interest. Because our team was multidisciplinary, we knew our designers and the wayfinding company, 2 x 4, were using the renovation to reimagine signage and other onsite navigational cues. We leveraged their expertise, and where we found challenges verbally guiding people through the building, 2 x 4 and the in-house design team creatively modified their plans, to the mutual benefit of both app-users and traditional visitors.

Even though we had used and created accessible applications before, we decided to partner with Sina Bahram at Prime Access Consulting to help the developers understand how to take full advantage of the continually evolving native accessibility features within iOS and Android devices, an integration which lowered the learning curve for all visitors. This included properly tagging content for the native text-to-speech capabilities, and applying a user's general accessibility settings to the app by default (with the ability for users to override these features in the app).

As we dove deeper into the instant vs. long-form experience (highlights vs themed podcasts) dichotomy using low-fidelity prototypes, a number of users showed an interest in the ability to flip between the instant object highlights and the involved podcast content, as well as between the museum app and their other apps. We wanted to ensure people could engage comfortably and seamlessly without feeling that the technology was working against them. We built in the ability to pause the podcast and switch to highlights, and reliably return to where you left off. If you were listening to audio and left the app to take a photo or share on social media, your audio did not suddenly stop, but continued to play in the background. Because of the decision tree and the early prototyping, we were able to allow visitors to use the app and their devices in a way that felt both comfortable and intuitive to them.

In each case, while searching for a solution to new challenges, we ran our ideas through the flow chart until we hit upon a satisfactory solution.

A month out from deployment, and the first time we could safely bring external users into the space, we contacted Beth Ziebarth, the director of the Smithsonian Institution Accessibility Program, who introduced us to a group of seven user/experts to test the application for us in-situ prior to opening. Five of the user/experts had vision loss; one user/expert was deaf; and one user/expert was a retiree, new to digital experiences.

Figure 6 - Pamela, who has low vision

Figure 7 - Laurie, who has low vision

The accessibility testing provided us with fantastic, implementable feedback from the expert users. Two specific experiences completely changed the way we thought about our content and presentation. The first came from an experience with Pamela, who has low vision, in a room full of Japanese folding screens. When she entered the gallery, she chose to listen to the gallery overview and two object highlights. When the audio ended, she couldn't reconcile the descriptions she was hearing with the term "screens:"

She associated the word "screen" with modern video monitors and was surprised to discover that the objects being painstakingly described were actually large, centuries-old paneled room dividers made with fabric. She said she needed disambiguation of the terms and more specific descriptions about the materials to form an accurate mental image of the artifacts.

Because it was so obvious to us that the room was filled with Japanese folding screens, it never occurred to us to differentiate our use of the term "screen" in the content. We had, instead, focused on language that described the activities in the scenes depicted on the screens. We came to the realization that what is clear to one person could be completely opaque to another, especially someone with low-vision.

This realization opened our minds. While we had gone through the trouble of creating a framework of inclusion for the technical build of the application, we had not shared this framework with the team creating the audio scripts and recorded content. We had fallen into the exact trap we had worked so hard to keep ourselves out of. Had we applied our own decision tree to this content we would have seen quite quickly that we were, in fact, not including everyone when the scripts were written and that small edits could improve the experience for everyone.

A similar experience occurred when Candice, who is blind, tested the app. She entered a gallery and started the *overview* audio that introduced the theme of the gallery as “Dirty Pictures.” Upon hearing the title, she pushed pause and said she did not want to listen to audio about obscene content. The title referenced Whistler’s murky nocturne and industrial paintings. It was very clear that context was needed for the title, and we would have to go beyond the terms employed even by the artists, critiques, and curators themselves to describe the works.

The *Freer User Expert Study* (Ziebarth, 2017) stated in the observations overview:

> All of the user/experts who are blind or have low vision stated that they would like to be told when they have entered a gallery and to have descriptions of the gallery spaces and/or distinct building features. One participant, when told there were sculptures throughout the room, became concerned about hitting them with her cane or bumping into them. She said that this would not have been a worry if she had been told that all the sculptures were on pedestals, under vitrines, and [had she been] given a general description of the path around them in the gallery.

Working with the accessibility consultants, we sourced a visual description of each gallery that included size, general content, and other descriptive information necessary to create an informative and relaxing experience for those with low to no vision, especially when the galleries were so carefully crafted to provide both information and relaxation for our visitors. Using the native accessibility features within iOS, we were able to leverage the built-in text-to-voice capabilities to read the visual descriptions upon entering each gallery, if the user had this accessibility feature enabled on their phone. While it would have been ideal to produce room descriptions in the same fashion as the podcast, with professional voice-over artists, this was a case where our decision tree concluded that the built-in accessibility feature met our time and budget constraints. The tree included the flexibility to compromise where necessary.

The feedback from the user/experts and the design philosophy we implemented to build agility into our workflow meant that we could adapt to these changes and bring in more functionality in the three weeks we had prior to opening. In this instance, we were able to leverage indoor location technologies and add in a visual description of each room that would be read out by screen readers to visitors who had the text-to-speech feature enabled. The effort we put in during the workshop and the frameworks that shaped the app gave us the ability to have this huge win at a very small price.

We had one other last-minute change/addition to the app. As we tested with various groups in-situ, we realized we lacked family content. We had worked to make the content in the app audience-friendly but had developed nothing specifically for families. We received feedback from users asking for a way to help adults and children connect the objects with their lives and start conversations. This was content that required a different skill set than was used for the other content. We reached out to people who make content for families and to our translation company to produce five multilingual audio experiences with discussion prompts. The flexibility and iterative nature of the app made adding this content a non-issue once it was done. As a result, we still launched that app before the reopening ceremony!

Although we tried to anticipate the experiences and needs of the widest possible audience, ultimately, we all operate within the framework and biases of our own life experiences. At every turn, it was the application of our agreed-upon design and development framework to the challenges illuminated by the skilled and generous user/experts that led us to practical, user-centered solutions to real-life challenges.

The UD framework helped ensure the goals that were set at the start of the process — creating content that was accessible by as many people as possible —

were met throughout and delivered on time in a way that met the needs of our audience. Ultimately, Freer Thinking was able to provide a welcoming, inclusive and engaging experience for all visitors to the Freer and Sackler who wished to take a deeper dive into the collection with the aid of a storytelling app.

Outcomes and Resources

Looking back at the project there are three levels of methodology that we utilized to help us make our decisions in an informed and confident manner.

At the project level, we chose to follow the stages as recommended by design thinking. Our favorite cheat sheet can be found on the Design Thinking Bootleg page hosted by Hasso Plattner Institute of Design at Stanford University: https://dschool.stanford.edu/resources/design-thinking-bootleg

The rules we chose to live by, to help us define the best and most accessible application, came from the seven principles developed by the Center for Universal Design in the College of Design at North Carolina State University (NCSU). Those principles, in their version 2.0, and the 29 associated guidelines can be found on the NCSU website: https://projects.ncsu.edu/www/ncsu/design/sod5/cud/pubs_p/docs/poster.pdf

Finally, the decision workflow that we used to quickly test our own design decisions and make sure we were weighing them against the time and financial constraints of our project can be found in the text of this document.

Conclusion

Although we hope we delivered on our promise of providing a framework to assist with your projects, this essay is not proposing that our experience provides a universal solution for the way you conduct your projects. On the contrary, we hope what we have shared is an approach to seeking out and applying design thinking-based frameworks that fit your own specific situations. The benefit of agreed-upon frameworks, particularly in design, is that they offer great assistance in decision-making — one of the most time-consuming and challenging elements in any project task — made only more difficult by the number of people involved in each project. Frameworks can also help you get unstuck when you've lost momentum.

We hope that the insights gained through our experience allow you to spend more time on the decisions that matter while focusing on the details required to create the most satisfying experience for your specific audiences. We are confident that the tools we shared will help get you to the pointy ends of the decision-making process more quickly and give you some assurance that the path you've chosen will lead you safely and expeditiously to your desired outcome.

[Note: Development of the Freer Thinking app began more than four years ago. Since its release, major changes in museum leadership and the reorganization of institutional priorities have resulted in shifts in app content and maintenance. This article should be viewed as a clear explanation of a completed process developed to create an app that adopted user/expert input and ensured that access for users who are hard of hearing or deaf and those who are blind or have low vision was a priority.]

Acknowledgments

Thank you to Sina Bahram, Marc Bretzfelder, Matthew Cock, Jocelyn Frank, Adriel Luis, Jason Orfanon, Dr. Julian Raby, Dr. Thomas Wide, Beth Ziebarth, and our amazing user/experts.

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Inclusive Digital Interactives

Best Practices + Research

Chapter 13

The Universal Design of the SOS Handbook: A Mobile Communication Method for Elderly People, Deaf People and Foreigners

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September 2020

Introduction

In 2020, the Olympic and Paralympic Games will be held in Tokyo. Many athletes and visitors will gather in Japan from all over the world. However, we cannot forget the disasters of the East Japan earthquakes and tsunami on March 11, 2011, where there were more than 15,000 victims, including elderly and disabled people. In these emergency situations, people are panicked, have trouble communicating, and may experience temporary cognitive decline. To support these issues as smoothly as possible, a booklet entitled the *SOS Handbook* was produced for people who are deaf and foreigners. So far, about 20,000 copies have been distributed for free to public facilities, including local fire stations, and they will be made available in ambulances. The *SOS Handbook* uses pictograms and icons so that people who are deaf and foreigners simply have to point to an image to communicate their status, their concerns, and their needs (Hosono, Inoue and Tomita, 2014).

A museum is a public space where diverse people – young and old, residents and foreigners, non-disabled and disabled – gather. There is always the possibility that a disaster, such as an earthquake, a fire in the building, or sudden illness may occur. In the event that a disaster occurs, elderly adults, foreigners, and disabled visitors will be disadvantaged in their ability to access updated emergency information. Information and communication technology (ICT) may be used to ensure the safety and security of everyone in a museum.

The *SOS Handbook* was originally developed for such situations. After an evaluation of the handbook was completed, however, it was found that while almost all users were satisfied with its quality, they requested that it be made available on a smartphone, which they always carry with them. The latest iPhones and Android smartphones are effective tools that enable digital interaction between humans, particularly for people with disabilities and people who are elderly. Currently, an experimental version of this handbook has been created for modern smartphones. It is now being evaluated in two languages, Japanese and English, with the goal of providing the information in 11 languages at the Olympic and Paralympic Games.

First, we will discuss the features of the original *SOS Handbook*. Then we will discuss the results of the evaluations carried out so far; and finally, the experimental smartphone version.

SOS Handbook Features

A deaf architect had a terrible experience when he suddenly fell sick and was rushed to the hospital by an ambulance where he faced issues communicating with the paramedics. As a patient, his priority was to tell the paramedics where his pain was and how severe it was. However, the paramedics were focused on finding the contact information for his family. This real-life experience became the motivation for designing and publishing a point-and-show style of an emergency handbook.

Figure 1: Cover page of the book.

Figure 2: Service list page.

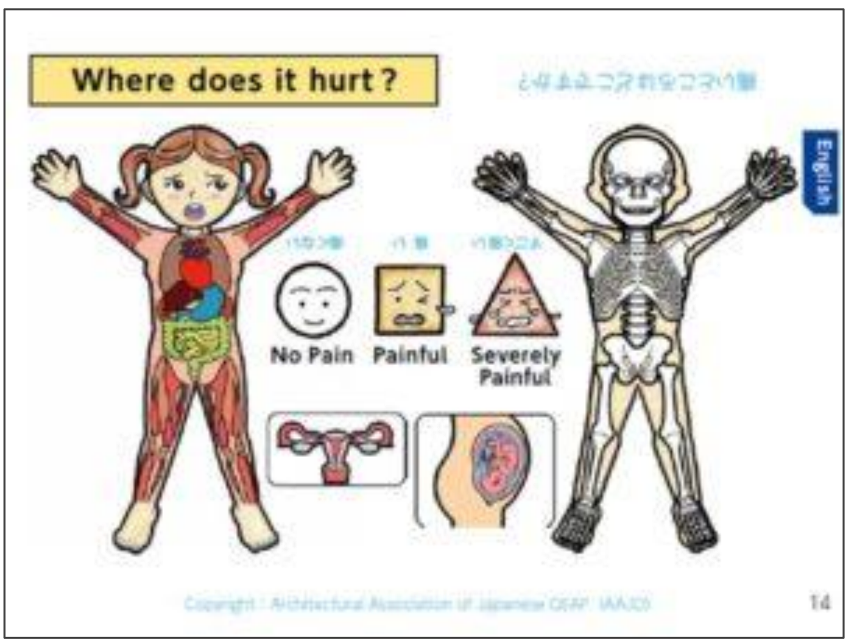


Figure 3: Pain description page.

The *SOS Handbook* was designed according to the principle of human-centered design (HCD) (ISO9241-210, 2010) and the context of use approach (ISO9241-11, 1998). “Context of use” is defined as “the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." As such, it was designed to enable deaf individuals and non-native Japanese speakers to interact easily in physical and social environments.

The features of the *SOS Handbook* are:

- It contains 11 languages in total: Japanese, English, Korean, Chinese (simplified, traditional), Portuguese, French, German, Spanish, Italian, and Russian.
- In line with the context of use approach, simplified icons and pictograms are used to enable clear communication with step-by-step procedures.
- Areas of the body where pain is felt are drawn in 2D. Pain depth and severity are drawn in 3D.
- To account for color blindness, the color arrangements are carefully considered and modified based on the Color Universal Design Organization (CUDO, 2020).
- To better facilitate face-to-face interactive communication between deaf patients and paramedics, additional Japanese letters, printed upside-down in blue, are included for readability from both sides (patient and paramedic).

About 20,000 copies of the handbook were printed, sponsored by The Tokyo Metropolitan Government and Toyota, and circulated to many government offices, hospitals, fire brigade stations, embassies, universities and deaf federations.

SOS Handbook Usability Evaluation

The results were analyzed under the “context of use” framework, evaluating the handbook’s effectiveness, efficiency, and satisfaction by participants.

Efficiency: When the corresponding time to call an ambulance was measured, it was found that they were about 1.5 times quicker with the handbook.

Satisfaction: In the interview after the evaluation, deaf individuals and foreigners indicated 80% satisfaction with the handbook. They also noted that the handbook made them feel safer, more comfortable, and secure during emergency situations.

Survey Questionnaire

After the handbook was circulated, a survey was conducted with a printed questionnaire which was distributed to about 175 recipients, including fire brigades, hospitals, and deaf end-users. The response rate was about 70%. The results were analyzed statistically, and are summarized below:

- The main respondents of the questionnaire are fire brigades (supporters) and deaf people (end-users).
- Both supporters and end-users answered in roughly the same way.
- They rated the quality of the handbook relatively high, but added that an instruction sheet would make it more effective (Figure 4).
- About 70% of respondents noted that having the handbook with them at all times gave them a sense of security and relief.
- Its A5 size (148 x 210mm) was a bit too bulky to carry around.
- About 80% of respondents requested that smartphone versions (iPhone and Android) be created (Figure 5).

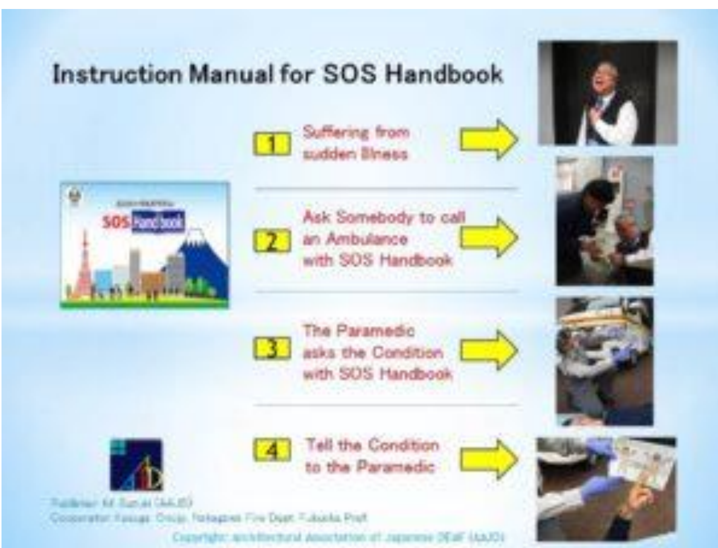
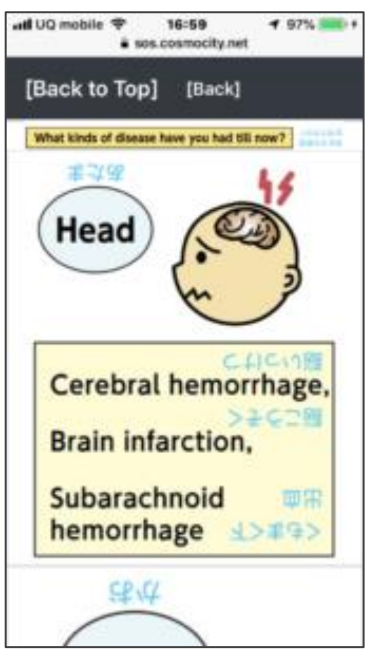
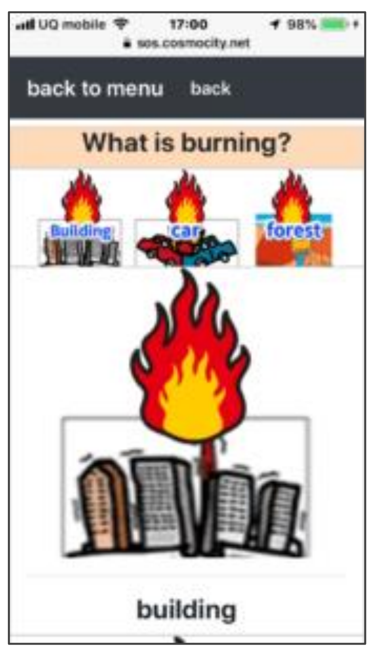


Figure 4: Instruction manual.
Figure 5: *SOS Handbook* on iPhone.

Implementation on Smartphones

In response to the survey results, we decided to implement the *SOS Handbook* as an application on smartphones. Selected sample screens are shown in the six screenshots below.





Figures 6 to 11, from top left to bottom right: language selection page; service list page; call emergency services page; pain description page; brain disease page; and fire page.

The seven main features of the web version are:

1. **QR code for access**: Users can easily access the web version with a QR code which is printed in the *SOS Handbook* or posted in public places. It points to a uniform resource locator (URL). Users simply scan the QR code which immediately opens the web application. They can then save it as a bookmark for future use without a QR code (Figure 12).

Figure 12: QR code that links to the *SOS Handbook* web application.

2. **11 languages**: The *SOS Handbook* on the smartphone will include 11 languages: Japanese English, Spanish, French, German, Russian, Portuguese, Italian, Korean, Traditional Chinese, and Simplified Chinese. Since it is created with HTML, it is easily scalable to add more languages, which we plan to do.
3. **Multiple uses**: The *SOS Handbook* can be used not only in emergency situations to call an ambulance or notify the fire brigade but also in daily use to ask for directions and as a communication tool between deaf and hearing people, or between foreigners and native Japanese speakers.
4. **Responsive web design**: The *SOS Handbook* can be used on smartphones, iPads (tablets), and personal computers (PCs). Since all ambulances throughout Japan now carry a specialized tablet terminal to communicate to the head office, all fire brigades are requested to display this application not only on smartphones but also on the tablets (Figure 13). To maintain a

consistent and cohesive look across devices, responsive web design (RWD) – a method which uses HTML and CSS to automatically resize, hide, shrink, or enlarge web content across devices – was applied during programming. (Figure 14).

Figure 13 (top) and Figure 14 (bottom): *SOS Handbook* on a tablet in the ambulance; responsive web design (RWD) method.

5. **Inclusive human interface design**: This application was designed for elderly and disabled people using Human Interface (HI) technology. The details will be discussed in the next section.
6. **Access for colorblind people**: The *SOS Handbook* uses many colors, but colorblind people sometimes have trouble discerning colors, particularly red-green colors. This handbook was reviewed and authenticated by the Color Universal Design Organization (CUDO, 2020) (Figure 15).

Figure 15: The authentication mark by Color Universal Design Organization (CUDO).

7. **Emergency attention alert**: After earthquakes or floods from typhoons, many houses or buildings are damaged or destroyed, leaving many victims trapped in broken buildings. Deaf people and/or non-native Japanese speakers face serious challenges, being unable to easily communicate their situation. To aid rescue, an attention alert system will indicate their position under the rubble, potentially saving their lives (Figure 16).

Figure 16: Attention alert page.

Human Interface Study for Elderly People

Before implementing the *SOS Handbook* for smartphones, the authors designed a study to test the effectiveness of the current Japanese ATMs with older adults and created ATM design principles based on cognitive decline due to aging (Akatsu, Miki, and Hosono, 2007). The authors thought the design principles could be applied to the *SOS Handbook* for smartphones since all people, including deaf people and non-native Japanese speakers, will be panicked – thus experiencing temporary cognitive decline – in emergency situations. With rapid increases in aging populations, special equipment is required to better assist elderly users. ATMs have always been considered difficult for elderly people to use. The usability testing showed that elderly users demonstrated the following characteristics when using ATM equipment:

1. Longer response times required than younger users.
2. Difficulty obtaining all the information in a short period of time.
3. Recurrence of the same errors.
4. Tendency to respond to items that are easily recognized or can be touched directly by hand.
5. Difficulty noticing quick changes to information displayed on the screen.

6. Difficulty extracting the necessary information or reading all information at once.

Considering the characteristics above, the following seven design principles were proposed as a solution for new ATM design:

1. **Just one operation on one screen**: Elderly users can perform banking transactions in a step-by-step manner.
2. **Easy-to-identify screen buttons**: Use of blinking buttons and screens that are placed side-by-side.
3. **Comprehensive operation flow**: The conventional ATM requires two-step operations of input and then confirmation. The new ATM divides them into two pages: an input screen and a confirmation screen. As a result, elderly users can use both with confidence.
4. **Easy to read**: Information with sufficient font size and contrast.
5. **Simple and carefully selected screen information**: The announcements generally support the operation, however sometimes they hinder operation due to inaccurate timing and content. Timing and accuracy of content needs to be considered.
6. **Synchronicity**: Display the same content as an announcement on the screen.
7. **The timing of an announcement**: It must finish just before changing to the next screen.

Inclusive Human Interface on Smartphones

Providing access to the smartphone guide for older adults also serves people who have other brain-based disabilities and people who may become panicked in emergency situations. To this end, the guidelines acquired through the evaluation of ATMs for elderly populations can be applied to the *SOS Handboo*k for smartphones. However, given that it will be used not only by elderly people but also by foreigners and disabled people, including deaf people, the ATM guidelines are modified for as follows:

1. **Simplify each screen with limited buttons**: Since the smartphone is handheld, and has limited screen space, each button must be the size of an average fingertip.
2. **Step-by-step procedure**: The user provides input on one screen then proceeds to the next screen.
3. **Gradually transitioning from one screen to the next**: Quick screen changes are a problem for users who cannot recognize the rapid change. It must be a reasonably slow change in order to make the change clear. The smartphone screen can move in two directions: vertical and horizontal. However, applying a mix of the two directions confuses users and causes them to get lost. Considering these issues, the *SOS Handbook* on smartphones uses only the vertical transition between screens. On the screen, there are only two operational buttons: “Back to previous screen” and “Back to the top.”

Conclusions and Future Work

The *SOS Handbook* has been distributed to deaf groups, administrative agencies, fire departments, hospitals, and others within or serving the public. The users rated it highly and admired it for its quality and ease of use. An experimental application with 11 languages has been completed for use on smartphones, tablets, and personal computers. This application must be evaluated by the participants, especially elderly people, deaf people, and foreigners. After analyzing the results, the application will be modified and improved. The revised application will be used at Tokyo Olympic and Paralympic Games in 2021.

Acknowledgements

This project is sponsored by Toyota Mobility Tokyo and The Tokyo Metropolitan Government. The Architectural Association of Japanese DEAF (AAJD) and Keio University supported the experimental evaluations of the SOS Handbook.

Dr. Yutaka Tomita (Keio University) and Dr. Katie Seaborn (RIKEN AIP) gave us valuable comments and advice, as well as support with English.

Special thanks to Janice Majewski (Director, Inclusive Cultural and Educational Projects, IHCD), Anoopa Sundararajan (Human Factors & Inclusive Technology Researcher, IHCD), and Valerie Fletcher (Executive Director, IHCD), who encouraged the authors to publish this essay.

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CUDO: http://www2.cudo.jp/wp/ retrieved on 22 January, 2020.

Hosono, N., Inoue, H., Tomita, Y., "Urgent Communication Method for Deaf, Language Dysfunctions and Foreigners", Computers Helping People with Special Needs, PP.397-403, LNCS8548, Part 2, ICCHP2014, Springer, 2014.

International Organization for Standardization: ISO9241-210 (former ISO13407:1999), "Ergonomics of human-system interaction – Part 210: Human-centred design processes for interactive systems," 2010.

International Organization for Standardization, ISO9241-11, "Ergonomic requirements for office work with visual display terminals (VDTs) – Part 11: Guidance on usability," 1998.

Inclusive Digital Interactives

Best Practices + Research

Chapter 14

Mobile Digital Wayfinding Tools: Enabling and Enhancing the Experience of Visitors with Different Access Needs

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September 2020

Introduction

In 2008, the San Francisco Museum of Modern Art (SFMOMA) staged its exhibition titled *Toward Participation in Art*. The show presented a history of participatory art in the museum context and the accompanying catalog included an essay by Rudolf Frieling, SFMOMA's curator of media arts. In it, Frieling discusses the potential for museums to become places that enable transformative experiences for visitors through their active involvement in the realization of artworks (Frieling et al., 2008). However, for people with physical and mental impairments, there are a raft of barriers in the physical environment that can restrict full participation in the creation of any such artworks. Fast forward to 2020 and the same museum is showing *The Chronicles of San Francisco*, a compelling digital mural by the artist JR that portrays the diversity of the city's community. Once again, for those with diverse access needs just visiting an artwork that celebrates, ironically, diversity and inclusion can be rife with barriers. These barriers are familiar and play out in museums, galleries and heritage sites worldwide, often stopping people with different access needs from becoming visitors, and visitors from becoming active participants in the dynamic life of a cultural institution.

Figure 1: The Chronicles of San Francisco, SFMOMA. Image: Jo Morrison.

At the crux of this essay is a call to expand the way that human-centered design is commonly framed, discussed and practiced in the museum context. By adopting a more inclusive and holistic design approach, the cultural heritage sector will be better able to serve *all* its visitors and remove, or limit, current obstacles. As Professor Sir Christopher Frayling states, “The need has never been greater for products, services and environments to be developed in such a way that they do not exclude, but instead reflect more accurately the diverse demands of today’s users…” (Clarkson, Coleman, & Keates, 2003).

One set of barriers that can significantly diminish disabled people’s access to cultural venues pertains to their experience of being in and moving around the sites. For example, people with sensory impairments, learning disabilities or memory loss can feel heightened anxiety when in a crowded or unfamiliar museum. Such anxieties may be lessened, substantially improving the overall museum experience, by supporting these visitors to find their way through a site independently and to locate the types of facilities they need at any particular moment, such as accessible toilets, seating or quiet places.

Over the past decade, due to the availability and advancement of digital technologies, there has been a rise in the number of digitally-enabled products and services deployed in cultural sites to support visitor orientation and navigation. More recently, there has been a growing interest in developing and deploying wayfinding technologies to support those with physical and mental impairments. Hence, now is an opportune time to explore this intersection of people, place and technology to address how designers, software developers, museum professionals and, crucially, the intended users, can inform the design of mobile digital wayfinding tools to enhance the museum experience of visitors with different access needs.

The primary motivation for writing this essay is to provide museum leadership teams and managers of accessibility programs with a greater strategic and operational understanding when envisioning and commissioning digital wayfinding tools to enhance the experience of visitors with less visible disabilities, some of whom may also have physical impairments.

Firstly, I highlight a number of barriers that people with less visible impairments experience when travelling to, and moving around, a museum and summarize their impact. I go on to explore different ways in which digital technologies have been employed to help people overcome these challenges by enabling them to navigate cultural venues and public spaces more easily, with an emphasis on two mobile wayfinding apps, UCAN GO and NavSta. Drawing on the insights derived from the design and development of both apps, I then discuss how the application of an inclusive and holistic design approach to the interconnected problem area of people, place, technology and data can produce location-specific, digitally-enabled tools that help users to overcome common barriers in the physical environment.

Barriers Experienced by People with Different Access Needs

What is meant by terms such as 'less visible impairments,' 'hidden disabilities,' and 'physical and mental difference'? For the purposes of this essay they are used more or less interchangeably as a way to encapsulate a range of impairments or conditions that are not immediately apparent or visible, in particular those concerning neurodivergence, cognitive difference, mental health issues and sensory impairments such as sight loss. For clarity, people's personal characteristics are *not* being positioned as barriers to having a good museum or gallery experience, rather, it is the institution's environment that is disabling, hence there is a mismatch between the built environment of the institution and the diverse needs of its visitors.

According to the United Nations' Disability and Development Report, "persons with disabilities often end up disconnected, living in isolation and facing discrimination" because "disability-based discrimination has severe effects on transport, cultural life and access to public places and services" (United Nations, 2018). In the museum context, this situation is vividly described by Professor Richard Sandell who claims that institutions routinely discriminate against disabled people, "especially those with learning and sensory impairments" and that "the cumulative effect of this widespread and persistent disregard is that many do not feel welcome in our cultural institutions and, as a result, visit less often" (Sandell, 2019).

For people with less visible impairments, being in a museum can prompt feelings of uncertainty, discomfort, confusion and apprehension that can quickly lead to high levels of anxiety. Rather than being a place of belonging, the physical, social and cultural space of the museum can contribute to feelings of agitation, or even alienation. If a museum visitor is unable to easily orient themselves, find and follow a route through a venue that suits their personal needs, locate specific facilities or readily access assistance at any time, then that person's experience is clearly being diminished by site-specific barriers. As these barriers that limit functioning and create disability are often commonplace across institutions, clearly their removal, or significant reduction, would enhance the visitor's experience, enabling them to enjoy the social and cultural benefits of being at a cultural heritage institution.

Digitally-Enabled Wayfinding

Fundamentally, the purpose of wayfinding is to find and follow a route — for example, from a railway station to a museum, or from a gallery entrance to a specific exhibit. Mobile apps such as Google Maps are widely used for outdoor navigation, and there is increasing access to apps for indoor wayfinding as well. In both cases, to benefit all users, the routes generated need to satisfy a set of constraints which include the characteristics of the built environment and those of the individual. Customizable mobile technologies such as smartphones and apps are able to deliver the necessary 'one-size-fits-one' information because of their ability to easily be personalized to the requirements of the user. Hence, these technologies can be designed to offer flexible support that is tailored to the specific requirements of individual visitors, helping them to navigate both, indoor and outdoor public spaces.

As the focus of this article is assisting people's movement around museums, whose visitor spaces are most often inside buildings, it is worth noting that some of the challenges of developing digital solutions for indoor wayfinding differ to those for the outdoors. Specific challenges include: locations not being mapped or no public availability of maps, requiring new mapping activities; GPS technology, so crucial to outdoor routing and tracking, will often not work indoors and it may be necessary to install new infrastructure. If there are relevant third-party data sets available the information they contain may need to be investigated to establish the level of accuracy. Thus, designing bespoke digitally-enabled solutions for indoor venues should not be assumed to be a straightforward extension of outdoor navigation techniques.

Mobile Wayfinding Tools to Support Access to Cultural Institutions

Due to their ubiquity and functionality, smartphones have become the predominant device for the delivery of mobile indoor wayfinding tools. A range of solutions, such as Lingar and Pigeon, have recently been introduced into the market to help people orient themselves, find their way around and better engage with the environment. Worldwide, cultural heritage sites have adopted a variety of smartphone solutions which include indoor mapping capabilities, and the United States appears to be leading the way. For example, the mobile tour Lumin at the Detroit Institute of Arts has wayfinding capability and the Art Institute of Chicago's app provides 'blue-dot wayfinding' inside the museum. Of particular relevance to this chapter are solutions which have been designed for use by people with disabilities. Here, examples include the Smithsonian Institution's deployment of Aira for blind and low vision visitors — Aira is a cloud-based smartphone app that uses augmented reality (AR), artificial intelligence (AI) and live voice guidance to help people experience the museum (Kaplin & St.Thomas, 2019). Another example is the American Printing House for the Blind's Indoor Explorer app that has been deployed in several museums and public buildings around Louisville, Kentucky (Skutchan, 2019). These examples illustrate the opportunities for cultural institutions to enhance their accessibility through digitally-enabled means.

It is evident that mobile wayfinding can assist museum visitors but the majority of digital wayfinding systems, like the examples above, employ infrastructure such as 4G mobile networks, Wi-Fi and Bluetooth radio technologies. This means that a solution that requires such infrastructure is unsuitable for institutions without complete and reliable and coverage. At this point in time, and for the foreseeable future, it is likely that the majority of cultural institutions globally will have a raft of different digital infrastructure situations, ranging from full reach and free to all, to patchy coverage, to non-existent. However, access to reliable digital infrastructure within a building is not essential for all mobile wayfinding systems to operate. Indeed, the two case studies that follow are examples of apps designed with the assumption of an unreliable infrastructure.

Case Studies: UCAN GO and NavSta Mobile Digital Wayfinding Tools

Having provided an overview of the ways in which digitally-enabled solutions are being used to support people to navigate public spaces, I shall now focus on two projects that have inclusive design and accessibility at their heart. The way that inclusive design has been understood and applied in both projects resonates with OCAD University's Inclusive Design Research Centre which defines inclusive design as "design that considers the full range of human diversity with respect to ability, language, culture, gender, age and other forms of human difference." Both projects were designed inclusively, working *with* people who shared similar types of impairments and access needs as the intended primary users of the wayfinding tools, thus ensuring that they were as accessible, adaptable and usable as possible.

The first project is the UCAN GO indoor wayfinding system that enables people with sight loss to navigate indoor cultural venues. The second is NavSta, a mobile wayfinding system to support people with less visible impairments and mobility issues to travel through railway stations.

These innovative projects have been selected as they share a number of characteristics and have both been approached from an applied research perspective but with real-world deployment and scalability in mind. Furthermore, both were developed by Calvium, a digital agency specializing in location-based products and services. Our experience of developing both mobile wayfinding solutions provides the evidence and insights that shall be discussed after the summaries of each app.

UCAN GO: Mobile Wayfinding System

UCAN GO is a standalone iOS app for visually impaired people to navigate complex indoor cultural spaces independently and with confidence. The app has two main functions: an overview option to orient users and a route finder to independently navigate a space. It is a free digital tool that "breaks new ground in disability research and mobile technology" (Fyfe and Vladichis, 2019).

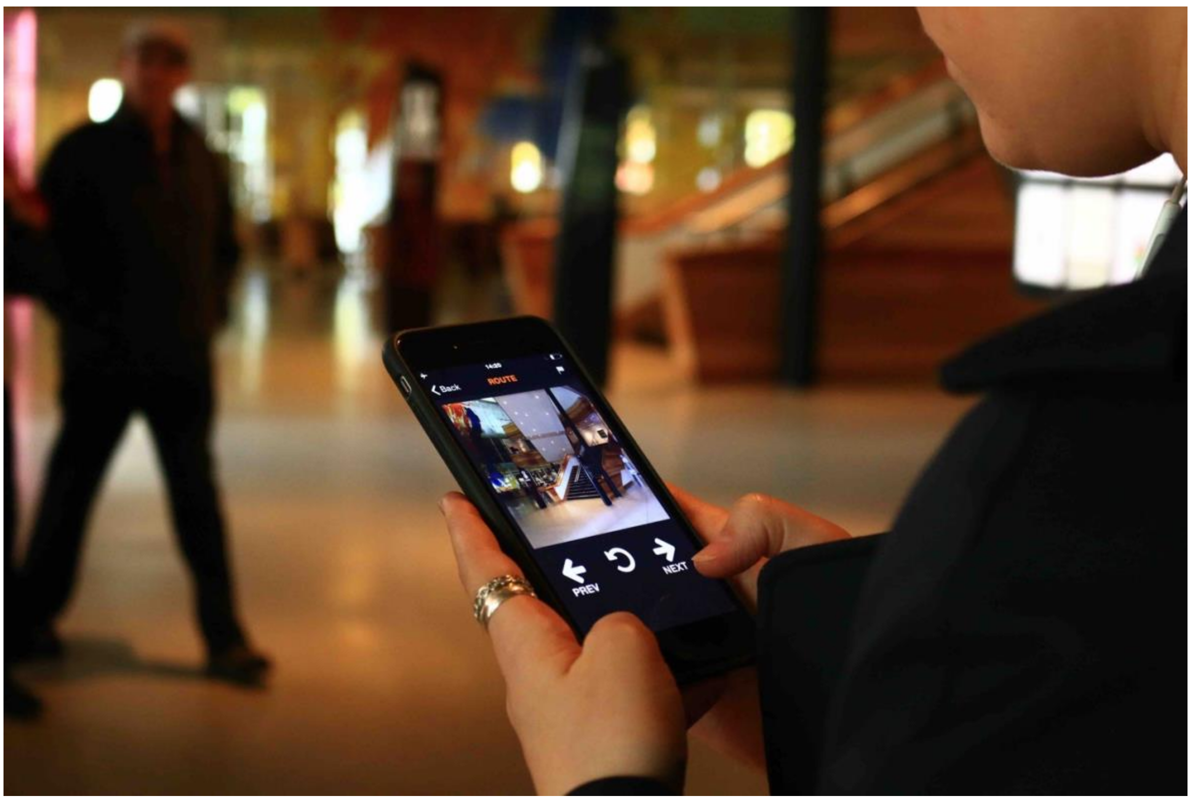

Figure 2: UCAN GO app being used at the Wales Millennium Centre, Cardiff.

A description of the building and accompanying images help users with sight loss create a mental map of the venue before visiting it. The routing feature enables a user to identify their position in a building and find their way around it through visual cues including images and text. Visitors receive simple step-by-step landmark-based instructions that direct them from their current position to their chosen destination, e.g. from the Wales Millennium Centre box office to its cafe. Alongside the visual information is an audio guide that provides the same information.

At the heart of UCAN GO is an ethos that embraces inclusive research and design. As such, a co-design approach was employed from the start of the project and maintained throughout, from concept to deployment. Young people with visual impairments worked alongside the designers and software engineers from Calvium to imagine, research, design and map the mobile solution. It is in this way that the key elements that make up the UCAN GO solution were identified: personalization of the app’s interface and routing options, landmark-based navigation communicated in multiple modes, and a mobile solution which was not dependent on digital connectivity or technical hardware installed at the venue.

“As the app has been designed by people with sight loss, it has features tailored to the needs or fears that the user group have.”

– Digital Skills Officer of the Royal National Institute of Blind People, calvium.com

Once installed on to an iPhone using a mobile data or Wi-Fi connection, the UCAN GO app requires no additional technology. Visitors to cultural venues only need to look at the interface or listen to audio instructions to use the routing function and move around the building. Due to the relative simplicity of the technology, users can also feel reassured that the app is unlikely to malfunction when they are in an unfamiliar venue. An additional benefit of this smartphone-based solution, identified during the project's development, is that young people with sight loss appear to be using their phones in the same mundane way as their sighted contemporaries, therefore they are not drawing attention to themselves as being "different" or "vulnerable.”

Figure 3: Five screens from the UCAN GO app interface.

Researchers from the University of Surrey carried out an independent assessment of the UCAN GO app and stated:

> Responses from formal user testing were overwhelmingly positive, fully confirming the app's value in enabling users to find their way around arts venues confidently. User testing also revealed the app's potential for non-visually impaired users, for example those [with] anxiety or low or no mobility." (Spence & Frohlich, 2015)

The report went on to say that:

> Feedback also revealed further, unexpected benefits. In addition to it being a transformative tool for those with visual impairments — users [with] anxiety or simply those who worry about visiting new places said they also found the app extremely helpful.

Figure 4: Woman with sight loss using the UCAN GO app to find her way through the Wales Millennium Centre, Cardiff.

The practice of considering inclusion in all aspects and at all stages of designing the UCAN GO wayfinding tool led to a solution that not only benefited the original user group, but had the potential for broader impact.

NavSta: Mobile Wayfinding System

It is accepted that less apparent impairments, such as autism, memory loss and depression, can be just as much of a barrier to travel as visible disabilities (Smith & Symonds, 2019). It is also acknowledged by many that to meet the needs of people with less visible disabilities any digital solution should be designed alongside them (Microsoft, 2020). As such, NavSta has been designed with the help and insights of neurodiverse people who have wide-ranging specialist knowledge of travelling on public transport and, critically, understand how to make it a better experience.

Figure 5: In the field user research to inform design of the NavSta Passenger app. Image by Jo Morrison.

The genesis of NavSta is UCAN GO and they share a number of primary functions as well as an inclusive co-design approach. NavSta is a mobile wayfinding system that enables people with hidden impairments to navigate railway stations independently and with more confidence. The NavSta Passenger app provides practical assistance to people when they plan, undertake, manage uncertainty during a journey. By providing the information that passengers need when they want it, NavSta aims to reduce the causes of heightened anxiety that many neurodiverse people experience when travelling through complex indoor environments, or when thinking about travelling through them.

“If a train is late and there are people pushing and shoving, it’s really frightening. I’m a grown man and I shouldn’t be frightened.”

– Participant, concept stage, NavSta user research workshop

To help users plan their journey, the smartphone app provides a variety of information about specific stations e.g. facilities including accessible toilets, stair-free access and quiet places. It also allows users to plan a route through a station in order to familiarize themselves with the venue and their journey through it prior to being on-site.

Once at the station, NavSta's primary function is to act as a personal travel companion and present a route through the station that most accurately matches the specific needs of the individual. For instance, if a passenger wishes to travel between two platforms on different levels and to do so without taking any stairs, then the app will present a route with only lifts or escalators.

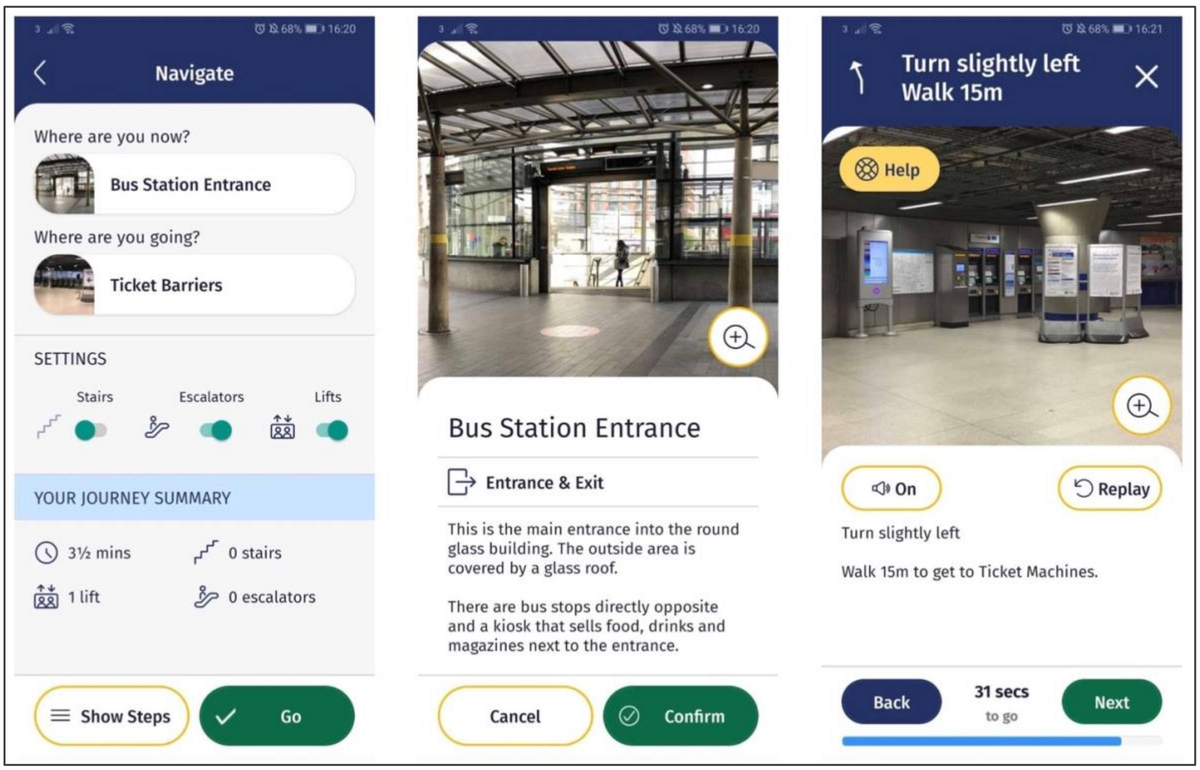

Figure 6: NavSta Passenger app user interface.

Should the state of the station change (for example, a broken elevator), as a person is following the prescribed route, an alternative route will be offered from the point of change — this is called dynamic re-routing. Similarly, should the passenger feel that their own state has changed and that they need to divert from the prescribed route, because of, say, an oncoming panic attack, they can press the in-app 'Help' button and be offered a range of assistance options.

"When it took me to a help point, it seems to work intelligently - I said I still couldn't go that way and so it directed me to a help point which I didn't notice was there. I was relieved. End of a problem, beginning of a solution."

- Participant, NavSta first on-site testing stage

For the duration of the project, from the early concept stage to the final round of on-site user testing, an inclusive co-design approach with neurodiverse participants was employed. One design session saw participants undertaking an on-site mapping design exercise with the project research team to inform the next version of the user interface design and its content. Throughout the creative workshops, hands-on in-lab and on-site user testing and on-site design sessions, the intended primary users of NavSta were critical to informing its design and development.

Together, these examples illustrate how indoor digital wayfinding tools can help people better understand a building when preparing for a visit and while at the venue, as well as to find their way around in a manner that suit their needs.

Considerations When Designing Mobile Digital Wayfinding Tools for Cultural Institutions

Before turning our attention to what UCAN GO and NavSta have revealed about designing and developing mobile wayfinding tools for museum visitors with less apparent impairments, it is worth pausing to explore briefly what human-centered design means in the context of this chapter as a stated aim is to stretch the way in which the approach is commonly framed and discussed within, and for, the museum environment. Firstly, I am employing some of the popular assumptions about the term that focus on prioritizing the abilities, preferences, wants and needs of people. Other commonly used terms that share the same sentiment include user-centered design, user-led design and people-centered design. So, for the purposes of this essay, the term human-centered design is not aligned to a particular theory or philosophy or politics. Secondly, the context within which human-centered design is being explored is at the intersection of people, place, technology and data — a complex, interconnected space. Finally, whilst the term inclusive design is used throughout the essay, it is not seen as being separate from human-centered design, rather, from the standpoint of this essay, the way that human-centered design is practiced should be inclusive and representative of all human diversity.

When describing the two case studies earlier, the user functionality of each was highlighted, however, the apps themselves are part of bespoke systems that were designed and developed to enable the NavSta and UCAN GO apps to become effective indoor wayfinding tools. To design both systems, it was necessary to simultaneously take into consideration the needs of visitors, the real-world context of the venues (e.g. physical, social and cultural aspects), as well as the technical context of operation which includes a raft of data, patchy connectivity and the different devices and mobile operating systems people use. Hence, the design of both mobile wayfinding tools, and the location-based systems underpinning them, was informed by all of these elements and more.

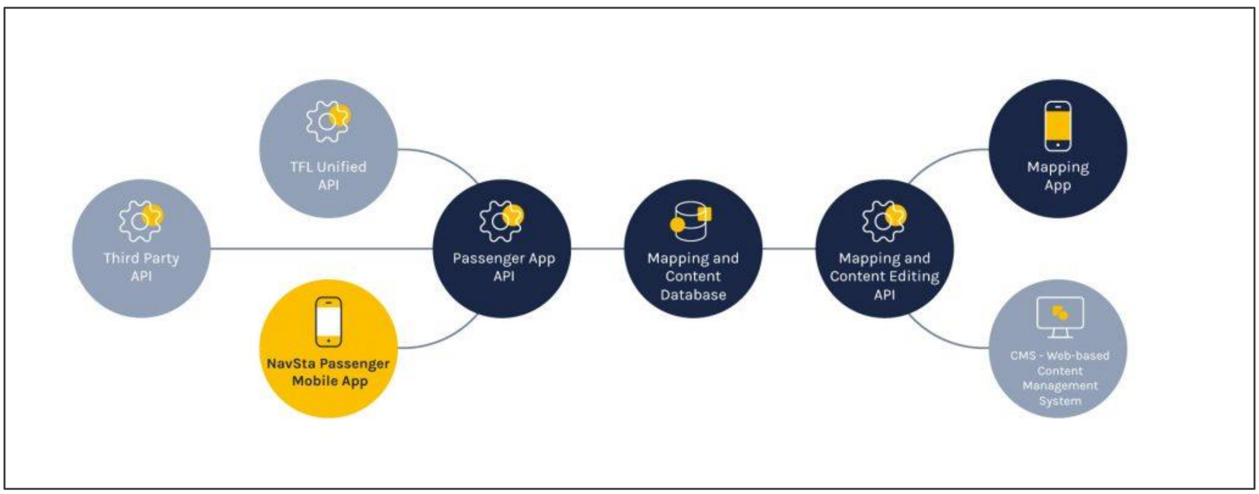

Figure 7: System architecture diagram of NavSta.

The system architecture diagram above (Figure 7) illustrates the different components of the NavSta wayfinding system. As mentioned earlier, the key categories for analysis are concerned with and informed by **people** (e.g. disabled visitors and institutional staff policies), **place** (e.g. physical realm and digital mapping), **technologies** (e.g. software and connectivity), and **data** (e.g. internally generated and externally sourced). Each category relates to and is dependent upon the others and therefore the edges should be viewed as being flexible and porous. It is these categories that will be used to frame the discussion that follows around designing mobile digital wayfinding tools to enable and enhance the museum experience for visitors with different access needs.

People

An inclusive co-design approach was adopted on both projects throughout their duration. The participants all self-identified as having less visible impairments, with some also having mobility restrictions. Working alongside the intended primary users meant that their lived experiences, insights and recommendations were at the forefront of all design considerations. We learned that some people's experiences of being in and navigating public spaces in the past had caused heightened anxiety at the time and made them reluctant to revisit those places: "I hate Kings Cross [station] because it's just too [overwhelming] and I was walking around crying - How do I get out?" and "If a train is late and there are people pushing and shoving, it's really frightening. I'm a grown man and I shouldn't be frightened." The sentiment of these words was common across the participants and it illustrates the negative emotional impact upon neurodiverse people when situated in an environment that fails to support their access needs.

At the early stage of both projects, participants identified a wealth of ways in which a mobile digital wayfinding tool could support them to travel around indoor public spaces. Suggestions ranged from abstract and fanciful to specific and implementable. However, there were four shared characteristics that all participants deemed essential for a wayfinding app to be truly useful, which are:

- **Familiarization and planning**: helping people familiarize themselves with a venue before arriving by providing suitable information and allowing them to plan their route through a location ahead of time.
- **Moving through a building**: enabling people to orient themselves, find a route and follow that route through a building.
- **Managing uncertainty**: if there is a change in the physical state of the building, such as a closed escalator, the wayfinding tool would re-route the user to their chosen destination. Also, if there was a change in the personal

situation of the individual then the app would be able to offer suitable information or help them locate human assistance to remedy the problem.
- **Personalization**: providing information in a way that is suitable for the needs of the individual at the time, whether that is to do with access needs at the museum or customization of the interface.

They agreed that wayfinding tools that offered this type of functionality would improve their self-confidence and enable greater independence when at that venue, both of which were deemed to be highly desirable:

> I get really bad anxiety. The fear of the unknown, the crowds, the noise, the overstimulation, having to think about a lot of different things. I need information, layout, visual cues about where I'm going to go, and a person accompanying me — but I don't enjoy someone travelling with me.

The wish not to appear as 'different' from others in a venue was shared among a significant number of participants, but not all. The smartphone was seen as an ideal device to deliver information as nobody would know if the user was selecting a route on the screen or sending a tweet, listening to routing instructions through headphones or music on Spotify. One participant said, "that would be good as nobody would think 'there goes one of them.'"

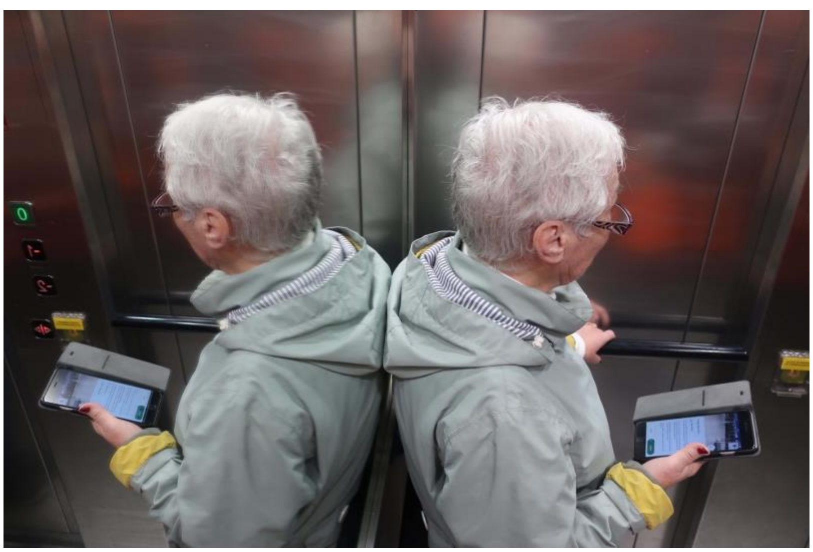

Figure 8: A participant using the NavSta Passenger app during in the field user trials. Image by Jo Morrison.

Regarding the design of a wayfinding tool's interface and content, both sets of participants identified practical and useful information delivered in a straightforward manner, a simple and easy-to-use interface, and multi-modal delivery of content (text, image and voice) as the key ingredients for usability success:

> Sometimes my vision gets bad so expandable content on the screen is useful, and clear text. It's a bit wobbly. It's variable, I don't know what's going to happen. On a bad day, it can be completely different, and I get tired-er.

As shown in the quote above, people can have different access needs on a daily basis, or more frequently, and it's therefore important to build a flexible, adaptable and customizable mobile wayfinding tool that can respond to the immediate needs of an individual. In doing so you are not designing one thing for all people, instead, as attributed to Susan Goltsman, "you're designing a diversity of ways to participate" (Holmes, 2019).

As a result of the early stage co-design sessions with NavSta participants, the project team devised a set of principles that would underpin the project and would be the criteria against which the project would be judged as it progressed:

1. **Trust**: Trusting that the information in the system is reliable and will not mislead the user.
2. **Safety**: A system that allows the safe passage of the user, through physical and digital interaction.
3. **Clarity**: The information in the system is displayed in a clear and understandable format.
4. **Personalization**: The user can tailor the services of the application to suit their individual needs.
5. **Usefulness & Relevance**: The information presented in the system supports the user to complete their tasks effectively.

These principles were specific to NavSta and I demonstrate their application later on, but there could be benefit in exploring their validity and usefulness for other projects of a similar nature.

Place

For the purposes of this section, place is seen as incorporating the physical, digital, and social realms of a venue. For both, UCAN GO and NavSta, research was undertaken at the start of the projects to understand these interconnected aspects of a place. For instance, when designing a wayfinding tool for the Wales Millennium Centre, Cardiff Library or the Hackney Empire, the UCAN GO teams would visit each venue, interview the staff to understand the processes, practices and policies they enact. They would also study the physical space of each venue in order to inform the mapping process, the type of information that the app would deliver and the content that would need to be gathered. All of this information would help to provide a deeper understanding of the location and provide a clearer sense of the problem area.

It is vital to spend time investigating an app's intended site to better understand the real-world context of its use. By doing so, assumptions can be challenged and tested. By meeting with staff at Canada Water Station as well as accessibility managers at Transport for London, the organization that runs the station, NavSta researchers were able to find out information that reshaped the project prior to commencing design. For example, we had assumed at the outset that the station's customer-facing staff would be able to participate in the design of the NavSta Passenger app and that there would be opportunities to make the app available on staff devices. Both assumptions were wrong and enabled us to reshape the project approach at an early and non-critical point in the project.

When designing a location-specific service that connects the physical and digital realms it is important to understand the different 'languages' of a place. People find their way through the built environment using different types of cues — some are explicit, such as signage or spoken instructions over a tannoy system, some are related to physical form and functionality (e.g. 'steps' suggest movement across levels and 'doorways' suggest entrances or exits), and other cues are social, (e.g. when asked, a customer services assistant may provide verbal directions to a destination). In combination these 'languages' should inform the design of a wayfinding tool. The risk of not doing so is that there is no alignment between the digital, the physical and the social spaces.

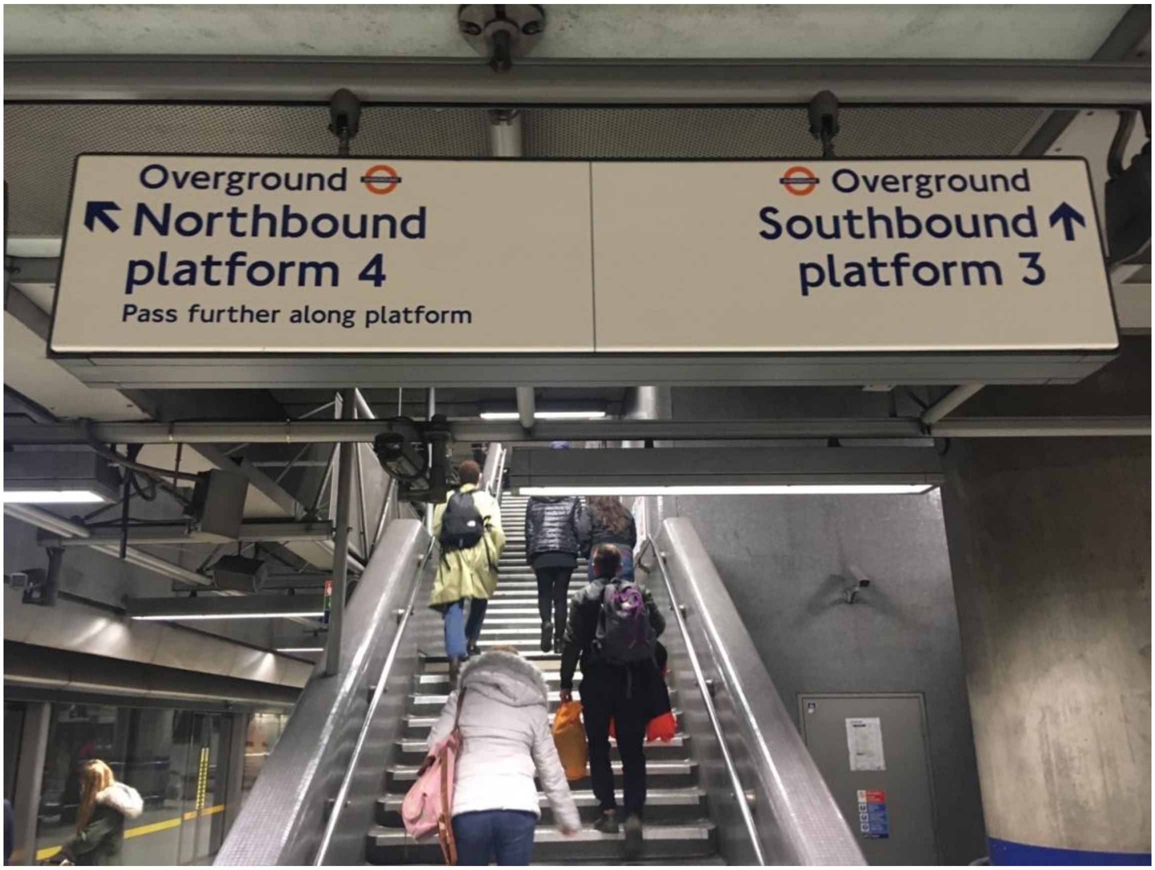

Figure 9: Canada Water Station. Image by Jo Morrison[/caption]

At this point it is worth re-emphasizing the importance of inclusive design and the active involvement of a project's intended users in its creation. As important as it is to understand the different elements of a place, it is also necessary to communicate the place effectively to users through the app's interface. With this in mind, the insights of the NavSta and UCAN GO expert participants proved invaluable. For example, when taking photographs of a downward escalator or stairs, it was advised that an image shows the adjoining handrails and not simply a close-up shot of the stairs themselves, to avoid the sensation of falling that some users would experience.

Technology

Digital technology can be positioned as something that limits a project by providing constraints or enriches it by offering opportunities. The case studies showed us that both positions are true. Technological constraints can relate to poor or no connectivity to the internet, patchy beacon coverage causing unreliable location sensing, limitations of smartphone functionality and more, whereas technological opportunities might mean that a user has access to up-to-date information, rich media experiences and that their device can be accurately positioned and tracked throughout a building. These technical constraints and opportunities depend on the technological environment of a building. The UCAN GO and NavSta projects showed how different physical spaces can be expected to have different technological environments, from rich to poor. They also demonstrated the benefits of investigating these environments at the start of a project and drawing on any insights as part of the considerations for design. By understanding the technical context of a place, the associated constraints and opportunities can be an active part of the creative process of designing a mobile tool for that particular situation.

As identified earlier, personalization is key. Whether that means an individual being able to receive information in their preferred mode or modes, the ability to choose a route that suits a person's immediate needs, or easily customizing the tool's user interface to ensure that the information is comprehensible. Personalization is not dependent on a deeply connected and sophisticated technical environment, nor is it disadvantaged by a poor space, but it *is* dependent on well informed design choices. For instance, Canada Water Station is technically impoverished in terms of indoor wayfinding as it has neither location sensing infrastructure nor robust internet connectivity. However, for the NavSta Passenger app we were able to provide the personalized functionality and features that were deemed essential by our users. It wasn't simply a fully automated process, rather, there was also manual user input, e.g. the app requires the user to identify or confirm their location. To be clear, the user will receive personalized information as they require it, what differs is the way in which the user interacts with the app to receive the information.

Having already illustrated NavSta's system architecture, it is worth noting that the UCAN GO system shares the same underlying model but, unlike NavSta, the components are not integrated, instead relying upon a collection of more ad hoc tools and manual processes, such as:

- **Mapping a venue**: mapping data is collected manually, using paper notebooks and cameras (or phones) and then collated into a spreadsheet on Google Drive.
- **Collating and storing data**: once complete, the data is exported from the spreadsheet in a defined format and uploaded to an online file server in the cloud.
- **User interaction**: the UCAN GO app then downloads the data for a particular venue from the online database when instructed by the user.

Whilst vastly simplified, this summary demonstrates that a lo-fi solution, with no automation or integration, can deliver the same types of user functionality as a more sophisticated implementation. That said, there are disadvantages — the mapping process is slower, there is no online database that can be viewed or verified independent of the app, and any changes made to the maps over time are not automatically updated. So, while both UCAN GO and NavSta are mobile wayfinding systems that deal with the interconnected nature of people, place, technology and data, the systems that underpin them have been constructed differently. This serves to demonstrate that there is no universal prescription for constructing a system and that the approach chosen should reflect the circumstances of the institution.

Data

The principles that guided the NavSta project were implicated in determining the data used within the system, i.e. the selection of data types and potential third-party providers. For instance, underpinned by 'usefulness and relevance,' early-stage research was carried out to discover the types of existing data sets that were available to use by the app. In particular, the team looked at open source data sets such as those made available by Transport for London — journey plans with accessibility preferences and crowding at key locations. In this way, the whole team was able to understand what type of features it would be possible to include in the app without needing to gather the data afresh. This knowledge about the availability of data provided a greater sense of the possibilities available when designing the app.

Trust in the system by the NavSta users was another active principle that was fundamental in data-related decision making. ‘Trust’ was therefore a criterion used to measure which potential third-party or project-generated data sets might be used; concerns included their provenance, accuracy, availability and maintenance. When Transport for London’s accessibility data was investigated it was discovered that some of the information about Canada Water Station was incorrect, hence that data set was not used. In addition, as there was no existing digital map of the station that could be used, we created a map ourselves. In doing so, mistakes were made in relation to compass bearings and, therefore, errors occurred in the data. These errors were not uncovered until the on-site user testing took place, whereupon, as a result of the errors, some incorrect routing instructions became apparent. Interestingly, some of the participants had vested such trust in the system by that point that even when they expressed their belief that the suggested route was incorrect, they persisted in following the instructions: “Oh well, let’s give it a go.” These examples show the importance of using accurate data and the human implications of not doing so.

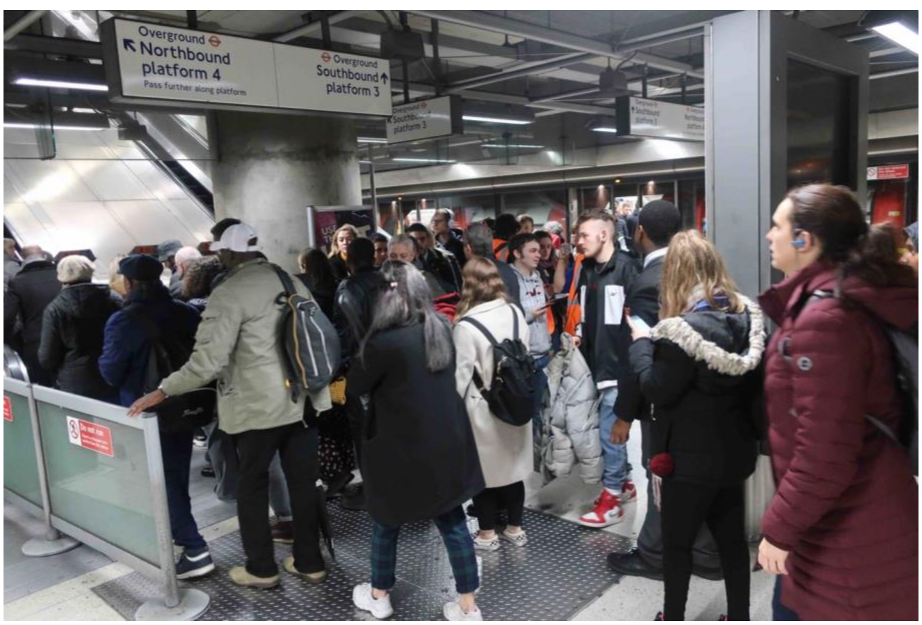

Figure 10: Canada Water Station. Image by Jo Morrison.

Finally, drawing on the ‘clarity’ principle, once accurate data has been sourced and put to use in a wayfinding app, it is vital that the information is made available to users in an easily digestible and timely manner. I am not referring to the layout of the user interface or navigation, which have been discussed already, instead I am referring to the negative impact on users when accurate information is communicated in the wrong fashion or delivered at the wrong time. For neurodiverse users who experience anxiety when traveling around public spaces, the evidence showed that their anxiety can be rapidly heightened if the wayfinding tool provides, say, too much information or if the tone in which information is provided causes insecurity.

New Concepts for Human-Centered Design

Having explored UCAN GO and NavSta through different lenses it is clear that new approaches and methods are needed when thinking about and developing digital wayfinding tools to enhance the museum experience for visitors with less visible disabilities. Maybe new concepts are needed as well? For instance, would it help us to frame the combined opportunities and constraints that people, place, technologies and data bring to a project as ‘materials’? Materials for research, design, development and delivery.

A striking insight from the case studies was the tactic of 'avoidance' adopted by the participants, all of whom had different access needs. It emerged that when planning and undertaking a visit, each person tried to avoid aspects of the physical, digital and social realms because of the potential negative impact upon themselves, mentally or physically. This factor, which adds a new layer of meaning, should be considered when designing location-specific digital systems for people with different access needs. Consequently, would '**designing for avoidance**' be a useful concept to progress in this expanded practice of human-centered design?

Conclusion

In summary, UCAN GO and NavSta have revealed the complexity of designing mobile location-based digital systems for use by people with less visible impairments in public spaces. Exploring these case studies through the interconnected themes of people, place, technology and data, and providing real-world examples of practice, has demonstrated the benefits of adopting a holistic and inclusive approach to designing such systems. As vital as participatory human-centered approaches are to ensure the best outcomes of mobile digital solutions, it is also necessary to spend as much time concurrently researching the spatial and technological context of a potential service. By doing so, thus expanding the way in which human-centered design is commonly framed, discussed and practiced in the museum context, interactive projects of this kind are informed by a much greater set of insights. These insights, in turn, provide a more successful outcome for all museum stakeholders with different access needs. In this way, and returning to SFMOMA, people with different access needs *can become* visitors and visitors *can become* active participants in the dynamic life of a cultural institution.

Acknowledgements

Dr. Richard Hull, Calvium
Vincent Martin, Apex Systems
Mary-Anne McCarron, Calvium

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Inclusive Digital Interactives

Best Practices + Research

Chapter 15

Inclusive Experiences for Audiences with Different Levels of Tech-Savviness: The Design and Evaluation of a Mixed Reality Dinosaur Exhibition

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September 2020

Introduction

The purpose of this essay is to present the design and evaluation of an inclusive and immersive experience for audiences with different abilities and levels of tech-savviness. The research case study is based on *The Little L Project*, an engaging mixed reality (MR) exhibition of a small polar dinosaur. *The Little L Project* was a small exhibition that took place at the National Wool Museum in Geelong, Australia, in 2018. For two months, visitors were able to learn about these dinosaurs through a 360-degree video of a real excavation nearby, a playful and immersive virtual reality (VR) coloring game, and a hands-on table with multi-material 3D-printed reconstructed dinosaur skin. A 3D-printed dinosaur skin stamp for holiday activities was also developed. This essay discusses the human-centered design process that the interdisciplinary team of museum professionals, designers, interpreters, engineers and paleontologists had undertaken in order to engage all museum visitors. All experiences were carefully designed to fulfill the expectations of museum visitors and anticipate different needs depending on visitors' abilities and digital proficiency. The results of the summative visitor evaluation are also presented based on the 43 hours of observation and 123 post-visit responses, together with the results of the online formative survey with 78 responses. Our interaction and exhibition design followed the general principles of Design for All, which are well reflected in the museum exhibition.

Designing Immersive Museum Interactions for All

The Integration of New and Emerging Technologies in Museum Exhibitions

Museums have always been early adopters of new technologies. They had been developing their web presence as the internet was just entering our homes, closely following digital trends, and showcasing the latest technologies as they were gaining attention from the audience, particularly the younger demographic (Cesário et al., 2017). Smaller museums, primarily regional and publicly funded ones, may not be perceived as early adopters of new technologies due to the relatively high cost of development, installation, and maintenance. Nevertheless, many of those museums partner with technology providers in order to explore the potential of cutting-edge interpretation tools for their audiences.

Quite naturally, museums have been quick to pick up on immersive technologies and to try to integrate them into their cultural mediations (Freeman et al., 2016; Virtual Multimodal Museum, 2018). Since the democratization of 3D printing in the late 2000s when the first patents expired and after the VR boom, a low-cost Oculus Rift Development Kit became available in 2013 — both technologies are now on the way to becoming widespread in museums. Yet, neither those technologies from both edges of Milgram and Kishino's (1994) Reality-Virtuality continuum — if we consider 3D-printed copies and reconstructions as “Real Environment” — nor any of the technologies in-between have become well integrated into museums exhibitions.

Immersive technologies are developing so rapidly that even terminology is left behind. For the purpose of the article, we use mixed reality as an overall term to describe various realities used in the presented *The Little L Project*, including 3D printing. However, it may happen that extended reality (XR) (Marr, 2019), all reality (Mann et al., 2018) or a newly introduced term may prevail in the future.

From Accessible to Inclusive Digital Museum Interactions

Digital experiences have often been developed by museums to increase access, drive diversity, and promote the well-being of all audiences (Ponselle & Allaman, 2015).

The pursuit of accessibility encourages cultural institutions to invent and develop many innovative bespoke digital solutions (Chan & Paterson, 2019). In many cases, organizations deploy specific digital devices to be used by a particular audience, to support and enhance their visit. For example, the Signly app at the Roald Dahl Museum and Story Centre (http://signly.co/apps/roald-dahl/) has been developed for the deaf audience and delivers “smart signed content directly to the user’s device” (http://jodiawards.org.uk/). In 2013, the heritage-listed castle Chateau d’Oiron launched Norio, a robot that could be controlled by visitors from a “control post” and that allows them to visit all spaces remotely (http://www.chateau-oiron.fr/en/Explore/Norio-the-tour-robot). This innovative technology, that would overcome complexity and cost to make the 16th century castle entirely accessible, was proposed to offer a satisfying experience for people with reduced mobility. The robot was designed to be easy to use by all visitors, regardless of their level of tech-savviness or fine motor skills — a simple joystick or computer mouse can be used to operate the robot. The design also embedded the social aspect of a museum visit as the device allows visitors to communicate with their groups, other visitors or a guide. These two examples (along with many more) have received a positive response from the sector and won awards for their accessible design while being aimed at one category of visitors.

The notions and terminology around the concept of access have evolved quite significantly in recent years, and it is interesting to note that museums have embraced the shift from accessibility strategies (often understood as having special considerations and conceiving dedicated devices for people with disabilities) to inclusive approaches (considering as many people's needs as possible). In his Adobe blog post, web accessibility expert Matt May offers an interesting insight on the reasons he chose to use inclusive design (instead of accessible design), defining the concept as follows: "a design that considers the full range of human diversity with respect to ability, language, culture, gender, age and other forms of human difference" (May, 2018). In this definition, inclusion is understood in its broad meaning and museums designing inclusive digital experiences must consider visitors with various abilities but also different age groups, vulnerable groups or culturally and linguistically different visitors.

This doesn't mean that museums must shy away from solutions they have previously conceived with specific needs in mind. For example, tactile models and 3D-printed replicas have been widely used by museums as potential solutions for people with vision impairments, to enable them to engage with the exhibits. Recent research has shown that 3D technologies and replicas were beneficial to an even broader audience as museum visitors "[favored] tactile or semi-tactile experiences with replica" and were ready "to negotiate with the inauthentic in order to have a tactile embodied experience" (Di Giuseppeantonio Di Franco et al., 2015). Tactile experience has often been combined with a sound component, whether by developing guided tours, audio guides or specific sound environments. The Louvre Museum opened its first touch gallery in 1995 (https://www.louvre.fr/en/tactile-gallerya-new-tour-sculpting-body), and it’s now completed by a dedicated audio guide on a Nintendo 3DS.

Our research follows a similar hypothesis that the use of a tactile experience combined with a virtual environment can offer a more engaging museum experience. That is to say that by using MR, we aim to design more inclusively, considering the needs and uses of a mixed audience.

Mixed Reality Experiences for Visitors with Different Levels of Tech-Savviness

Recognizing that museums are confronted with similar accessibility challenges in the digital age, it is necessary, when developing mixed reality experiences, to understand how these issues were addressed in the past. The digital divide (the inequality of access to the internet and technology between people) has been observed since the democratization of the internet in the late 90s and is still the subject of research studies (Morato et al., 2016). In the digital era, inclusion should also englobe people with various levels of tech-savviness and “digitally excluded” people, who are “at risk of being excluded from access and use of digital technologies” (Morato et al., 2016). This issue has found a substantial echo in cultural institutions and especially in museums as they are often presenting national and public collections that should be, in theory, accessible to all audiences.

Up until now, MR technologies were often only an appendage to the main exhibition content targeting the younger generations amongst museum visitors. Today, even if young visitors are quick on picking up new digital devices in museums, most visitors are comfortable manipulating tactile screens and other devices, as digital technologies are omnipresent in the domestic space (Dufay, 2019). The level of tech-savviness, which used to correlate with age, may become more linked to one's socio-economic background and personal interests. Moreover, in recent years, interacting with digital technologies such as video, touchscreens, and social media have become a daily routine for many, and we may assume this will soon also happen with VR and other immersive technologies. When they go to a museum, visitors expect to interact with media they are familiar with. Therefore, it may not be too far in the future when all the excitement about immersive experiences is a minimum expectation for visitors.

Each technology may not be a separate experience, but a mélange of various MR technologies combined into a single exhibition in a way that best serves the narrative and desired interaction.

To design an inclusive museum exhibition that will respond to the needs and wants of audiences with different abilities and levels of tech-savviness, implementation will require a holistic integration of various immersive technologies with other traditional interpretation tools including images, text, and tactile reconstructions. With this in mind, we should avoid designing separate “attractions” with the notion of *la technologie pour la technologie* (technology for technology's sake). Each technology invites a different method of engagement and a different level of participative interaction with museum content. No size fits all, but if well developed and spread across the exhibition appropriately, different interactive stations may accommodate not only visitors with limited digital literacy skills but also those with diverse impairments and disabilities. However, not all museum visitors are “rejectors” on the human-centered design extreme users diagram (Stanford d. School and IDEO; Kimya, 2018). Some of them may be “power users,” and their needs should be accommodated as well. From the content point of view, these visitors may be subject matter experts (in our case dinosaur enthusiasts), but from the perspective of digital interaction they may possess advanced technological skills and easily get bored if the exhibition only provides content with limited digital engagement. As one of our visitors in the 26-35 age group pointed out: “[it] seemed more like a silly game.”

The Imperative of Co-Creation for Inclusive Digital Experiences

In his blog post for the Victoria and Albert Museum, Andrew Lewis analyzes different studies that conducted direct observations of visitors using digitally-mediated experiences in museums. He concludes by highlighting several criteria for success. While unaware of this article during the conception of *The Little L Project*, our team was driven by very similar ideas to create an inclusive user experience. One criterion identified by the author is "familiarity with technology" — if visitors are not used to a specific interaction, they may find it challenging. Our immersive experience was seeking a high degree of visitor familiarity with alternating between clicking on buttons or using gestures that mimic painting with a brush. The author also highlights that many visitors may be eager to use touch as a “discovery aide.” This point was also at the heart of our immersive experience with visitors being able to touch a replica of the model as they were painting it virtually. Finally, “the atmosphere” of the space played an important role in inciting a sense of adventure or mystery in visitors (Lewis, 2014).

In *The Little L Project*, the exhibition space was conceived to reflect a science laboratory and convey the idea that the device was a prototype. Visitors were not only observing but also participating in science at work and encouraged to provide feedback. Some insight was used immediately to modify the experience while it was still being offered at the National Wool Museum while other input will be used for future iterations of the project, making the user experience a shared responsibility between museum experts, technology experts, content experts, and the visitors — experts of their own co-designed experience. Museums have used co-design strategies to develop exhibitions and many other museum media (Gibbs Howard, 2019; Hand & Cymru 2019). Designing inclusive digital experiences requires that visitors be more than just visitors. It requires them to be content and interaction creators as much as consumers (Antlej et al., 2017).

The Little L Project

The Little L Project was a small mixed reality dinosaur exhibition presented in 2018 at the National Wool Museum in Geelong, a regional post-industrial city near Melbourne, Australia (Antlej et al., 2018a, Antlej et al., 2018b). After the then-recent closure of major manufacturing plants, the city had embarked on its new digital innovation journey. In 2017, Geelong inaugurated its "clever and creative" 30-year vision and was designated a UNESCO City of Design.

The National Wool Museum is managed by the City of Greater Geelong. The museum presents the Australian wool story whilst undertaking the role of a public space for exploring stories of potential interest to the local community.

One of those stories is about polar dinosaur discoveries along the Victorian coast of Australia.

In *The Little L Project* exhibition (Figure 1), a wallaby-sized, plant-eating local polar dinosaur, *Leaellynasaura amicagraphica* (lovingly called Little L), recovered from the 105 million-year-old Cretaceous rocks southwest of Geelong, was showcased to investigate how creative and meaningful content can utilize immersive technologies and 3D printing to provide engaging and accessible experiences for visitors with different levels of digital literacy. In 1987, the first bones were found by two co-authors of this essay, paleontologists Professor Patricia Vickers-Rich and Dr. Tom Rich, not far from Geelong (Trusler, P, Vickers-Rich, P & Rich, T., 2010; Vickers Rich, P. & Rich T., 2014). Since then, Little L's bones have appeared in a few museum exhibitions. She even appeared on the cover of the Australian edition of *Time Magazine*. However, never before had people been able to fully experience Little L's world in a personally engaging reality.

The Little L Project investigated innovative means for such engagement. Our target group was a diverse local Greater Geelong audience, from families with children, teenagers and young adults, to seniors and vulnerable groups who could experience difficulties with the technology, migrants for whom English may have been a second language, as well as individuals who may have had limited access to advanced digital communication tools.

In addition, *The Little L Project* also addressed the underrepresentation of women in science, technology, engineering, and math (STEM), with an aim to inspire girls and young women to choose science or engineering as their career paths. Surprisingly, Little L, named after the discoverers' daughter Leaellyn, is still only one of few dinosaurs in the world with a feminine name (in Latin, names ending in a and not us denote the female gender), celebrating women's contribution to the paleontological science. With a strong involvement of four leading female researchers (an engineer/designer, a paleontologist, and two curators) *The Little L Project* emphasized that science and engineering can be inclusive and creative for everyone.

With an aim to provide welcoming and inclusive experiences, our interaction and exhibition design processes followed the general principles of inclusive design, which are well reflected in the exhibition. However, there were certain technical limitations, partially overcome with the development of exhibition stations offering different levels of interactivity and complexity. Visitors with low vision or blindness were considered as much as possible throughout the design process. However, due to the nature of the technology we used, full accessibility remained a challenge.

Visitors with Limited Experiences with Mixed Reality

Along with the social value assessment, our formative evaluation suggested that around half of the participants had never experienced or might have had only one encounter with MR technologies. Out of 66 participants who answered an online survey question: "how much experience do you have with Mixed Reality?" 48.5% had one experience with 3D printing while 28.8% had none; 43.9% had one interaction with augmented reality including smartphone applications while 31.8% had none; and 56.1% had a single experience with virtual reality while 36.4% had none. Despite 3D printing and VR being around for a while, our design had to consider the diverse digital literacy of the visitors. As part of the solution, along with the video and written instructions, at least one trained volunteer out of 20 recruited was present at all times to facilitate visitors trying the VR headsets. The exhibition also had a strong tactile component to accommodate those visitors who preferred touching as a way to interact with exhibits over a total digital immersion.

Visitor Evaluations with Post-Visit Surveys

In order to provide recommendations for future development of immersive digital interactives at the National Wool Museum and other museums in general, the exhibition was observed carefully and evaluated in-depth. Qualitative and quantitative evaluations have been conducted during 43 hours of observation and a user experience evaluation with 123 participants who completed a post-visit survey. The online survey (83 respondents in total) was open to local adult residents with a Victorian postal code; the paper version (40 respondents in total) was also open to children aged 10+ accompanied by parents or guardians.

In general, the exhibition was well accepted by local visitors. 95.9% of 123 participants enjoyed the experience (57.7% very much, 38.2% a lot), and 97.4% of 117 participants would like to have a similar experience again (56.4% very much, 41% a lot). A detailed analysis of both quantitative and qualitative data shows that the numbers are relatively accurate, however perhaps still slightly too optimistic. It is widely known that post-visit surveys may be biased as participants don't want to disappoint the authors. Fortunately, our survey generated rich qualitative data that supports our assumptions: most visitors were positively surprised by the immersive capability of MR experiences; they enjoyed the exhibition overall, but due to the technical limitations of some of the equipment, a few visitors had difficulties interacting. Some visitors remarked: “Very immersive! Very different way of experiencing typical museum exhibits. Maybe a little bit technological for some...” Other visitors suggested, “more museum exhibitions should use this technology as you engage with the content and material more." A detailed discussion related to each of the interactives is provided below.

Figure 1: The entrance to The Little L Project exhibition at the National Wool Museum. Photo by Kaja Antlej.

360-Degree Video of a Paleontological Dig

At the exhibition, the visitor journey began with an immersive 360-degree video of a real paleontological dig on a public beach along the Victorian coast (Figure 2). A short, pre-recorded VR experience with narration provided a unique window into the world of paleontologists who have been digging in the region for more than 30 years. “It was cool to listen to the guide talk about the excavation and be able to look around and see what he was talking about,” commented one visitor.

A 360-degree video is not considered a real VR experience as it does not allow the six degrees of freedom movement. Instead, while immersed using a VR headset, the user stays still observing the recorded surrounding at all degrees. We installed this first VR experience near the entrance to increase visitors' curiosity but kept the level of interactivity relatively low so as to not alienate visitors with potential technophobia. Overall, the exhibition was designed to slowly encourage active participation — interaction with potentially unfamiliar technological tools and interpreted scientific paleontological content.

Despite being a very simple experience, it was still extremely immersive according to survey respondents: “I would really love to see more interactive installations similar to the video/lecture at the dig. It made me feel like I was there and involved. Even better if multiple people can be there.” Unfortunately, due to limited resources, we were not able to provide a multi-user experience. However, a large TV screen synchronized with the users' interaction enabled the creation of a visual story that could be watched by those who did not want to be immersed or those who wanted to interact with a co-visitor.

The 360-degree video, in particular, was favored by visitors who were not very tech-savvy. They felt included into something that, at first glance, looked technologically sophisticated. Per our observations, some visually impaired visitors were able to see the video with prescription eyewear and some by adjusting the VR headset. However, there is still a lot to be resolved by producers who should ergonomically design goggles to accommodate a variety of visitors with glasses. “Headsets were slightly difficult to use if viewer [is] wearing glasses,” mentioned one of the respondents. The VR headset hung from the ceiling with adjustable height to accommodate visitors (Figure 3), including those in a wheelchair. Due to the 360-degree nature of the video (it could be experienced in every direction in the space), a chair for visitors who may prefer to sit was not readily available but a facilitator was able to provide one on demand. We could have added a rotating chair, but this idea was abandoned as some users immersed in the experience could accidentally bump into it.

Figure 2: A spherical image of the 360-degree video of the dinosaur dig. Photo by Chax Rivera.

Figure 3: A visitor watching a 360-degree video of the dinosaur dig. Photo by Kaja Antlej.

Hands-on Table with 3D-Printed Dinosaur Skin

The second station introduced the shape of Little L and showed how paleontologists reconstruct dinosaurs based on their bones. Next to the cast of Little L's fossilized skull, two 3D-printed reconstructions of dinosaur skin provided distinct hypotheses on the shape of the scales. Both patches, sized 15 x 15 cm, were flexible enough for visitors to fold around their hands and play with their surfaces (Figure 4). One of them was made with a multi-material 3D printer, which provided a unique tactile experience of rigid scales and flexible flesh.

Most survey respondents enjoyed the tactile aspects, with one older visitor stating, "Tactile experiences are always reinforcing of experiences." It was a new experience for some visitors. A young adult visitor said, "I have never had a tactile experience of dinosaur skin before. It allowed me to contextualize the dinosaur easily." On the other hand, some visitors were not particularly excited about the quality of the 3D-printed surfaces, saying, "The textile piece was not as exciting as it felt a bit plasticky." They also suggested, "It would have been good to have more skin samples to compare, e.g. snake, crocodile, lizard." As tactile 3D-printed reconstructions have been proven to be a great learning resource for people with visual impairments (Anagnostakis et al., 2016; Jafri & Ali, 2015), the experience was designed with the intention to assist blind and low vision visitors who may wish to interact with exhibits by touching them.

As the exhibition was in Geelong over the Easter school holidays, the museum developed a special activity for children and adults. Over four mornings, a creative workshop titled 'Drop-in Dino Fun' attracted 150 participants, who spent between 10 and 90 minutes designing on paper and textile (Figures 5 and 6) with various objects including a 3D-printed dinosaur stamp based on Little L's skin (Figure 7).

Figure 4: A 3D-printed reconstruction of dinosaur skin available for visitors to interact with. Photo by Kaja Antlej.

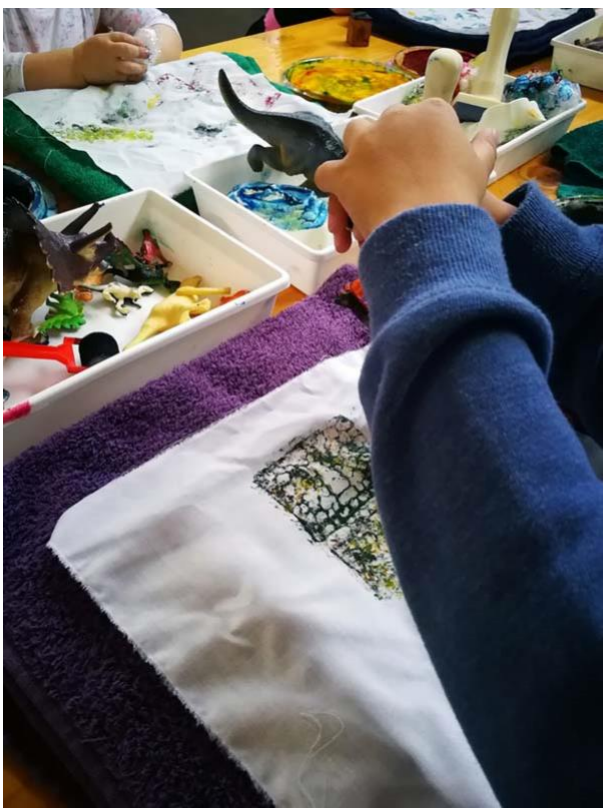

Figure 5: Visitors to the school holidays activities were invited to print with a 3D-printed dinosaur impression. Photo by Marie Allaman.

Figure 6 (left): An impression of a dinosaur created with a 3D-printed stamp. Photo by Marie Allaman.
Figure 7 (right): A 3D-printed stamp with a dinosaur skin impression. Photo by Kaja Antlej.

Virtual Coloring of a 3D-Printed Dinosaur

The second space in *The Little L Project* was a lab-like area featuring a 3D-printed reconstruction of Little L on a pedestal. The model was available for visitors to look at and touch from all around the pedestal. A large projection screen at the end of the room featured the same dinosaur, this time immersed in a virtual polar Early Cretaceous. The long, spiky dinosaur tail was only featured in VR in order to prevent any potential injuries to visitors or to the exhibit.

The 3D-printed model was synchronized with the VR experience. While immersed using a VR headset, visitors were able to walk around the dinosaur, and if they patted it, a green-yellow texture or the original 3D-scanned plaster model appeared. If they did not touch it, Little L stayed white, waiting to be painted by visitors.

A tactile-immersive MR coloring game was developed to tell the story of how paleontologists determine the color of dinosaurs based on the evidence in nature today (Figure 8). Facilitators and text panels informed visitors about two current hypotheses offering reasons why Little L might have been colorful like some birds, or might have had a camouflage quality as she was a relatively small herbivorous dinosaur. Visitors were free to follow either of the two hypotheses presented, or their own imaginations (Figure 9). The coloring game utilized a Leap Motion sensor for its interaction. A large color and texture palette appeared if the user opened their left hand. A pinch made with their right hand generated a virtual airbrush, which enabled users to spray Little L with different colors using virtual brushes of different sizes. In addition, the virtual environment itself offered a well-curated soundscape of bugs and other animals from that time period.

This co-creative game was, in a way, designed to be accessible to visitors in a wheelchair. Shorter visitors, such as small children, were provided with a step stool. The visual universe which had been created in VR presented many technical limitations for people with vision impairments. The MR experience used feedback from visitors with low vision to provide access and improve the experience. For example, there were many modifications to the coloring experience, including larger icons in the coloring palette (Figure 10).

The VR coloring interaction provided a multimodal experience, prompting one visitor to say, “All of the senses being engaged led to a very informative and fun way to learn.” Various means of engagement were used to prompt emotions in visitors: one user said, “[I] came here with my family. I liked to see the smile on their faces;" others said it triggered conversation, made them talk about what they were experiencing, and prompted discussion during and after the experience. Some experiences were multigenerational with participants teaching parents how to interact while others preferred to just watch. A young girl who was with her younger brother was so inspired by painting the dinosaur that when they moved on to other galleries, she continued her creative endeavors. After a while, she returned with her brother and surprised the researchers surveying *The Little L Project* with a present: a small dinosaur she made out of Lego bricks duplicating the same color pattern she had used in the coloring game (Figure 11). Her pattern is pictured on the left in the second row in Figure 9.

As fun as the interaction was for some visitors, it was relatively complex for those who weren't as tech-savvy. One middle-aged adult visitor said they had issues with "volume, wearing glasses, time to get used to technology.”

Some visitors noted that total immersion in the VR experience excluded them from what was happening in the gallery, saying, “You put on a VR headset and you can't see anyone else.”

Figure 8: Two museum visitors interacting with the virtual coloring experience. Photo by Donna Squire.

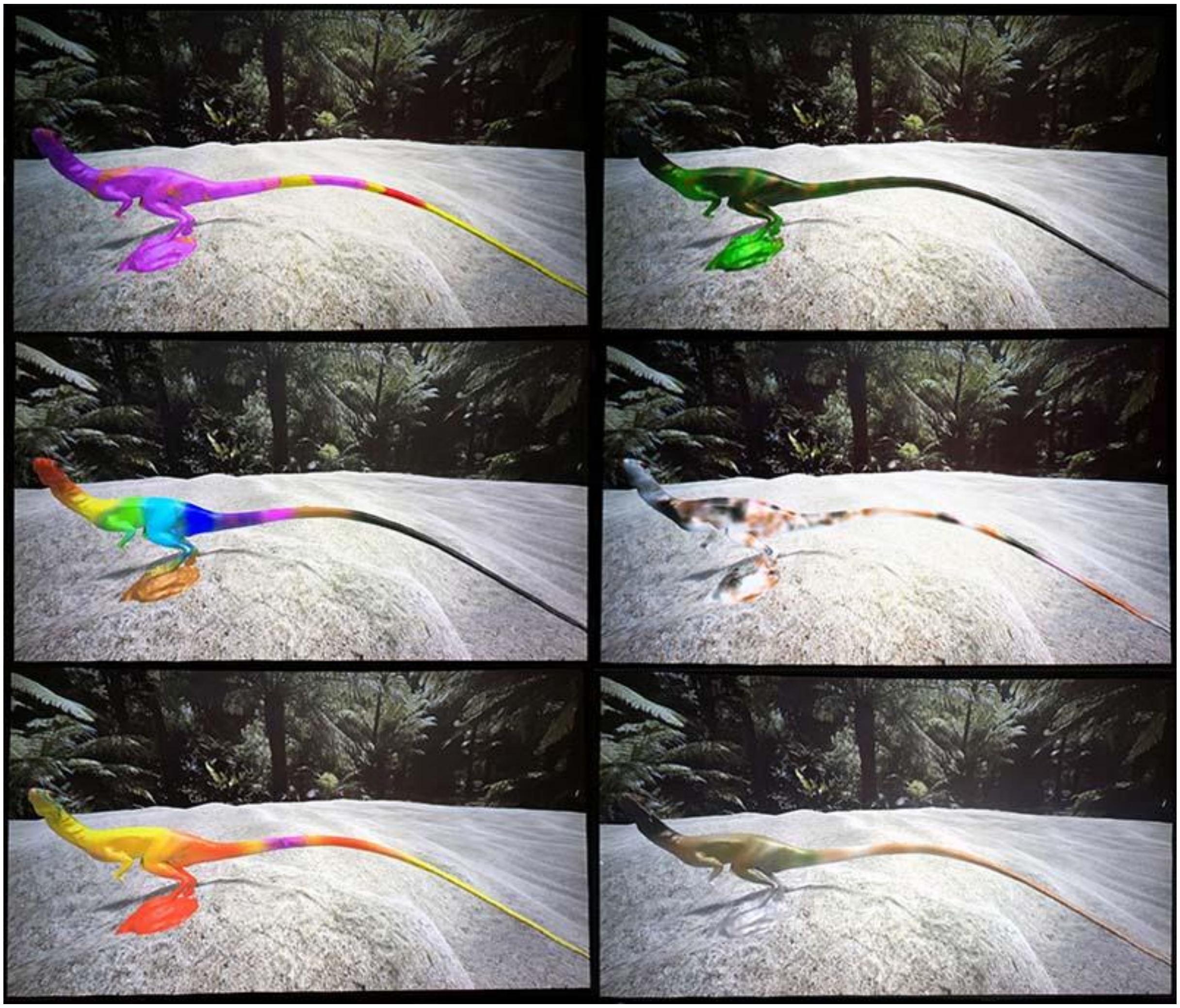

Figure 9: Six examples of visitors' artwork following the colorful (left) or camouflage (right) hypotheses. Photo by Kaja Antlej.

Figure 10: A virtual palette for coloring the dinosaur. Photo by Kaja Antlej.

Figure 11: A reconstructed dinosaur built from Lego bricks based on one painted in the virtual coloring exhibit. Created by the young girl portrayed on the right. Photo by Kaja Antlej.

Age is Not Always a Barrier When Interacting with Virtual Reality, but…

The Little L Project was visited by a very diverse population in terms of age. Various generations often came together. This correlates with the survey results in which 73.4% of respondents said they visited the exhibition with family. We note that many respondents completed the survey after interacting with the coloring game, therefore, the percentage may not be an accurate representation of all visitors to the exhibition. Nevertheless, of those who completed the survey, young adults between 26 and 35 years old were the most highly represented at 25.2%. The 36 to 45 and 46 to 65 age groups were equally represented, each at almost one-fifth (19.5%) of all participants and 13.8% of respondents were young adults between 18 and 25 years old. Some visitors 66 years and older may have been reluctant to play the coloring game, accounting for their relatively low response rate: 7.3%. Similarly, only children aged 10 and older were eligible to take the survey and they were limited to the paper-based version, therefore the 10 to 17 age group constituted 6.5% of all respondents.

Based on the qualitative analysis, respondents referred to the second VR experience, the coloring game, and the 360-degree video the most. The hands-on table with dinosaur skin received only limited mention. It may have gone unnoticed due to its relatively small size, or have fallen short compared to the VR experience which caused a lot of excitement. One visitor noted that younger visitors were more excited by VR than by 3D-printed reconstructions: "I [enjoyed the hands-on table]. Not sure about the teenagers. I think they were just itching to get their headsets on!" This observation was supported by our researchers as well.

As noted above, overall satisfaction with the exhibition may be slightly biased. A question encouraging participants to provide negative feedback has yielded incredibly useful recommendations and guidelines for further developments. Most participants who answered the question "Did you find the experience difficult to interact/play with? Tell us why…" did not recall any issues with interaction but 22.7% of respondents found it challenging.

Before the exhibition, we assumed visitors' age would strictly define their tech-savviness and ability to interact with VR. Our observations and surveys proved our assumption wrong. Willingness to interact with VR was more closely related to previous experiences with the technology as well as general openness to learning. In general, virtual reality and gesture-based interaction are still relatively new ways to engage with technology. Our formative study results were confirmed after the exhibition as many of our visitors experienced mixed reality for the first time. A great many of them from all age groups enjoyed it, saying, "[I] hadn't used VR before. Interesting experience to be placed somewhere," "First experience with 3D reality – enjoyed it," and "very much enjoyed my first experience of VR." However, some, even younger visitors, found it relatively challenging, saying, "I learnt that it's very hard to control a VR machine."

Some older visitors were reluctant to interact with the more complex of the VR interactions, but those who engaged with it had few difficulties, often less than some younger visitors. One adult visitor in the 46 to 65 age group who liked the VR experience "very much" said they were "cautious as [they] have never done it before, then fascinated." An older visitor (66+) said it was "unusual, intriguing, & informative." Another older respondent said of the VR painting, "[it] develops imagination, gets your brain working."

As there are no industry standards on deciding what the minimum age is for a safe and enjoyable interaction in VR, we chose to follow the recommendations from other museums, including the National Museum of Australia in Canberra and VR producers like Oculus whose experiences are designed for ages 13 and over. Based on our observations, most visitors with small children not only allowed but even encouraged them to try a VR headset. One visitor said:

> [our] kids loved experiencing VR for the first time, Deakin staff and volunteers [were] so helpful and kind [to] our children 7 and 4 years old who were keen to give it a try! […] Being able to experience the VR allowed the kids to see the dinosaur "come to life!"

Children ages 9 and 10 were relatively familiar with the user interfaces, likely from playing games, but also because technology is increasingly provided in schools as a learning tool. Despite being amazed by the virtual space, younger children had much more difficulty interacting with the coloring game but enjoyed the 360-degree video. Not only was the VR headset incompatible for younger children as it was too large and too heavy, but the Leap Motion sensors were also sometimes unable to recognize their fingers when they did a pinch gesture to trigger the virtual airbrush. They also had more difficulty listening to the instructions and translating them into the required gestures, or correctly manipulating their left/right hands. Gesture-based interfaces are relatively new and the "gestural grammar" has yet to be standardized and better known among lay users.

Our observation that seniors were more likely to feel dizzy was also noted by one of our older participants: "Some of our group couldn't look through the headset because of getting dizzy. I loved it." Another older visitor was slightly confused as well: "I got a little confuse[d] about [where my hand was], but this is me, kids might not have these problems."

The Role of Exhibition Facilitators

While technology is still evolving, it is crucial to involve trained facilitators to assist those visitors who wish to be guided. After content and technology, facilitators were the third important theme identified by post-visit survey participants. The facilitators were mentioned relatively often throughout the survey, despite there not being a dedicated question about their involvement in the exhibition. A visitor emphasized: "Discussion with the instructor was more helpful than virtual reality goggles for engaging with the topic of dinosaurs." They "[…] enjoyed chatting [with] informative and open staff." Having a staff-supported exhibition may not be the best solution for all but based on our survey, facilitators played a major role in the satisfaction of our visitors. This leads us to ask — how important is human interaction in today's digital world when everything is automated, from vending machines to self-service cashier systems? Museums should be aware of how crucial it is to involve staff (and volunteers) to be the face of the museum, and how eager visitors are for human narration and assistance.

Discussion

The project yielded encouraging results on how MR could contribute to creating more inclusive museum experiences. Mixed reality can be used successfully with visitors regardless of their age, as our evaluation showed no differences in responses between age groups despite our preconception of younger visitors being keener to interact with new technologies.

An interesting outcome highlighted by the evaluation is that visitors could have a satisfying experience even without being able to experience all the components, whether due to a vision impairment, lack of familiarity with technology or a language barrier. A teacher said:

> The technology added to the interest immensely. The written material and the guide also helped to provide context which I found useful. We did have three students with limited English so some of the background/context was lost on them. However, the technology they found fascinating.

This is great encouragement to keep developing immersive digital experiences that aim toward more and more inclusivity.

Furthermore, this project has confirmed the great value of presenting an immersive experience as an unfinished prototype, to be able to receive feedback and modify the interaction based on users' experiences. The consistent presence of researchers — collecting insights from observation, reading post-visit evaluations, and volunteers' feedback — has been instrumental to developing inclusivity. Inclusivity cannot be reached without the voices and experiences of people with various needs.

Conclusions

The design and evaluation of our immersive digital experience gave us true insight on how best to conceive inclusive, immersive and science-based museum content for audiences with different levels of digital proficiency and with different backgrounds. We think that our pilot project could be adapted in the future to cater to more diverse needs, with many design challenges since resolved. In future iterations of the project, greater inclusivity can be reached by working with diverse focus groups prior to presenting the experience in the museum and by reinforcing the social aspect of the experience. The evaluation confirmed that visitors are eager to access shared immersive experiences: “VR means you are participating in it on your own unless you had 2 or more sets of goggles. Perhaps a "team" game to reconstruct a skeleton from fossils would encourage more interaction.” Coincidently, this experience was later developed at the Natural History Museum in New York within the *T. rex: The Ultimate Predator* exhibition and proved to be a great success.

This project also confirms the role of museums — even smaller regional museums with limited funding — as public platforms where local audiences can discover and learn about new technologies that may otherwise be difficult to access and gain confidence with. In that regard, inclusive immersive experiences in museums could contribute to reducing digital exclusion.

Acknowledgements

The Little L Project has been co-funded by the Deakin University internal fund and the National Wool Museum, City of Greater Geelong. It was also supported by in-kind contribution by the researchers. The project was developed by Deakin’s School of Engineering researchers in collaboration with paleontologists from PrimeSCI! at both Swinburne and Monash Universities, Museums Victoria, and museum professionals from the National Wool Museum. We want to thank Michael Mortimer, Chax Rivera, Damien Elderfield, Robert Leen, Ian Gibbson, Anant Gupta, Clara Usma, Paul Collins, Robynne Hall, Georgia Melville, Peter Trusler, DinosaurDreaming excavators, the Geelong Botanic Gardens – City of

Greater Geelong, and everyone who contributed to this project. *The Little L Project* has been highly commended at Museum and Galleries National Awards 2019 (Interpretation, Learning and Audience Engagement) and shortlisted for the Museums Australasia Multimedia & Publication Design Awards 2019 (Multimedia) which is administered by the Australian Museums and Galleries Association. It was also highly commended at the 2018 Victorian Museum Awards (Medium Museums), and at the 2019 Municipal Association of Victoria Technology Awards for excellence (collaboration or partnership achievement of the year).

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Inclusive Digital Interactives

Best Practices + Research

Chapter 16

The Lubbock Lake Landmark's Digital Experience: A Small Museum's Efforts to Integrate Inclusive Design in Exhibit Interactives

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September 2020

Overview

Over the last few years, the Lubbock Lake Landmark has prioritized experimentation with different digital interactives to create meaningful and inclusive learning experiences. The Landmark is an established, small satellite facility of the Museum of Texas Tech University, without a digital team or a development budget for digital projects. Despite these challenges, the Landmark serves as a case study for how a commitment to inclusion can lead to meaningful change. By utilizing an agile, iterative design approach, a small number of staff members have been able to test and refine digital interactives. These interactives range from 3D-printed components to Internet of Things (IoT) hardware to a mobile application.

Challenges, often stemming from the lack of a formal budget, opportunities for review and evaluation, and the technology that was being implemented, did not halt progress, but did lead Landmark staff to look for creative solutions. The adoption of universal design (UD) as a key aim from the earliest phases of development is argued to be the most important outcome of experimentation at the Landmark. Future goals for digital projects at the Landmark reflect a mindset shift and greater awareness of UD principles.

Introduction

The Lubbock Lake Landmark is a National Historic Landmark, a State Archeological Landmark, and a satellite facility of the Museum of Texas Tech University (Johnson, 1987). Discovered in 1936, with current year-round facilities dedicated in 1991, the Landmark has since thrived as a small museum. With a full-time staff of 11, part-time staff of one, and volunteer support, the Landmark maintains a rigorous program of community offerings. The Interpretive Center features permanent galleries and a temporary exhibit space that changes annually. On average, 27,000 annual visitors experience the exhibits and 336 acres of restored prairie. The Landmark has no formal budget for digital initiatives but has a strong desire to experiment with these tools to improve accessibility and inclusion in its exhibits.

The Landmark has undertaken two case studies to explore the significant change that a commitment to inclusion can generate, even in a setting with limited resources. Landmark staff decided that they were not willing to let limited funding excuse ignoring a portion of their community. In the Landmark's case, staff identified an opportunity to increase inclusive exhibit and educational initiatives through a shift in thinking and practice. The Landmark's experience illustrated that an institution does not need perfect or final solutions to create an institutional shift in mindset. That change in mindset was one of the biggest outcomes of the Landmark's experience as it effected a change in exhibit practice without the reliance on a large influx of financial resources.

The Landmark chose to focus on digital interactives initially, in part due to staff interest, administrative support, and community preferences. Community preference was established based on a 2016–2017 visitor study completed at the Landmark that revealed visitor interest in technology usage in museum exhibitions. The study results included 78.14% of respondents expressing the expectation to encounter technology usage in a museum exhibition (Stepp, 2018).

The Landmark's first venture into digital interactives was through the adoption of photogrammetry to create three dimensional (3D) models of collection objects. The creation of these 3D models led to experimentation with 3D printing and the merging of the two technologies to produce the *Engaging Folsom (10,800–10,200) Hunter-Gatherers with 3D Technologies* exhibit (*Engaging Folsom* exhibit), a temporary exhibit that opened in Fall 2017. The *Engaging Folsom* exhibit pushed the Landmark's digital interactive accomplishments with the incorporation of 3D-printed braille and Raspberry Pi-powered interactives. The *Engaging Folsom* exhibit also prompted an overhaul of the Landmark's website. The website updates and upgrades had a significant impact on accessibility.

Based on the success of both the *Engaging Folsom's* use of 3D technology and website upgrades, the Landmark built on digital offerings through a new temporary exhibit, *From Enormous to Tiny: Ice Age Animals of the Southern High*

Plains (*From Enormous to Tiny* exhibit), and the creation of a museum-wide mobile application. The *From Enormous to Tiny* exhibit incorporated 3D-printed objects, but the objects were painted realistically and included assistive orientation marks. A major role of the mobile application was as a platform for continued accessibility improvements, and to host additional exhibit experiences.

To achieve the goals of accessibility and inclusion, the Landmark utilized an agile, iterative design approach. Remaining flexible has allowed a small number of staff members to test and refine digital interactives over the past several years. In addition to flexibility, the Landmark took a realistic, scaled, and phased approach to digital interactive implementation. By starting with small objectives and projects, the Landmark established new digital benchmarks and then built on that success to expand the digital program.

The Landmark's experimentation with digital interactives also caused a ripple effect within its heritage education program and community offerings. The Landmark's heritage education staff created new workshops teaching 3D printing and photogrammetry principles; new summer camps for kids centered around 3D technologies; and established a new senior digital literacy course. The graduate program in heritage and museum sciences at Texas Tech University also expanded the topics covered in coursework due to the Landmark's incorporation of new digital interactives. Finally, the Landmark received two grants to support digital projects. This timetable illustrated the success a small institution can experience by using agile, iterative, and scaled design approaches.

The Landmark staff became major stakeholders for new digital interactives. This stakeholder group was incredibly important given the small size of the staff and the reliance on their support for the initiatives to succeed. Staff input was gathered at each stage of planning and demonstrations were conducted to familiarize staff with new digital offerings. Community stakeholders were engaged through surveys and a hands-on focus group. The Landmark's experience was unique in that a synergy of circumstances occurred: several staff members were interested in digital interactives, staff members were given protected time to work on digital projects, and the Landmark administration fully supported experimentation with digital projects to expand inclusive interactives. Lack of time, lack of interest, and lack of support may represent barriers at other institutions.

Through its digital projects, the Landmark has attempted to use technology as a tool to achieve greater inclusivity, and has prioritized inclusion throughout the development process. The Landmark has worked to expand its understanding of designing for inclusion through 3D modelling, 3D printing, IoT technology, and mobile app development. The two exhibits, *Engaging Folsom* and *From Enormous to Tiny,* that became the focus of these shifts, form case studies that highlight the Landmark's progress as well as the challenges faced.

Shifting Institutional Process

Agile

As Landmark staff began to experiment with more inclusive interactives, it became clear that it was not realistic to expect these interactives to be final products at the time of exhibit launch. With limitations including knowledge and resources, Landmark staff turned to an agile methodology to design interactives in small blocks. Limited resources were not an obstacle to implementing change when using agile methodology (Hegley et al., 2016). These interactives then were revised based on user feedback. Additional completed components were added to interactives as they were developed (Beck et al., 2001). Merritt (2017) noted that setting small project objectives and using a prototyping approach encourages experimentation within museum practice. This strategy allowed Landmark staff to be flexible and create a "culture of continuous improvement" (Merritt, 2017). It also removed the pressure of feeling that interactives had to be final at the start of the exhibit, and allowed staff to take risks.

Starting small and iterating often was the agile principle that resonated most with Landmark staff (Hegley et al., 2016). Rather than focusing on one large, perfect design, following the minimum viable product (MVP) principles led to building and testing smaller products (Flury, 2015). For the Landmark, MVP was applied across both exhibits that formed the basis for the Landmark's new approach to inclusion. By keeping objectives small in scope and focusing on the MVP approach, a snowball effect of growing success was achieved by a small group of Landmark staff. For example, in preparing for the *Engaging Folsom* exhibit, staff practiced printing open-source 3D models first to learn the process and then progressed to printing 3D models of Landmark collections objects. Once the Landmark collections objects were printed at satisfactory quality, staff experimented with adding braille and copyright logos to the 3D models. As success with braille and the copyright logo was established, staff experimented with creating a Raspberry Pi-powered interactive for the exhibit linking the 3D prints to the exhibit text. The success of the *Engaging Folsom* interactives encouraged additional projects, including website updates, experimentation with augmented reality (AR), a mobile app, and ultimately, the *From Enormous to Tiny* exhibit (Figure 2).

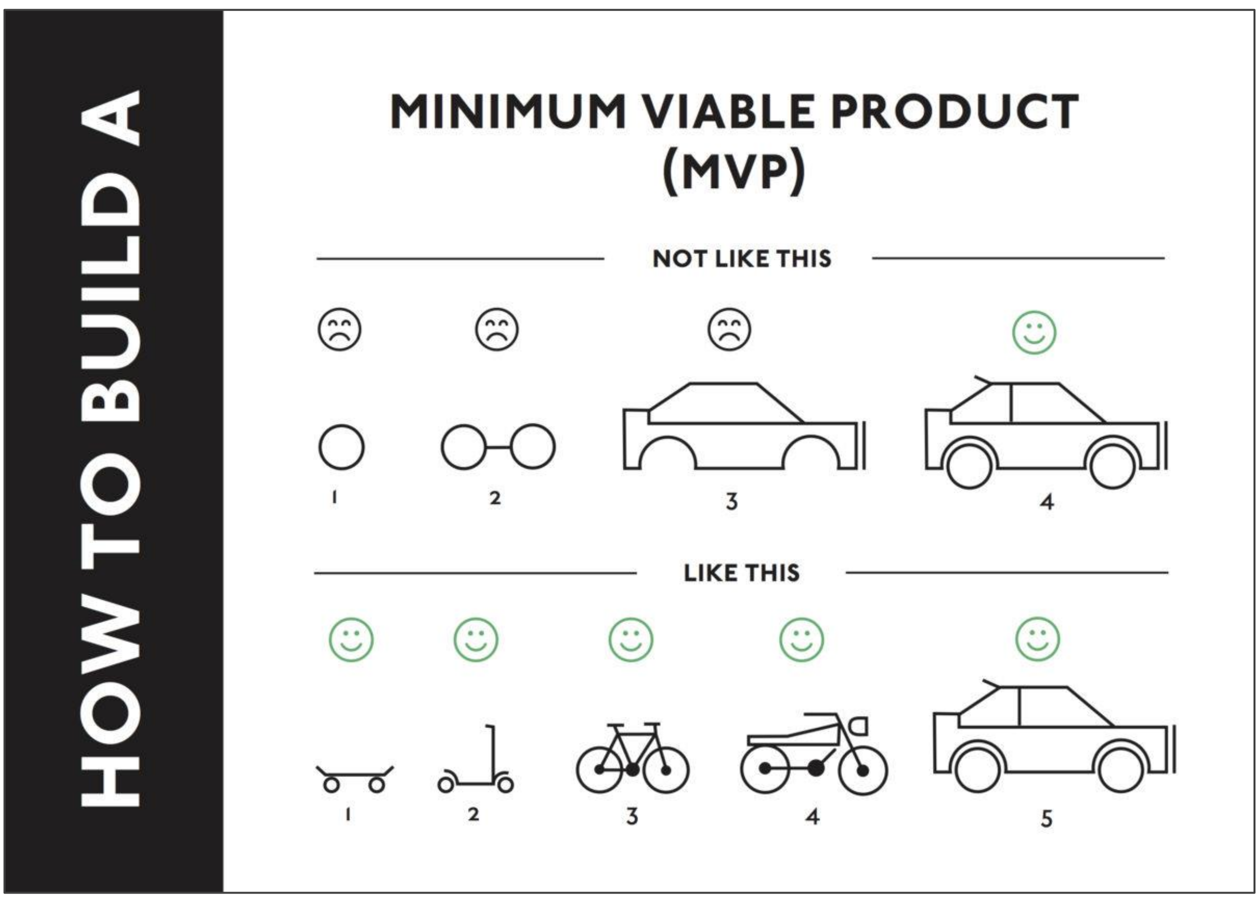

Figure 1: The minimum viable product (MVP) approach prioritizes prototyping, testing, and iteration (Flury, 2015).

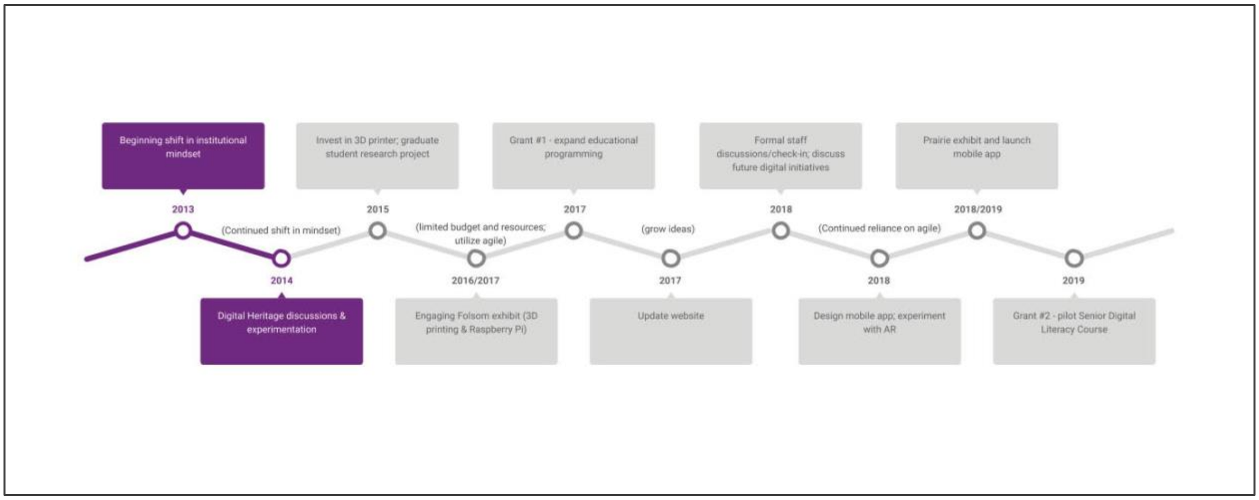

Figure 2: Landmark Shifting Institutional Process Timeline.

Universal Design and Universal Design for Learning

Landmark staff placed an importance on utilizing UD and Universal Design for Learning (UDL) while experimenting with digital interactives. Utilizing UD and UDL ensured that Landmark staff took a broad approach with design and placed accessibility and inclusion at the forefront of design decisions. For example, UD principles mandated that designs should be equitable, flexible, and simple to use (Connell et al., 1997) while UDL directed the what, why, and how of learning (CAST, 2018). Landmark staff applied these approaches in both the *Engaging Folsom* and *From Enormous to Tiny* exhibit interactives. The *Engaging Folsom* interactives acknowledged that visitors prefer to learn and engage with museum exhibits in a variety of modalities and, therefore, combined tactile and auditory components. Similarly, the digital interactives in *From Enormous to Tiny* provided tactile and auditory experiences through the layering of a mobile app with 3D-printed objects. The app went a step further and provided AR experiences for visitors who might enjoy additional visual experiences. Landmark staff recognized that offering content through an app presented a barrier to access, breaking UD principles. To counteract this barrier, a free device checkout program was established through the support of a grant. The device checkout program provided free iPads for visitor use with the app preloaded. The checkout program also provided important accessible hardware such as headphones and carrying cases with straps.

Understanding that visitors have different learning preferences strengthened the achievement of the exhibit's educational objectives with digital interactives. For example, a learning objective of the *Engaging Folsom* exhibit was to relate the importance to Folsom peoples of portability of stone tools. While this facet of life was explained in the exhibit text, it was underscored by the use of 3D-printed stone tools.

Grant Funding

Because internal funds did not exist to support digital interactive experimentation, the Landmark staff investigated alternate funding sources. Grant funding for educational programming associated with the *Engaging Folsom* exhibit and for digital interactives was received from the Community Foundation of West Texas. Specifically, this grant supported the purchase of a 3D printer, printing pens, filament, a Structure laser scanner, and the Raspberry Pi interactive hardware. The grant was capacity building for the Landmark, allowing for a growth in educational program offerings and further experimentation with 3D printing and modeling.

Landmark staff applied for and received a second grant from the Community Foundation of West Texas associated with the next temporary exhibit, *From Enormous to Tiny: Ice Age Animals of the Southern High Plains*. This grant covered the purchase of 10 iPads, carrying cases, headphones and earbuds, neck loops to interface with hearing aids, an app developer license, and other incidentals such as a locking case with charging for the iPads and wipes to clean the headphones (Table 1). Development and testing of the interactives was completed in-house.

Item	Cost
iPads	$3,090
Case with carrying strap	$220
Locking storage unit	$140
Over ear headphones	$200
Earbud headphones	$116
Neck loops	$399
Headphone splitters	$66
Sanitizing wipes	$45
Developer license	$99
Total:	**$4,415**

Table 1: The grant budget for the iPad checkout program associated with the *From Enormous to Tiny* exhibit.

Exhibit Case Study One: *Engaging Folsom (10,800-10,200) Hunter-Gatherers with 3D Technologies* Exhibit

The *Engaging Folsom* temporary exhibit served as a launching point for the Landmark to test digital in-gallery interactives. The exhibit explored the lives of Folsom peoples, the technology they created, their movement across the landscape, and their interactions with ancient bison and the landscape.
The *Engaging Folsom* exhibit interactives used 3D-printed objects and Raspberry Pis to maximize a small gallery space through intuitive, inclusive, and cost-effective methods.

By 3D modeling objects, the Landmark offered visitors unprecedented access to Folsom artifacts through the resulting 3D-printed objects (Figure 3). They offered tactile access to the objects for all visitors, especially those with visual impairments. Additionally, 3D-printed braille was incorporated in two ways: directly on the objects, and separate braille object labels. Raspberry Pi-powered capacitive touch sensors added an additional layer of accessibility to the exhibit displays. Visitors automatically engaged a recorded interpretive audio message by touching a 3D-printed object.

3D-printed braille and Raspberry Pi-powered capacitive touch sensors were used to transform static, inaccessible exhibit text into accessible, tactile exhibit interactives. Prior temporary exhibits at the Landmark relied primarily on photographs, text panels, labels, and museum objects. The *Engaging Folsom* exhibit marked a shift in practice for the Landmark. An internal, institutional mindset of experimentation with accessible interactives laid the foundation for the *Engaging Folsom* exhibit. The 3D modeling and printing elements used in the *Engaging Folsom* exhibit created a multisensory visitor experience that strove to be accessible and inclusive. Neumüller et al. (2014) emphasized that multisensory methods to experiencing cultural heritage increases access for a wider variety of audiences. The technologies were used as an interpretive tool to form new connections both between the museum and the visitor as well as the visitor and the collections objects (Suchy, 2004; Schur and Lee, 2015; Cameron, 2012).

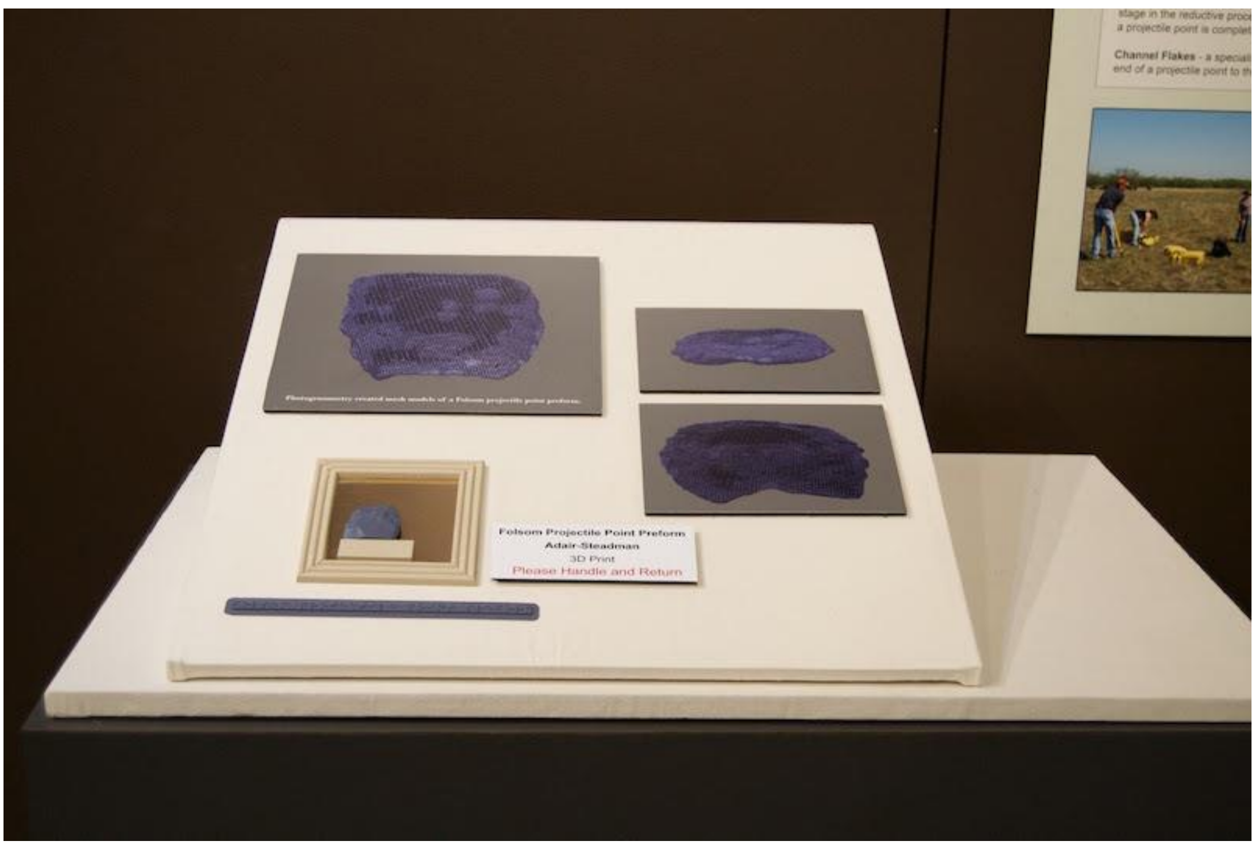

Figure 3: *The Engaging Folsom (10,800–10,200) Hunter Gatherers with 3D Technologies* exhibit contained several pedestals. Each pedestal included a 3D-printed object and braille object label on a slanted top platform. The Raspberry Pi capacitive touch interactive hardware components were housed underneath the slanted top. A visitor engaged the touch sensor by contacting the copper plate when touching or picking up the 3D-printed object. Courtesy of the Lubbock Lake Landmark.

Exhibit Technology

A Lulzbot Taz 5 3D printer has been used to create the prints for the *Engaging Folsom* exhibit. A Lulzbot Taz 5 is a type of 3D printer known as a fused filament fabrication (FFF) 3D printer. An FFF printer can use a variety of filament types to produce a 3D print. The most common type of filament used in FFF printers is plastic and the type of filament used for the *Engaging Folsom* exhibit was high impact polystyrene (HIPS), a type of plastic. An FFF printer and plastic filament are more affordable than other types of 3D printers and filaments. The level of detail achievable, however, is not as high as with other 3D printers. All 3D printers rely on support structures to produce a print. The placement and density of support structures can have a major impact on the quality of the resulting print. Support structures tend to be harder to remove when produced on an FFF printer so optimizing the print orientation and location of support structures is paramount.

A Raspberry Pi is a microcomputer roughly the size of a credit card. It is a powerful and affordable piece of hardware that can be used in a variety of ways to produce an exhibit interactive. As a microcomputer, the Raspberry Pi is a blank slate allowing the user to create a unique computer program to enact their desired results. A number of tutorials, a thriving user community, and open-source code all available on the internet ensure that the barrier to Raspberry Pi implementation is low, especially for beginners.

In the Landmark's case, a Raspberry Pi was used to create an inexpensive touch sensor with audio playback. To fully realize the interactive, a capacitive touch sensor hardware attached on top (HAT), ribbon cable, copper plate, copper tape, copper wiring, microSD card, flash drive, and speakers were used in addition to the Raspberry Pi. The *Engaging Folsom* exhibit webpage, available at, https://www.depts.ttu.edu/museumttu/lll/EngagingFolsom.html, included explanation on 3D printing as a component of the overall exhibit.

Exhibit Design

The Landmark used 3D technologies in the *Engaging Folsom* exhibit to convey the physical attributes of stone tools and abstract concepts of Folsom hunter-gatherer life. For example, by providing a 3D-printed stone tool, a visitor was able to feel the extreme thinness or the concave depressions and undulations resulting from flaking (removing pieces of stone) to shape the tool. Hearing or reading exhibit information while holding the 3D-printed stone tool provided an opportunity for a deeper connection to the highly mobile lifestyle of Folsom peoples. Increasing access to the tangible and intangible heritage of Folsom hunter-gatherers was made possible by the use of 3D-printed objects (Hurst et al., 2017; Stepp et al., 2018; Stepp, 2018).

Achieving high quality 3D prints required multiple iterations and prototyping phases, especially to identify the best location for braille on the objects. The braille could not obscure important object features, but had to be printed vertically to ensure legibility so the prototyping phases were critical.

Similarly, the design of the audio interactives was accomplished through prototyping. The audio interactive was low-cost and constructed with a Raspberry Pi, capacitive touch sensor HAT, ribbon cable, copper plate, copper tape, copper wiring, and speakers. The first prototyping phase made use of soldering the copper wires directly to the Raspberry Pi, but this method reduced the sustainable use of the Raspberry Pi in the future. The ribbon cable was added to the setup so that no direct soldering onto the Raspberry Pi occurred, ensuring easy repurposing of the Raspberry Pis. Further sustainability and easy maintenance were ensured with the separate housing of the operating system on a microSD card and the software and files for audio on a USB flash drive. By keeping the items separate, each could be removed and replaced quickly and efficiently while the exhibit was open. All of the hardware components, including the speakers, were housed out of the way underneath the slanted platform (Figure 3). The only exposed piece of the interactive was the copper plate that was necessary because it acted as the capacitive touch conductor.

Design decisions were made after careful discussion among several staff members and a volunteer. The decision was made to keep the 3D prints unfinished, i.e., unpainted and not weighted. They were sanded in the spots where the support structures were removed, but no alterations were made to color or weight. Stone tools were printed in grey plastic, while bones were printed in white plastic. For this first experimentation of exhibiting 3D-printed objects, Landmark staff wanted to be very intentional in relaying that the objects were replicas.

Incorporating the Raspberry Pi interactives was also discussed and several design paths were identified:

1. place one message on each Raspberry Pi;
2. place multiple messages on each Raspberry Pi;
3. use one Raspberry Pi for each 3D-printed object;
4. use one Raspberry Pi for multiple 3D-printed objects;
5. once triggered, auto play each message to completion; and
6. allow the user to interrupt a playing message to start a new message.

Options one, three, and five were chosen as they offered the simplest and most straightforward design for the interactives. Options two, four, and six left the staff with more questions and concerns than answers. For example, if one Raspberry Pi contained messages for multiple 3D-printed objects, would users be confused which object the message regarded? Would user A find it frustrating if user B could pause and interrupt the message user A started? Considering users who may be visually impaired, how frustrating would interrupting messages become? Without extensive user testing, the exhibit team decided options two, four, and six were not feasible. The other options were feasible within the short exhibit timeframe and could be tested while on display. Ultimately, a simpler interactive design path allowed the Landmark to implement an interactive rapidly with a limited budget.

Visitor Experience

While creating the *Engaging Folsom* exhibit, Landmark staff has recognized that museum visitors' preferences are diverse and that 3D technologies are not the only means to increasing accessibility to collections objects. Landmark staff approached 3D printing with the mindset that these versions would not replace original objects, they would be supplemental, as a means to provide a different avenue of engagement for visitors. Providing various forms of physical and digital information access is incredibly important in museum spaces (Lisney et al., 2013). As museums continue to rely on technology for visitor experiences, the number of visual experiences is increasing. Without a similar increase in tactile experiences, however, visually impaired visitors are left with a lack of access points. Therefore, tactile components such as 3D-printed objects or Raspberry Pi touch sensors can be very impactful. Lisney et al. (2013) stress that designing for inclusion improves accessibility for a wider audience.

Visitor feedback was collected through electronic and paper surveys. Observation evaluation data was also collected during the run of the exhibit. While in the exhibit space, visitors took similar movement paths through the space, but they did not stop at the same elements in the same order. Rather, the open, circular layout of the exhibit encouraged free-choice and visitor directed movement through the space. The 3D-printed displays acted as magnetic points of interest representing 44.54% of all visitor stops — the most stops of any exhibit components (Stepp, 2018). Overall, they provided a gateway for direct, tactile interaction with tangible and intangible heritage as evidenced through the survey results and observed behaviors. For example, in regard to the 3D-printed objects, survey respondents stated: "I liked that it tells the story and gives the feel of the actual piece" and "Gave us a piece of history to touch" (Stepp, 2018). Another respondent commented, "Touching the items makes them seem even more real [and] helps me understand the size [and] shape better" (Stepp, 2018). Visitor satisfaction was high with 93.5% of the respondents being extremely satisfied, very satisfied, or moderately satisfied. Likewise, 100% of respondents answered that they enjoyed interacting with the 3D-printed objects (Stepp, 2018).

In addition, visitors were observed displaying innate curiosity and excitement at interacting with the interactives. During one observation session, a young girl approached the Folsom Point pedestal and confidently touched the 3D-printed version. Her reaction included gasping, drawing her hands to her chest, and taking a step away from the pedestal. Two other visitors joined her, one of whom was an older woman. The woman reassured the girl that it was okay that she touched the 3D print. She encouraged the young girl to listen as the message was telling her about the object.

During a different observation session, a man engaged the Folsom Point interactive and listened intently. When he was joined by a female companion, he engaged the Folsom Point interactive a second time. During the second interaction, he picked up the 3D-printed object and showed it to his companion, pointing out the features highlighted on the audio message. Landmark staff viewed these behaviors positively and as markers of success. Despite not having realistically painted or weighted 3D prints or the most high-tech interactives, visitors were touching, engaging with, and discussing the exhibit content. This initial success encouraged the Landmark to keep experimenting with digital interactives, as seen in the *From Enormous to Tiny: Ice Age Animals of the Southern High Plains* exhibit.

Exhibit Case Study Two: *From Enormous to Tiny: Ice Age Animals of the Southern High Plains* Exhibit and Mobile Application

The Landmark's commitment to creating inclusive exhibit opportunities continued in its new temporary exhibit, *From Enormous to Tiny: Ice Age Animals of the Southern High Plains,* with the launch of a mobile application to coincide with the exhibit's opening in November 2018. This app was designed to expand a small gallery space digitally and create additional opportunities for educational outcomes. It was initially launched as a museum-wide app intended to immerse the visitor in important aspects of the Landmark, including its trails, wildlife and wildflowers, and archaeological and paleontological research from its broad approach to the Quaternary period. Particular emphasis was placed on using the app as a way to expand interactives in the Landmark's *From Enormous to Tiny* exhibit (Figure 4).

Figure 4: The Landmark's mobile app was used as a way to digitally expand a small gallery space in the *From Enormous to Tiny: Ice Age Animals of the Southern High Plains* exhibit. Headphones and an iPad from the device checkout program are used here to play audio in front of a 3D-printed extinct camel skull. Courtesy of the Lubbock Lake Landmark.

Inclusion was considered from the earliest phases of design. Mobile apps, if developed with regard to platform standards for accessibility, can allow greater freedom for users with disabilities to engage with content (Nasta and Adam, 2017). Apps were used successfully in museum settings as a way to provide additional accessible content when designed inclusively (Wyman et al., 2016). The Landmark app was designed as a native iOS app, following both Web Content Accessibility Guidelines (WCAG) (Patch et al., 2018), and iOS recommendations for accessible app design. To help ensure that these standards were being adhered to while allowing for potential limitations of staff knowledge, the app was reviewed through an accessibility review at Texas Tech

University. It was continually reviewed and updated for accessibility in-house, and external opportunities for review were sought as they became available. Among the many standards that staff considered when designing the app were screen reader compatibility, written transcripts for audio components, text resizing, high contrast colors, and size requirements for buttons. Accessibility was never considered complete, but rather viewed as a process. It was an area where staff continued to solicit feedback and expand their own knowledge to best meet community needs.

A free iPad checkout program also was established at the Landmark to facilitate visitor use of the app onsite. This program was intended to mitigate the need for a visitor to own their own smart-device, and, therefore, the potential barrier the requirement of owning a smart-device might pose to community use. Over-the-ear headphones, earbuds, headphone splitters, and neck loops for hearing aids were also offered for free as part of the checkout program as a way to preempt potential obstacles to using the iPad interactives. Devices offered for checkout were funded through a grant.

Interactives triggered through the app included a mural interactive and AR content such as models of collection objects (Figures 5, 6). Additionally, the app incorporated audio content to supplement the ways in which visitors could interact with a primarily text-driven exhibit. Based on the success of 3D-printed collections objects in the *Engaging Folsom* exhibit, 3D prints were incorporated into this exhibit as well. Offering a range of content delivery methods was an important way for the Landmark to continue towards its inclusivity goal.

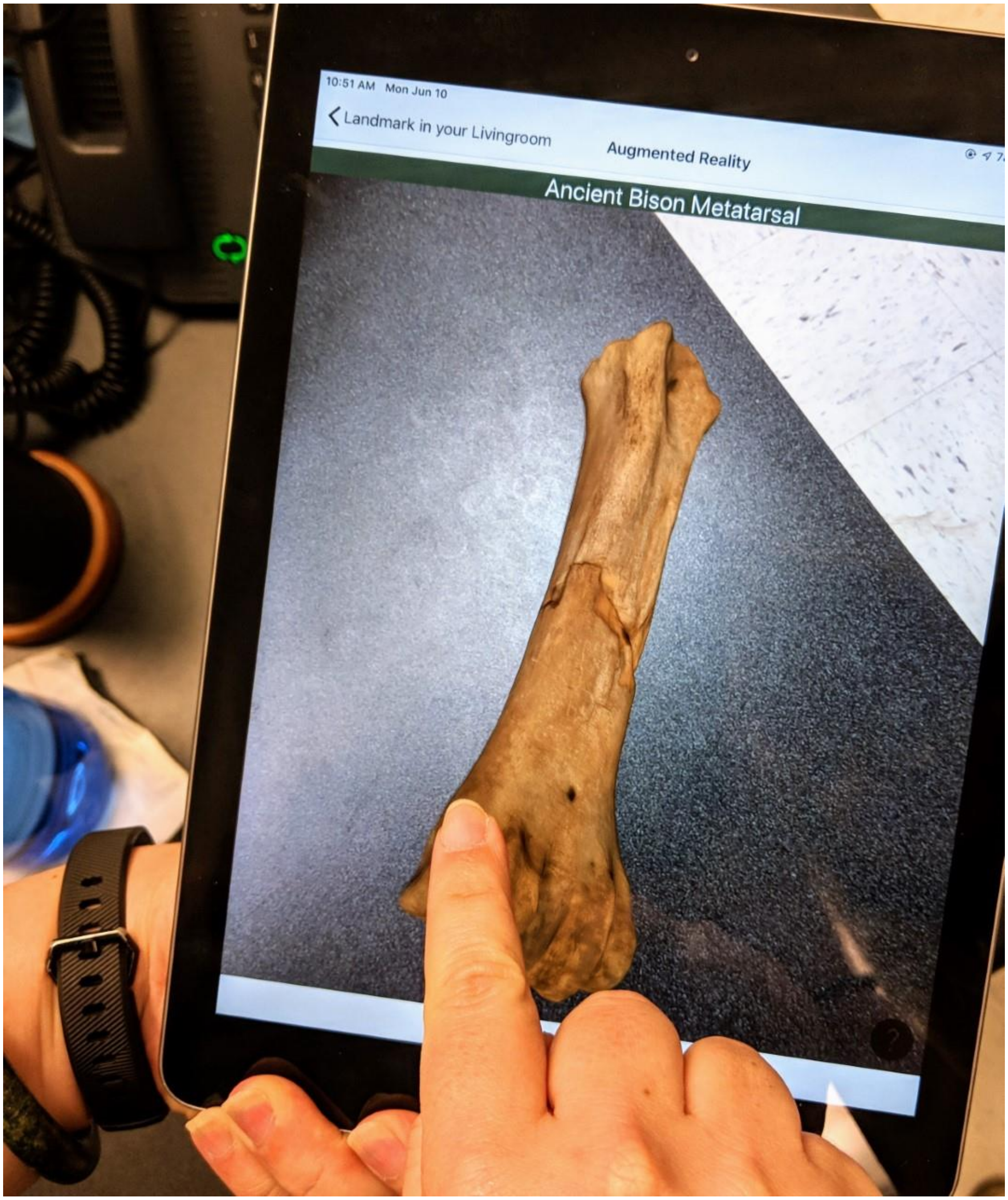

Figure 5: User testing of interacting with an ancient bison metatarsal projected in AR. Courtesy of the Lubbock Lake Landmark.

Figure 6: A user projects a bison bone in AR in the gallery. Courtesy of the Lubbock Lake Landmark.

The mural interactive, triggered through the app, was based on image recognition. When a visitor scanned an animal in the mural with the iPad, facts about the animal, its name, and its extinction status would appear on the iPad screen. Animals were color coded to allow the user to distinguish quickly if they were extinct, extirpated (i.e., no longer living in the region), or extant — an important takeaway of the exhibit (Figure 7). The interactive was designed in response to informal testing with 11 and 12-year-olds from a summer youth camp. Summer camp participants had responded positively to interactives that allowed them to work collaboratively to solve problems. The mural interactive was then designed to allow this collaboration while meeting the exhibit's educational goals of understanding the extinction status of different Ice Age animals. Other AR models of collections objects were incorporated into the app to allow the Landmark's community access to the objects in 3D that they would not otherwise have. It was also a way to reach segments of the community that may not be able to experience the Landmark in person.

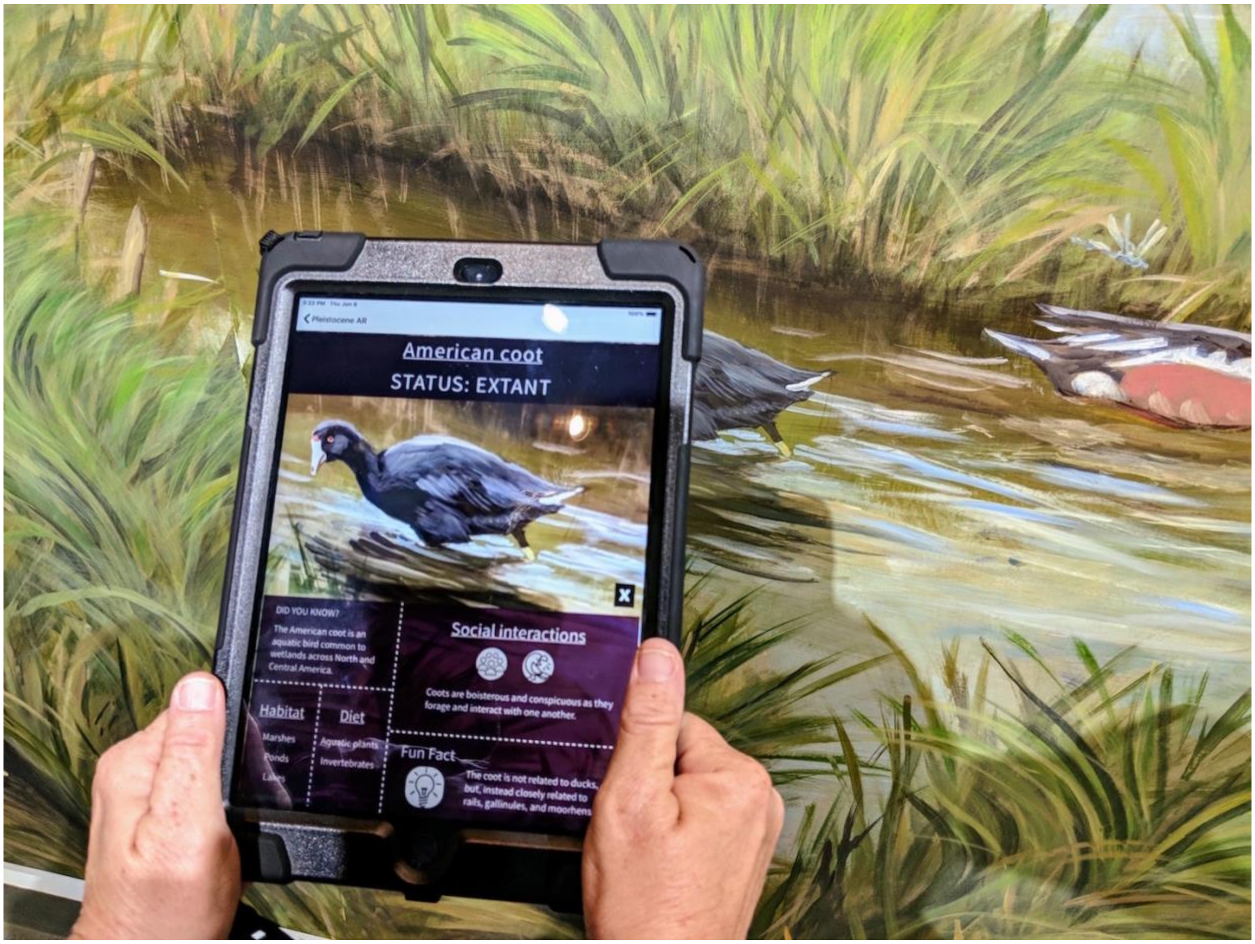

Figure 7: Animals in the mural were color coded based on whether they were extinct, extant, or extirpated. Courtesy of the Lubbock Lake Landmark.

Challenges and Moving Forward

The realities of trying to expand gallery interactives in a setting without a formal budget have led to the app being viewed internally as a platform for accessible content, rather than a finished product. The intent of this platform is to allow new interactives and content to be deployed frequently, responding to visitor feedback in an agile way. For example, the initial app includes extra exhibit content as audio tour files, with an optional transcript. Full visual descriptive tours that can meet the needs of visitors better and will be able to be incorporated within the same audio platform are currently being developed.

One of the main challenges in using the app to increase inclusive interactives is figuring out how to present these in an equitable way for all visitors. For example, adding collections objects that could be viewed in AR has opened up access to individuals who could not visit the Landmark in person, or who were more comfortable learning and experiencing the objects in this way. The option to add augmented reality models, however, currently does not address the needs of visually impaired visitors. The Landmark is continuing to offer touchable, 3D-printed versions of collections objects in exhibits as a way to reach the broadest possible audience. Going forward, however, an important objective is to better integrate these various ways of interacting with content.

As with the *Engaging Folsom* exhibit, the *From Enormous to Tiny* exhibit interactives has served as an important test of the Landmark's inclusive initiatives. Visitor feedback is currently being recorded through paper-based surveys. Informal observation and evaluation, in addition to the surveys, have allowed the Landmark development team to respond quickly and update components of the app to meet visitors' needs. Preliminary results indicate that between February and September 2019, 76 iPads were checked out to groups composing a minimum of 273 individuals. Feedback is generally positive, including statements like "It was interesting to observe the artifacts as if they were in my hand," and "I enjoyed the AR program and think it is a unique addition to the museum."

Comments that indicated any difficulties using the app were addressed as quickly as possible after they were noted, based on staff time. For example, an early mural interactive became too difficult for visitors to read as they scanned multiple animals. To address this comment, a new version was developed that triggered text to appear on the user's screen separately for each animal they scanned. This version was launched in April 2019 (both versions shown in Figure 8). This update included additional user instructions and clarifications. The ability to respond quickly to visitor feedback was one way the Landmark strove to compensate for the lack of a formal development budget. Survey responses will form a foundation for interactives in the next temporary exhibit to be opened at the Landmark.

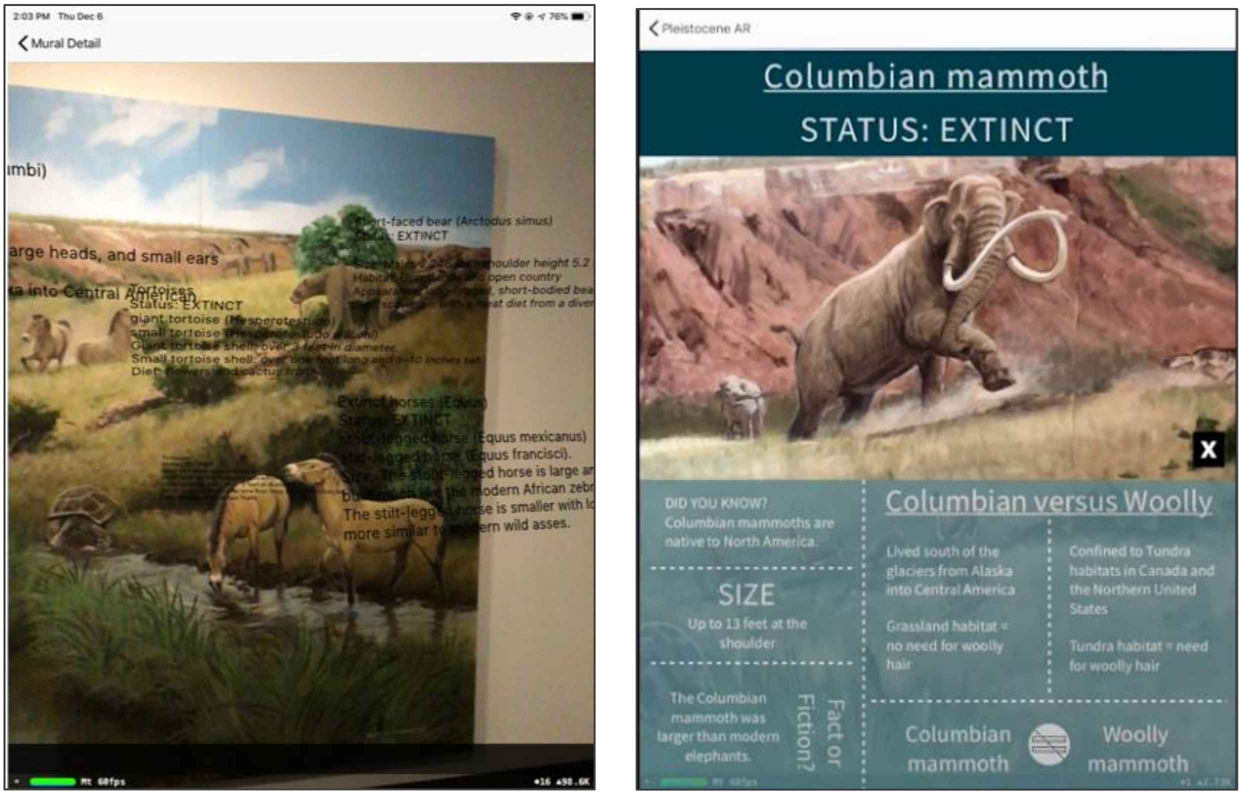

Figure 8: *Left*: The early mural AR interactive was simple in design, but the text was too difficult to read.
Right: After several design iterations and user testing, the current mural AR interactive screen ensures text is legible through shading and text blocking. Courtesy of the Lubbock Lake Landmark.

Results and Discussion

Interactives for both the *Engaging Folsom* and the *From Enormous to Tiny* exhibits were completed in-house without a development budget. Grant funding facilitated the purchase of capacitive touch sensor components in the case of the *Engaging Folsom* exhibit, and the device checkout in the case of the *From Enormous to Tiny* exhibit. In response to a limited budget and small staff size, the Landmark staff relied on an agile approach to development. By following agile design principles, the Landmark was able to develop smaller, complete experiences for its audience and launch the experiences quickly. A guiding principle of agile design was creating working products often and maintaining flexibility while working with important stakeholders (Beck et al., 2001). By developing smaller products at a quick pace, the Landmark continued to build on interactives throughout the life of the exhibit. For example, a simple AR interactive was developed quickly (within three months) for app testing purposes that follows the agile design principles to deliver products on a quick timescale (Beck et al., 2001). The interactive was then refined for several months based on user feedback. By not focusing on a perfect version of the AR interactive before sharing the iteration, staff were able to meet project deadlines and receive feedback quickly. Achieving those results was critical for a small staff.

Landmark staff also relied on a scaled approach to design. This approach allowed staff to cope with limited resources, while still trying to achieve the Landmark's interactive objectives. Staff applied a scaled approach within individual interactive projects and broadly to the overall interactive program. By setting smaller interactive objectives, a small staff was able to achieve the large project goals over time. The incorporation of 3D printing into exhibit interactives was achieved through a scaled approach. The first step was to become familiar with the technology and then experiment with printing Landmark collections objects. As confidence with 3D printing grew, experimentation and new project objectives formed such as adding braille and a copyright logo. Several versions of each were tested, tapping into agile principles. Staff working on the 3D printing process routinely sought feedback regarding printing quality so that adjustments happened rapidly. Staff achieved success with 3D printing braille and a copyright logo in part because of the realistic, scaled approach.

This approach, however, did mean abandoning the idea of launching one complete product, as that was not feasible with the resources available. Major challenges Landmark staff faced were lack of budget, limited knowledge, and small staff size. Interactives did not always work as intended. A more flexible, responsive program of interactives inherently came with risks that they would not meet the Landmark's ultimate goals. Even when problems with interactives were identified, however, community support for additional interactives remained high, based on the surveys. The benefits of trying new things ultimately outweighed the potential negative impacts of taking risks.

Significantly, design elements for both exhibit interactives included anticipating requirements for creating inclusive experiences from the earliest stages of development. With a small staff of two to three working on interactive projects, staff time was a scarce resource. Acknowledging that time was tight and that building inclusive interactives was a corner piece of each project, staff prioritized addressing inclusion at each step. By focusing on inclusion from the beginning, Landmark staff built better interactives and did not have to rework project timelines to address concerns around inclusion at the end of a project. Inclusion is neither difficult nor expensive to achieve — the mistake of not focusing on inclusion from the start is what creates difficulty and expense. The Landmark incorporated inclusive design by looking to universal design principles, applying current best practices for inclusive and accessible experiences, and through testing and feedback. Given the usage of digital interactives, they cannot be implemented at the cost of educational outcomes and museums should not focus solely on physical accommodations as the only marker of increased accessibility and inclusion. Rappolt-Schlichtmann and Daley (2013) stressed:

1. the importance of meaningful education outcomes for all visitors, rather than solely physical accommodations; and
2. how a Universal Design for Learning approach can improve the experience for all.

This mindset was adopted by the Landmark as one of its founding principles in creating digital interactives.

Conclusions

Over the last few years, the Lubbock Lake Landmark was able to shift from static, text-based exhibits to include tactile and audio components as a regular part of its exhibit design. These additional components ranged from 3D-printed collections objects and braille to additional audio content and augmented reality interactives. Throughout, the Landmark used an agile design approach, and a scaled development process to reach its goals of accessibility and inclusion within a cost-conscious framework.

Landmark staff created new interactives and also faced several challenges throughout the development of its digital projects. Interactives did not always work as intended initially and had to be revised through several iterations. As staff learned more about what was required to be inclusive, they were better able to conceive products that met visitors' needs and to revise products that did not. They also became more comfortable with experimentation, more creative, and more willing to take risks.

A shift in mindset towards a universal design process was ultimately the most important outcome of the interactives associated with the *Engaging Folsom* and the *From Enormous to Tiny* exhibits. This new mindset led to alternate forms of content, including tactile and audio, becoming a standard part of the design process for new exhibits. It also led to a greater understanding of what inclusivity means in the context of digital interactives. As the Landmark looks forward to future exhibits, this mindset will underpin planning for all interactives.

Acknowledgments

Research conducted as part of the *Engaging Folsom* exhibit was approved under the IRB2017-407 project: Visitor Perceptions of Museums and the Use of 3D Technologies. Educational programming for the *Engaging Folsom* exhibit was funded through the Helen Jones Foundation and a grant from the Community fund of the Community Foundation of West Texas. The iPad checkout program and assistive device checkout for the *From Enormous to Tiny* exhibit were supported by a grant from the E. Jay Matsler Trust for Historic Preservation fund of the Community Foundation of West Texas. Educational programming for the *From Enormous to Tiny* exhibit was funded through the Helen Jones Foundation. Models and 3D prints were created in the Museum of Texas Tech University's Digital Heritage Lab overseen by Dr. Stance Hurst. This article represents part of the ongoing Lubbock Lake Landmark regional research efforts and community involvement.

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