UNIVERSAL DESIGN OF INTERACTIVES FOR MUSEUM EXHIBITIONS

Research Report

Report Written by Christine A. Reich
May 2005
Report #2005-3
Funded by the National Science Foundation

National Center for Technological Literacy

Museum of Science, Boston

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Universal design of interactives for museum exhibitions

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Technologies in Museum Education

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May 2005

ABSTRACT

Museums are places where visitors of all abilities and disabilities are invited to learn. This diversity offers a unique challenge—how can museums ensure that everyone can benefit from the learning experience? Universal design, which is "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" (Center for Universal Design, 2002), puts forward a potential solution.

This paper offers an overview of universal design, including its practice in the museum, formal education, and digital media fields, and more specifically, its application at the Museum of Science, Boston. It then presents results of a research study examining how 16 users of a broad range of abilities and disabilities use interactives designed to be accessible for persons with disabilities. Study findings yield insights on how individuals with disabilities interact with computer interactives and illustrate that design is not benign and can either support and enable, or detract and disable, an individual's ability to learn. In addition, study findings demonstrate that certain design features support learning for a broad range of users and that features implemented to provide access for one audience can lead to improved experiences for another. However, results also suggest that experiences that are "usable by all people, to the greatest extent possible" are not always "better for all."

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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, one of the founders of the universal design movement in museums (Association of Science-Technology Centers, 2000b)*

Museum professionals frequently assert that informal education institutions provide opportunities for those who are labeled as disabled in the classrooms to excel at learning and acquiring new information because these institutions foster interactive and self-paced learning (Baum, 2004; Rudy, 2004). The notion that the ability to learn is contextual, and that certain learners can do extremely well in some environments yet fail in others, is also shared amongst those who advocate for the social model of disability and promote a socio-cultural framework for understanding learning (McDermott, 1996; Rose & Meyer, 2002).

The social model defines disability as society's response to "human difference" which results in the design of environments for persons whose physical characteristics fall into the narrow range defined as "normal" and the exclusion of individuals who fall outside of that range (Gill, 1999).

> *The social model of disability represents nothing more complicated than a focus on the economic, environmental and cultural barriers encountered by people viewed by others as having some form of impairment. These include inaccessible education, information and communication systems, working environments, inadequate disability benefits, discriminatory health and social support services, inaccessible transport, houses and public buildings and amenities, and the devaluing of disabled people through negative images in the media- films, television and newspapers. (Barnes, 2003)*

The social model of disability is a radical departure from the traditional, medical model which defines disability as a medical defect that should be treated or fixed (Gill, 1999). The medical model of disability is pervasive in American culture, where it is present in the images of media celebrities who fight against all odds to remove themselves from the "constraints" of a wheelchair (Groopman, 2003) and even in the definition of disability used by the US Census Bureau (Waldrop & Stern, 2003). Disability studies scholars argue that the medical model of disability leads to "ableism" and a denial of rights that coincides with the notion that persons with disabilities are somehow "other" (Gill, 1999; Smith, 2001).

Museums have a responsibility to consider how the design of the educational interactives, programs, and exhibits they create prevent against "ableism" and the denial of rights for persons based on physical differentiation, and support learning for all members of the public, including those traditionally labeled as 'disabled.' As stated by Robert McC. Adams, former Secretary of the Smithsonian Institution,

> *Were we to ask our colleagues, "Would you deny a person access to your museums' collections or programs solely on the basis of his individual differences?" they would surely say "No, never." Yet for years this is exactly what we have unknowingly done to people with disabilities. We have set up, albeit inadvertently, physical and attitudinal barriers that have kept disabled people from enjoying educational experiences our museums have to offer…This exclusion of disabled visitors has been due to neglect, not malevolence. The problem at first was not knowing there was a problem. Once we recognized it, we did not know how to correct it…It is time to educate ourselves about disabilities and about how they affect people's lives…*

This paper offers insights on how universal design can be employed by museums to create interactives that are accessible and equitable for museum visitors of a broad range of abilities and disabilities. It provides an overview of universal design, including its practice in the museum, formal education, and information technology fields, and then more specifically, its application at the Museum of Science, Boston. It then presents results of a research study that examines how 16 users of a broad range of abilities and disabilities interact with digital media-based interactives at the Museum of Science that were designed to be accessible for persons traditionally labeled as “disabled.”

This paper embraces the notion that it is the intersection of the person and the designed environment that defines who is able and disable to learn. Therefore, the use of the term “persons with disabilities” may appear to be a misnomer as an individual who is disable to learn in one environment may be able to learn in another. However, one cannot ignore that there are many individuals who are traditionally labeled as “disabled” and for whom the label is an essential part of his or her identity and life experiences. For this reason, the term “persons with disabilities” will be used to define this segment of the population, despite its appearance as a contradiction to the social model of disability.

The study intentionally focuses on the universal design of digital media[1] as it offers museums new solutions for creating interactive exhibitions that are accessible to all. The ability of digital media to convey information simultaneously through audio, written text, and moving images, provides access to learning for visitors who are traditionally excluded when only one of those elements is available. Individuals working in the field of formal education have recognized the potential of digital media as a learning tool:

> *Traditional classroom materials and media, like books and speech, come in “one size” for all, but they do not fit everyone. Inflexible media actually create barriers to learning…new classroom media, like digital text, sounds, images and the World*

[1] In the 1997 Journal of Museum Education issue titled “Digital Media in Museums,” the editors define digital media as “communication stored in formats a computer can display such as videodisks, software programs, CD-ROM, and Web pages.” (Rusk & Slafer, 1997)

> *Wide Web, can be adjusted for different individuals and can open doors to learning. (Rose & Meyer, 2002)*

Despite this potential, most museums do not take advantage of digital media to provide learning experiences that are accessible to all. In most cases, exhibit developers simply don't know how or where to begin. This study is a first step towards providing the museum industry with information exhibit developers and designers can use to develop digital media-based interactives that are accessible to all.

Background on universal design

Few, if any, studies have previously examined ways to design computer interactives for use in museum exhibitions that are accessible for visitors with a broad range of abilities and disabilities. However, the scope of this study (and the design of the computer interface being studied) were strongly influenced by literature describing the philosophy behind universal design, information about persons labeled as disabled as a museum-going audience, and research relating to the design of digital media.

What is universal design?

> *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 (Center for Universal Design, 2002).*

Universal design is a democratic design philosophy that promotes inclusion and access for all through a designed environment that does not stigmatize based on physical differentiation. Iwarsson and Stahl consider universal design to be about "changing attitudes throughout society, emphasizing democracy, equality and citizenship" (Iwarsson & Stahl, 2003). For this reason, the authors state, "universal design denotes more of a process than a definite result." Advocates of universal design believe that this process creates environments that are better for everyone. Story, a researcher from the Center for

Universal Design, tells us “Successfully designed universal solutions do not call attention to themselves as being anything more than easier for everyone to use, which is exactly what they are” (Story, 1998).

Universal design is not the only method used to create environments that include the needs of persons with disabilities. Other approaches include accessible design, and assistive technology. While these terms are often used interchangeably and imply relatively similar goals, there are subtle differences in these approaches that define the end product and the process that is used to develop it.

Assistive technology focuses on the creation of products tailored to the specific needs of an individual, to be used by that individual as he or she navigates through an environment (be it virtual or real). A wheelchair is an example of assistive technology. Accessible design focuses on designing environments to be used by individuals who have disabilities and considers how the person and the assistive technology interact with the designed environment (for example, curb cuts take into consideration that some individuals use wheelchairs to move around). Universal design looks more broadly at the potential user base, and considers not just how to design for the person and the wheelchair, but all potential users such as persons who are blind who may have difficulty detecting the curb cut unless it is demarcated with tactile grooves.

Those who advocate for the use of universal design differentiate it from accessibility and assistive technology. Accessibility is often defined as the adherence to specific codes or requirements created specifically for persons with disabilities (Iwarsson & Stahl, 2003; Story, 1998). Iwarsson and Stahl (2003) tell us that accessible design is generally measured quantitatively (how well you meet required specifications) with little to no input from the actual users, as compared to universal design where user input is a critical part of the design process. Story (1998) feels that the concept behind accessible design leads to stigmatization of persons with disabilities, as the adherence to the mandated codes often leads to “separate design features for ‘special’ user groups,” which “segregate people with disabilities from the majority of the users and make them feel out of place.”

The process that leads to the development of universal design reflects a philosophy that considers all users to be located on a broad spectrum that ranges from able to disabled. Where a person is positioned on that spectrum depends upon his or her individual needs and the designed environment. Universal design focuses on the users at one end of the spectrum, and tries to determine ways these individuals can become more “able” to complete a given task. It is assumed that if user needs at the ends of the spectrum are met, access will increase for everyone (Rose & Meyer, 2002). This philosophy reflects the social model of disability, where it is the environment and cultural attitudes that define whether a person is “able” or “disabled”, and not the physical attributes of the person.

Universal design also reflects a push towards creating environments that promote inclusion, as opposed to “separate but equal” accommodations for persons with disabilities. Blamires (1999) considers inclusion to be an essential element in the universal design of learning environments. He defines inclusion in three different categories: physical, social and cognitive, and considers inclusion to be a function of both access to and engagement in a learning experience. In the United Kingdom, the term “inclusive design” is often used in place of “universal design.” In 2004, new inclusive design codes were created for the City of London, which includes codes for museums (Fleck, 2004). This document lists three defining characteristics of an inclusive design:

- Can be used safely and easily by as many people as possible without undue effort, separation or special treatment;
- Offer the freedom to choose and the ability to participate equally in the development's mainstream activities; and
- Value diversity and difference.

In addition to what it is trying to achieve, universal design is also defined in terms of *how* it can be achieved. A number of authors have developed "Principles of Universal Design" that define criteria for judging whether or not an experience is a universal design. The most notable example is the "Principles of Universal Design" developed by the Center for Universal Design (Story, 1998):

- Principle 1: Equitable use
- Principle 2: Flexibility in use
- Principle 3: Simple and intuitive
- Principle 4: Perceptible information
- Principle 5: Tolerance for error
- Principle 6: Low physical effort
- Principle 7: Size and space for approach and use

An alternative framework developed specifically for formal learning at the university level is the "Principles for the Universal Design of Instruction," which are based on the original principles developed by the Center for Universal Design (Bowe, 2000):

- Equitable use
- Flexibility in use
- Simple and intuitive instruction
- Perceptible information
- Tolerance for error
- Low physical effort
- Size and space for approach and use
- A community of learners
- Instructional climate (welcoming and inclusive environment for learning)

The Center for Applied and Specialized Technologies (CAST) also developed principles of universal design, which were created to address the development of curriculum and multimedia for the K-12 classroom (Rose & Meyer, 2002):

- To represent information in multiple formats and media;
- To provide multiple pathways for student's action and expression; and
- To provide multiple ways to engage students' interest and motivation.

Few studies have examined the effectiveness of applying any of the above stated principles to create environments that are "better for everyone." One exception is a study conducted at the Lighthouse, Inc. building in New York City examining reactions to, and use of, a universally designed building by both disabled and abled participants (Danford, 2003). The results of this study were mixed. While both the abled and disabled participants were able to successfully navigate through the building and thought the design was better than most they had visited before, the abled participants expressed frustration with some aspects of the building's design such as the multimedia map and the lack of traditional signage. Another example is a study that compared how both abled and disabled students performed on a test that met the principles of universal design and one that did not (Johnstone, 2003). The results of this study were more positive than the Lighthouse, Inc. building study. It found that all students, including those with disabilities and those without, performed better on the test designed using the principles of universal design.

Persons with disabilities as a museum-going audience

Over the last twenty years, museums across the United States have increasingly incorporated the needs of diverse learners when creating exhibitions. Numerous publications, websites, and professional development workshops have been developed that provide architectural guidelines for creating accessible exhibitions. These guidelines are based on federal standards and regulations, such as the Americans with Disabilities Act (ADA). Publications that address the physical differences among individuals and the resulting space and architectural requirements include *Everyone's Welcome* (American Association of Museums, 1998), *The Smithsonian Institution's Guidelines for Accessible Museums* (Smithsonian Accessibility Program, 1996), and *Hands-on Exhibits that Work* (Kennedy, 1997). Additionally, two other publications including *New Dimensions for Traditional Dioramas* (Davidson, 1991) and the Museum of Science's *Universal Design* website (Museum of Science Boston, 2001), go beyond physical accessibility and assert that universal design for learning involves creating multi-sensory, multi-modal learning experiences from which all visitors can learn by touching, seeing, listening, smelling, and sometimes even tasting.

In 1999 the Association of Science-Technology Centers (ASTC) began an "Accessible Best Practices" initiative to increase awareness of federal regulations and accessible design to science center professionals (Association of Science-Technology Centers, 2000a). This effort resulted in an increased attention towards access-related issues at annual science center conferences. According to George Hein, the evaluator for the project:

> *Both directly and indirectly the Accessible Practices project has had an increasing impact on the content of the ASTC meetings. The total number of sessions devoted to accessible practices has increased annually. (Hein, 2002)*

Museums are also beginning to include visitors with disabilities in both formative and summative evaluation of exhibitions. Examples include the formative evaluation of the Smithsonian Institution's traveling exhibition *Invention at Play*, the summative evaluation of the most recent traveling exhibitions created by the TEAMS 2 collaborative, the summative evaluation conducted by the Institute for Learning Innovation of the traveling exhibition *Dogs! Wolf, Myth, Hero and Friend*, and the formative and summative evaluation of the Museum of Science's *New England Lifezones, Secrets of Aging,* and *Making Models* exhibitions.

While these efforts are notable, there exists an absence of visitor *research* related to the universal design of museum exhibitions. A search for articles in a database focused on museum learning (www.informalscience.org) found fewer than 10 papers that address accessibility or disability and learning in museums.[2] Less than one third of these 10 papers were research-based, and almost all were unpublished Master's Theses and these

[2] This search was performed using a variety of related keywords, including disabled, handicapped, access, accessibility, disability, wheelchair, blind, deaf, vision, hearing, and universal.

did not address accessibility in exhibitions. A similar search conducted using the Educational Resources Information Center (ERIC) database found only 13 citations related to accessibility or universal design and museums. Two of these articles were research-based, and neither addressed science education or museum exhibitions. The only published articles that present results of a study on the accessibility of exhibitions include a study of the *New England Lifezones* gallery that was conducted at the Museum of Science in the late 1980's (Davidson, 1991), and studies that address the needs of older adults as museum learners (Kelly, Savage, Landman, & Tonkin, 2002; C. Reich & Borun, 2001).

The search results listed above echo the findings of Steve Tokar, a graduate of the John F. Kennedy University Department of Museum Studies whose Master's Thesis focused on the application of universal design by museum exhibition developers.

> *At present, universal design in museums remains under-evaluated. There has been very little formal visitor research and evaluation specifically designed to measure the effectiveness of UD in hands-on science museums. Many people I spoke with had a great deal of anecdotal information at their disposal—at the Museum of Science, there are notes and records going back over 10 years—but extremely little in the way of summative evaluations published in peer-reviewed journals. Such research studies are unlikely to take place unless funding for them is budgeted into exhibition grant proposals. (Tokar, 2003)*

A few studies are currently underway that focus on the use of digital handheld devices to provide access to learning in museums for persons with disabilities (Brookfield Zoo, 2002; Giusti & Landau, 2004; Kirk, 2001; Tate Modern, 2004). These efforts, however, are focused on creating assistive technologies that supplement a user's experience in an exhibition, and do not examine ways to make the actual exhibitions accessible to a broader audience. As discovered in an evaluation of an audio tour at the

New York Hall of Science, simply adding assistive technologies to an inaccessible exhibition is not sufficient for creating an environment where visitors of a broad range of abilities disabilities can learn (Friedman, 2000).

There is also little information about the museum going habits of persons with disabilities. It is difficult to find data that estimates the number of people with disabilities who attend museums on a regular basis, or information about whom they attend museums with. In the 1995 report “Who Attends Our Cultural Institutions? A Progress Report” produced by the Smithsonian Institution, there is no mention of persons with disabilities as a museum-going audience (Doering, 1995). Again, in the 1998 article “Visitors: Who does, who doesn’t and why,” no mention is made of persons with disabilities and their presence (or lack thereof) in the museum-going population (Falk, 1998).

While the number of persons with disabilities who attend museums is still unknown, this population could potentially represent a significant portion of the museum audience. In the 2000 U.S. Census, close to 50 million people, 19 percent of the US population, reported that they had a “long-lasting condition or disability” (Waldrop & Stern, 2003). The percentage of the population that has a disability is expected to increase during the next 30 years. By the year 2030, it is predicted that 20 percent of the US population will be over 65 (Federal Interagency Forum on Aging-Related Statistics, 2000). While growing older does not guarantee the development of a disability, the percentage of the population with a disability increases with age.

If museums are going to provide a learning environment for all people, attention will need to be given to designing exhibits and programs that accommodate a wide variety of needs. Therefore, research studies such as the one described in this report, are essential for providing museums with the information they need in order for them to serve this large and ever-growing audience.

Universal design of digital media

The use of digital media as a learning tool is a growing phenomenon in museums of all types and sizes (C. Reich, 2002). This is reflected in the formation of the American Association of Museums (AAM) Media and Technology Committee, and the annual Museums and the Web conference. It is not surprising, therefore, that museums have begun to explore how digital media can be used to create learning environments that are inclusive of persons with disabilities. A number of studies are currently underway or have recently been completed that focus on the use of digital handheld devices to provide access to learning for persons with disabilities (Brookfield Zoo, 2002; Giusti & Landau, 2004; Kirk, 2001; Tate Modern, 2004). While noteworthy, none of these studies have focused on the universal design of computer kiosks in museums, despite the fact they are commonly used in museum exhibitions (C. Reich, 2002). This study is the first study conducted in the museum industry that addresses this topic.

Museum guidelines such as those created by the Smithsonian Accessibility Program (Smithsonian Accessibility Program, 1996) and the American Association of Museums (American Association of Museums, 1998) provide information on the design of the kiosk that houses a computer interactive and limited information about the controls, but do not address the actual user interface. The ASTC accessible best practices website contains some information on making museum websites accessible to visitors with disabilities, but this information is not directly applicable to the design and planning of digital media-based interactives for use in exhibitions (Association of Science-

Technology Centers, 2000a). Only a few museums or groups have made significant contributions to this area, the most notable example being the Museum of Science (Museum of Science Boston, 2001).

Despite the lack of data available in the museum field, lessons learned from research performed in the fields of assistive technology, web site development, educational technologies, and software development can serve as a starting point for museums as they develop strategies to use digital media to enhance access for all.

Studies conducted in the field of multimedia learning have demonstrated that the use of multimedia to deliver content simultaneously through both images and audio has a positive impact on learners who do not have disabilities. One study of second-language learners found that students were better able to recall the meaning of words when they were presented with both visual and verbal representations of the terms (Plass, Chun, Mayer, & Leutner, 1998). In another study, students' ability to remember weather-related content and apply that content to problem-solving increased when the students looked at a computer animation and heard a description of the content read aloud, as opposed to when the students watched the animation along with text written on the screen (Meyer & Moreno, 1998). While these studies did not include students with disabilities in the testing, nor did they specifically address the principles of universal design, they do suggest that software designed to include persons with disabilities (and therefore simultaneously presents information through audio, images and text) may in fact create experiences that benefit all learners.

Over the past five to seven years, a number of guidelines have been produced within the fields of website and software development that provide standards, techniques and strategies for providing universal access to information (Burgstahler, 2002; Chisholm, Vanderheiden, & Jacobs, 1999; Coyne & Nielsen, 2001; Foley & Regan, 2003; Freed, Rothberg, & Wlodkowski, 2003; "Rehabilitation Act," 1998; Schmidt & Wlodkowski, 2003; Spry Foundation, 1999; Vanderheiden, 1994). Review of these guidelines reveals that certain recommendations are consistently repeated. Table 1 summarizes these recommendations and presents those that are the most directly applicable to the design of computer kiosks for use in museums. Interactives chosen for inclusion in this research study were those that utilized a push-button interface developed by the Museum of Science and best met these design recommendations. In addition, these design recommendations are used as a starting point for data analysis and the derivation of new recommendations based on study findings.

TABLE 1: ESSENTIAL DESIGN FEATURES: UNIVERSAL ACCESS THROUGH DIGITAL MEDIA	
Feature	**Audience members who benefit**
Captioning of all audio and video	• Visitors who are deaf and hard of hearing • Older adults
Audio descriptions for videos, images, and other visually-based presentations	• Visitors who are blind and have low vision • Visitors who have difficulty interpreting images
Text-to-speech capabilities (text is read aloud to the visitor)	• Visitors who are blind or have low vision • Visitors who are learning to read • Visitors with cognitive or learning disabilities • Visitors whose first language is not English
Easy to read text (high color contrast; a large, clear type-face; and ample space between lettering and text lines)	• Visitors with low vision (including older adults) • Visitors at extreme heights (low and high) who may be subjected to glare from the overhead lighting
Images that convey content	• Visitors learning to read • Visitors with cognitive impairments • Visitors for whom English is a foreign language (including American Sign Language users)
Minimized flickering of images	• Visitors who are subject to seizures
Use of the clearest, simplest text possible	• Visitors learning to read • Visitors with cognitive impairments • Visitors for whom English is a foreign language (including American Sign Language users)
Text that makes sense when read aloud and not viewed (such as "**Return to main menu**" vs. "**Main Menu**")	• Visitors who are blind or have low vision • Visitors with cognitive impairments • Visitors who are not frequent computer users
Present information in a clear, consistent and repetitive layout	• Visitors with cognitive impairments • Visitors who are blind or have low vision (and therefore rely heavily on auditory working memory to navigate the interface) • Older adults and infrequent computer users
Limit the number of choices available on the screen at any point in time	• Visitors who are blind or have low vision (and have to rely on their auditory working memory) • Visitors with cognitive or learning disabilities
Minimize the need for scrolling on the screen	• Visitors with low vision • Visitors who have learning disabilities
Control over the pace at which visitors receive information	• Visitors with low vision • Visitors with learning disabilities • Visitors learning to read

Overview of universal design at the Museum of Science

Over the last 15 years, the Museum of Science has played a leadership role in creating and disseminating knowledge about educational experiences that engage all museum visitors, including those with disabilities. In 1987 Betty Davidson, Ph.D., secured funding from the National Science Foundation to remodel an existing diorama exhibition to be accessible for people with disabilities. This exhibition originally consisted of several glassed-in habitat scenes that conveyed information about the varied habitats of New England, and the adaptations of the animals and plants in each one. Multi-sensory additions included consistently placed audio descriptions of the scenes, smells, revised text labels with simpler and more straight forward language, tactile elements such as a bear mount, and a series of wheelchair accessible interactives with audio descriptions and instructions.

Summative evaluation results showed the remodeled exhibition improved the learning experience for all visitors, including those with disabilities. In the native state, fewer than 20% of the visitors who had seen the exhibition could name one animal adaptation in a follow-up interview. After the remodeling, this number increased to 100%. The number of visitors to the exhibition and the duration of their stay also increased dramatically. (Hein & Heald, 1989)

The remodeled exhibition impacted the culture of the Museum of Science; universal design was adopted as a criterion for exhibitions. Education experts who have disabilities frequently serve as members of the Museum’s exhibition teams. Universal design features, such as audio labels and multi-sensory interactives, are now standard in all new exhibitions. (C. A. Reich, 2000)

The impact on the industry was dramatic as well. After reading Dr. Davidson's book (1991) other institutions, such as the Denver Museum of Natural History, emulated the project and instituted similar changes. The Museum of Science became an acknowledged leader in the field of universal design.

The Museum of Science button interface

The Museum of Science is again leading the museum field in universal design. Since 1997 the Museum has been working to create user interfaces for digital media-based interactives that are universally accessible with the assistance of computer experts who have disabilities. Standards used across these interactives include audio, text, and images that deliver information, stools for resting, and easy to reach tactile controls.

The Museum of Science interface was developed by Robert Rayle, technical designer, and Betty Davidson, Ph.D., exhibit planner. They developed this system for *Messages,* the first major exhibition after *New England Habitats* that addressed accessibility in a significant way. They originally devised the system for visitors who are blind, hoping it would serve as an alternative to the touchscreen and trackball interfaces that are inaccessible for this audience and had traditionally been used by the Museum. Later, they expanded the audience addressed by this design to include visitors with limited upper body mobility. The initial design consisted of two rectangular-shaped buttons that were used as arrow keys for scrolling through options, a round "Enter" button used to make selections, and a one-inch square button that activated extended audio description (see Figure 1). In addition, the available information was delivered through both audio and text, and all videos and animations were captioned. This interface bears a striking similarity to the EZ Access© interface developed by the Trace Center at the University of Wisconsin-Madison (Vanderheiden, 1999). Surprisingly, these two systems were developed in parallel, and the Museum of Science staff did not learn about the EZ Access interface until after the first implementation of the push-button interface in the *Messages* exhibition.

Figure 1: Early implementation of the Museum of Science interface

Through the years, this system has been substantially modified in response to information learned through user testing. Advice from visitors who are blind prompted the Museum to change the shape of the scrolling buttons from rectangles to triangles that point in opposing directions. This new shape better reflects the intended purpose of the buttons as “arrow” keys. Feedback from sighted visitors led the Museum to implement designs where the graphic layout on the screen reflected the button layout on the console so visitors could clearly map their tactile actions on the console to the visual feedback provided on the screen. Some of the newer designs also feature large, rectangular “Go Back” or “Start Over” buttons that allow visitors to easily rectify accidental mistakes and errors. Figure 2 illustrates one of these newer interfaces.

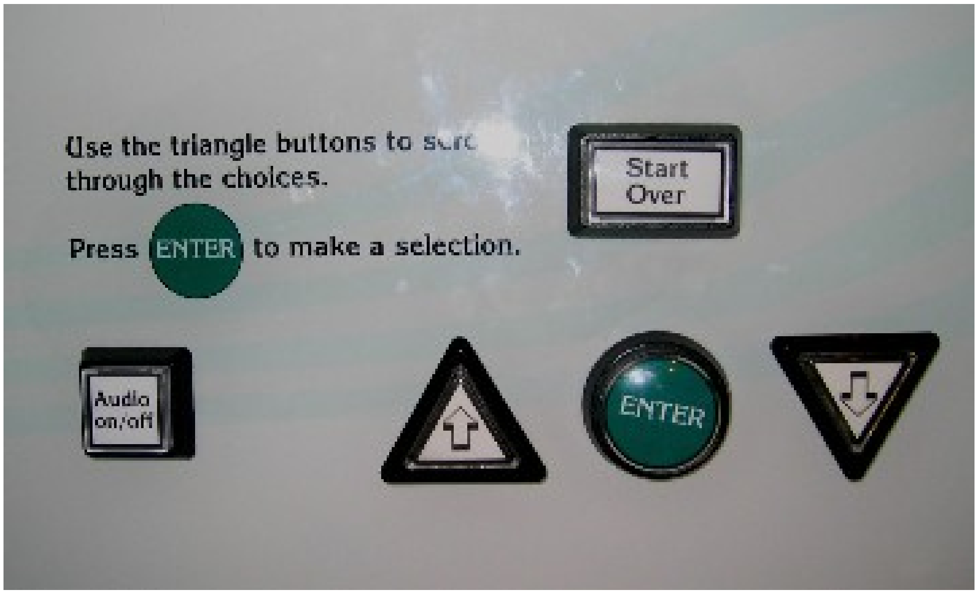

Figure 2: An example of a more recent Museum of Science computer interface

Modifications have also been made to the design based on the varying needs of the interactives themselves. In some cases, new interactives did not require visitors to scroll through options as the programs only offered two choices (such as the "yes" and "no"). In these situations, the triangle keys were replaced with two buttons of different shapes so that the form of the interface better matched its function (see Figure 3).

Figure 3: An example of the Yes or No computer interface

Guidance from visitors who have limited upper-body mobility led to a change in the positioning of the buttons. When the arrow/ Enter button interface was first implemented, the table surface that presented the button was quite thick. This made the buttons difficult to reach for visitors with limited upper body mobility, or small children sitting on stools. The table, unfortunately, could not be made thinner as the buttons need 3 inches of clearance beneath them. Figure 1 provides an example of how thick the table needed to be to house the computer buttons.

When building the touchscreen-based kiosks for *A Bird's World* (Figure 4), the team invited visitors with limited upper body mobility to the Museum and asked them to test different button placements to see which worked best. Buttons placed on slanted surfaces with room for resting the hand was found to be optimal. Slanting the surface also provided more room for button casings within the slanted table, thus allowing the buttons to be placed closer to the user. At the same time that *A Bird's World* was being produced, another exhibit titled *Computing Revolution* was also being designed (Figure 5). The *Computing Revolution* design team applied the same kiosk design to the informational computer kiosks in this gallery. In more recent implementations, the buttons are placed on small slanted consoles that sit on top of a flat table and allow room for the visitor to rest the heel of his or her hand on the edge of the table while pressing the buttons (Figure 6).

Figure 4: "A Bird's World" combined touchscreen and push button interface

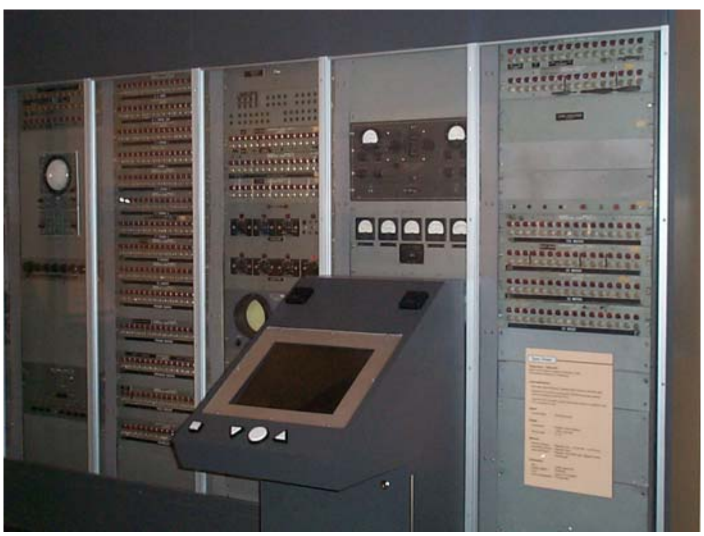

Figure 5: "Whirlwind" interactive in "Computing Revolution" with slanted monitor

Figure 6: Slanted console for buttons used in "Making Models"

Design elements outside of the user interface are also essential to providing universal access. For example, easily moved stools placed near the computer interactive ease the comfort of many visitors. Visitors who have limited mobility but do not use a wheelchair (such as older adults) report that stools greatly increase their comfort level in science center exhibitions (C. Reich & Borun, 2001). Stools also help adults with lower back pain as they use computer interactives designed for the height of wheelchair users, and provide an opportunity for visitors with low vision to get close to the computer screen without fear of "sticking their butt out" into the pathway of other museum visitors. Evaluation findings also suggest that stools increase visitor dwell time at all interactive components.

The Museum of Science has also learned that the presentation of educational information plays a critical role in providing access for all. Limiting the number of available choices assists visitors who need to rely on their auditory working memory to navigate through the screens (such as visitors who are blind), and prevents visitors with cognitive disabilities from feeling overwhelmed. Informative images presented with clear and simple language supports the learning of young children, and also assists visitors who are deaf, have learning disabilities, or speak English as a second language.

Interactives highlighted in this study

The interactives chosen for this study each use buttons as the primary user interface, and together, represent the variety of learning experiences that computers can provide in museum exhibitions. One interactive, titled "Personal Computers" provides object interpretation. Another, "Mammal Skull Mystery," guides visitors through a tactile activity. The third, "Fish Farming," is a stand-alone simulation. Descriptions of each of these activities are provided below.

"Personal Computers" in Computing Revolution

> *This computer-based interactive video will allow visitors to learn about the personal computer, how it came to be, see period videos of the different machines, and watch interviews with the people who actually built and used them. The component will be mounted in front of the PCs highlight case. It will serve as the primary means of learning about the computers. A simple three-button interface (Prev, Next, Enter) will allow visitors to step through the menu options for every screen. Videos will be open captioned. (Rodley, 2004)*

The above paragraph is a description of "Personal Computers" provided by the interactive's content developer, Edward Rodley. This interactive is part of *The Computing Revolution*, an exhibition about the history of computing from ancient times to the present. Figure 7 below provides a picture of this interactive.

Figure 7: The Personal Computers interactive as presented in Computing Revolution

As described above, "Personal Computers" is a computer kiosk that provides interpretive information about the artifacts presented in the "PC highlights" case. This case presents four historic personal computers, including the Altair 8800, IBM PC, Apple II, and the Macintosh. The PC highlight case is divided into two separate sections, each presented on either side of the computer kiosk. In front of the kiosk is a circular stainless steel stool. The kiosk itself is a rather sleek design, with a black, white, gray and silver color scheme. The screen is presented along a 45 degree slanted surface with space for users to rest their arms on either side of the screen. Beneath the screen, along the same surface, are four buttons visitors can use to navigate the computer interface. These buttons include, in order from left to right, a one-inch square button labeled "audio text", a triangle with its apex pointing down, a circular button 2 inches in diameter, and another triangle with its apex pointing up. As visitors approach the interactive, they see the attract screen, which is a recreation of the 1980's video game "Breakout," along with the words "Press any key to begin." Once visitors begin the interactive, a menu appears on the right-hand side of the screen. Visitors use the triangle buttons to scroll through the menu options. Each time a visitor presses a triangle button, one of the menu choices is highlighted in pale green and read aloud by a female voice if the audio text is on. If they would like to learn more about one of these menu choices, they can press the large circular button to select it. To the left of the menu tree is a block of text with supportive images. If the audio text is on, visitors also hear this text read aloud, again, by the same female voice. Any informational videos are also presented in this area. Figure 8 presents an image of one of the Personal Computers menu screens.

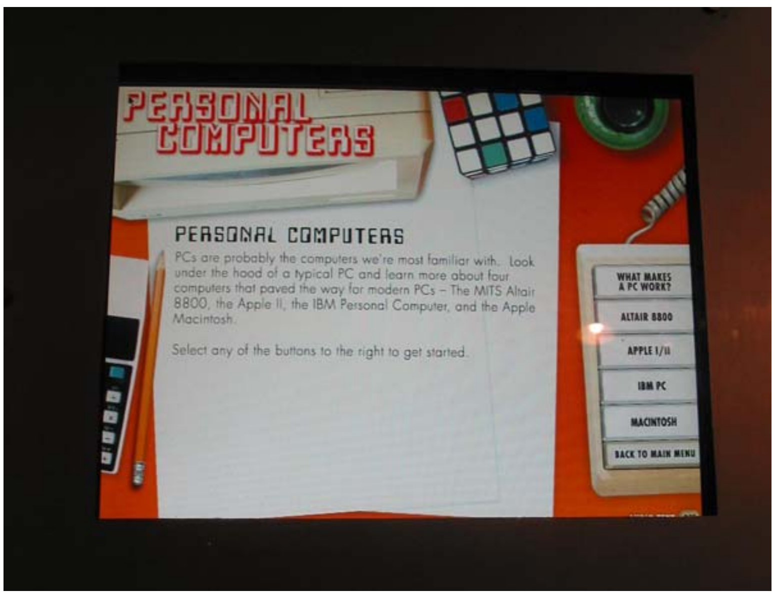

Figure 8: Close-up of the Personal Computers screen

The designer and content developer designed this interactive with the intention that all visitors would be able to complete the following tasks:

- Choose to turn the audio on/off by pressing the one-inch square button;
- Navigate through the menu choices using the triangle buttons;
- Select a menu choice using the circular button;
- Perceive the available information through sight or sound; and

- Make connections between the objects displayed in the glass case and the information provided through the interactive.

"Mammal Skull Mystery" in ***Natural Mysteries***

> *Educational goal: Biologists use dichotomous keys to identify skulls. Identification is one of the functions of classification that is outlined on the exhibit classification kiosk. Each successive step of the key gets you from a more to a less general classification: in this case from Class, Mammal, to Genus. Following the keys makes visitors look more closely at skulls and make connections between form and function.*
>
> *Description: This is a computer component that will be accessible to visitors with visual impairments. There are two computer screens and seven mammal skulls. Visitors choose a skull and answer the yes or no questions present on the A screen. As they make their choices, images of animals on the B screen are eliminated and grouped according to their classification. For example, if a visitor answers that his or her skull has canines, all the rodents disappear from the B screen. (Parkes, 2004)*

The "Mammal Skull Mystery" is part of the *Natural Mysteries* activity center, an exhibition filled with natural history artifacts and interactive activities that engage visitors in using and developing classification systems to solve "mysteries" in the natural world.

"Mammal Skull Mystery" is a unique interactive design. As visitors approach the interactive, they see a multi-sided wooden table that doesn't have regular angles and looks somewhat organic in form. On top of the table sit seven plastic mammal skulls presented on a slightly slanted semi-circular surface covered in green felt. These tactile skulls were specifically added to the interactive to facilitate learning for visitors who are blind. Behind the skulls are two side-by-side computer monitors. Above the monitors is a wooden sign with white paint lettering that reads "Mammal Skull Mystery." In front of the table are two round wooden stools. As a visitor sits on one of these stools, he or she would notice a semi-circular dome hovering above that projects Native American music into the gallery. On the table, directly in front of the array of skulls, at the center most point of the semi-circle, are three arcade-like buttons. To the left of center is a red one-inch in diameter circle button with a raised N beneath. To the right of center is a green triangle button with a raised Y beneath it. Above both of these buttons is a 2-inch long rectangular button with a raised symbol beneath it. This symbol consists of a straight line followed by two backward facing triangles, similar to the one used to designate "rewind" on a VCR. At the far-left corner of the table sits a one-inch square button that reads "audio text." Figure 9 provides an image of this interactive, shown with the adjacent skull case that houses real mammal skull specimens.

Figure 9: Mammal Skull Mystery interactive as presented in Natural Mysteries

When visitors first look at the screen, they see the words "Press any key to begin." Pressing any key, including the audio text button, begins the computer program. The first screen instructs visitors, through both text and audio (again, a female voice), to "Pick a skull, follow these questions to identify your skull…" As visitors continue along, they are asked a series of questions about their skull. Images of different types of skulls are provided to assist visitors in answering the questions. Figure 10 provides a close up of the starting screen and the button layout for the interactive.

Figure 10: Close-up of Mammal Skull Mystery

As described above, the content developers and designers designed the interactive with the intention that all visitors, including visitors who are blind or have low vision, would be able to complete the following interactions when using this activity:

- Initiate the activity by pressing any key;
- Pick one of the seven skulls to classify;
- Listen to or read a question about the skull;
- Examine the chosen skull to determine an answer;
- Correctly answer yes or no by pressing either the triangle or circle button, or pressing the “go back” button to review the answer;
- Compare the computer’s answer to the actual answer; and
- Make connections between the skulls on the table and the skulls in the case.

"Fish Farming" from Making Models

> *In this role-play activity, visitors will use a computer simulation to solve a fish farming dilemma- what's the best way to stop a disease from spreading in your tank? Visitors can adjust the number of fish in the tank, and the % vaccinated, and run simulations to see how these factors influence the number of fish that survive... Learning objective- Visitors use a computer simulation model to test solutions in a life-like scenario. (C. A. Reich, 2003)*

Fish Farming is a part of the *Making Models* activity center, an exhibition that provides visitors with opportunities to recognize, assess, use and create models of various forms. The description above was written by the content developer for the interactive, who is also the author of this paper. This interactive is a stand-along kiosk, presented in the "Using Models" section of *Making Models*. As visitors approach the interactive, they see a small metal stool that sits in front of table with a wooden surface and thin metal legs. At the back of the table is a 9-foot tall, elongated, purple trapezoid that frames the entire interactive. At the top of the kiosk is a colorful label that reads "Fish Farming: Using models to find solutions…Press the round ENTER button to begin." In front of the trapezoid and on top of the table sits a large 19-inch flat screen LCD monitor. Presented on the monitor is an attract screen, that shows floating fish that swim across a green, blue, and aqua amoebae-like surface. Between the swimming fish is a moving sign that reads "Fish Farming: Can you stop the disease?"

In front of the monitor is a small, slanted control panel with a series of buttons visitors can use to interact with the game. On the left side of the control panel is a one-inch square button labeled "audio on/off." Next to the square button is a blue triangle button with its apex pointing down, a one-inch in diameter circle button and another yellow triangle button that is also pointing down. Above these buttons is a rectangular shaped button that reads “Start Over.” Figure 11 provides a close-up of this interactive.

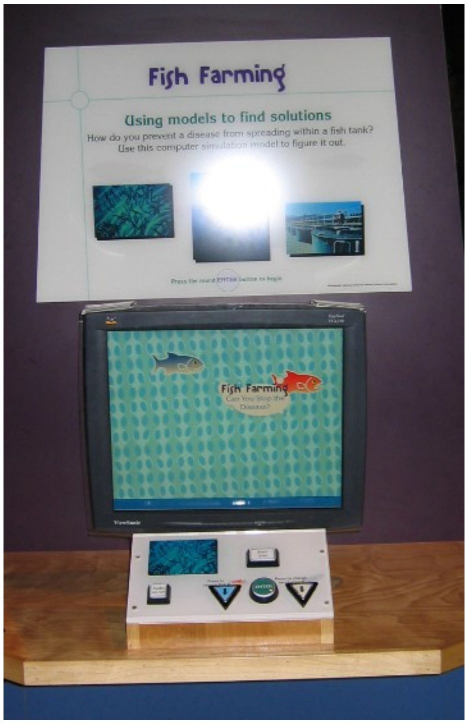

Figure 11: Close-up of the Fish Farming interactive as displayed in Making Models

Visitors begin this interactive by pressing any button on the control panel. The first screen is a text screen that provides a brief 40-word overview of the activity and introduces the idea that the visitor is playing the role of a fish farmer. The second screen is also a text screen and it introduces two challenges for the visitors to try. Both of these screens are read aloud in a female voice if the audio is on. The third screen is the simulation screen. Here, visitors are presented with a “virtual” tank containing up to 1000 fish on the left-hand side of the screen. Beneath the tank is a text box where visitors receive instructions for what to do. The information in this text box changes as visitors interact with the simulation, and is read aloud if the audio is on. To the right is a small text box that repeats the challenges. This information does not change and is not read aloud. On the screen is also a small chart that presents the results from the last five runs of the simulation, and a graph that plots the number of fish in the tank in real-time.

Visitors can use the left arrow button to change the number of fish in the tank, the right arrow button to change the percent of fish vaccinated, and the ENTER button to run the simulation. When the simulation is running, the fish move about the tank and the number of fish changes over time. This change is represented visually through the real-time graph and the number of fish in the tank, and aurally through a tone that decreases in proportion to the visual decline of the fish on the screen. The final number of fish in the tank after the simulation has run its course is both read aloud and portrayed visually in the chart.

As described above, the purpose of this interactive is for visitors to use a computer simulation model to find a solution to a problem. Given this intention, in order to successfully engage in the activity as intended, the visitors must complete the following steps:

- Choose to turn the audio on/off using the one-inch square audio on/off button;
- Read/ listen to the role-play scenario and directions;
- Run the simulation by pressing the round ENTER button;
- Perceive (through sight or sound) changes in the fish population over time; and
- Change one or both of the variables by pressing the triangle buttons.

METHODOLOGY

The concept of universal design represents a relationship between the designed environment and the functional abilities of its users and occupants. For this reason, the participatory design process, where the users are considered experts and are actively solicited for feedback during a design's creation, is advocated as a means for achieving universal design (Ringaert, 2001; Wright, 2003). Practitioners of participatory design utilize a variety of research methods, such as ethnographic observations, user interviews and focus groups (Kensing & Blomberg, 1998; Kensing, Simonsen, & Bodker, 1998; Sperschneider & Bagger, 2003), all of which are commonly used in the evaluation of museum exhibitions. Another framework frequently used for research and evaluation project pertaining to universal design is to focus on the defects of the environment, and not the "defects" of the users when assessing who is able or unable to fully participate in a given environment (Gill, 1999; Mertens, 1999).

To date, very few research studies have been conducted in the area of universal design. Therefore, few standardized instruments or methodologies exist for studying it. In 1998, an international forum was held in Greece titled "Towards an Information Society for All." During this meeting, researchers from around the globe met to set an agenda for creating human-computer interactions that met the needs of diverse users. One of the key findings from this meeting was the need to develop effective user testing methods that take into consideration that users have varying abilities. As stated in the conference report,

> *User involvement in the design of computer-based interactive systems has long been a challenging issue. Despite its potential value, it needs to be carefully planned and assessed in different phases of a product's life cycle. Participatory design has provided useful insights into how user*

> *involvement might be managed in practice and offers several tools and guiding principles. However, the existing wisdom offers very little in the direction of involving different user groups with diverse abilities, skills, requirements, and preferences. Therefore, actions should be undertaken to refine and extend the available instruments so that they can effectively guide the design of new computer-mediated human activities (Stephanidis & Salvendy, 1999).*

Following publication of the workshop proceedings, at least one publication has been produced that addresses ways to involve users with diverse abilities and backgrounds in user testing (Coyne & Nielsen, 2003). However, this publication was published after the methodology for this study was set in place and therefore it is not reflected in the methods employed for this study.

A participatory design approach

The purpose of this study is to examine the effectiveness of an interface created by the Museum of Science that was designed to be accessible for museum visitors of all ages, abilities and disabilities. It addresses the following questions:

- How do visitors of a broad range of abilities and disabilities interact with the Museum of Science button interface?
- Which design features provide access to learning, and which present barriers for visitors of a broad range of abilities and disabilities?
- What other features, beyond the push buttons and the use of audio and text, are needed to provide visitors with disabilities with the access to the learning experience?

The research methodology employed for this study reflects the practices of participatory design. Study participants are considered “experts” and asked to share information about how they feel the design supports or hinders their learning, and to contribute ideas for possible redesigns. Their opinions and thoughts about the experience are viewed as accurate portrayals of their perceptions of their experiences and are considered a better reflection than the observer's interpretation of their actions. Appendix A provides copies of the instruments used to conduct this study.

Sampling method

To gather feedback on the universal accessibility of the Museum of Science button interface, participants were chosen so that a broad range of abilities and disabilities are represented. Participants were recruited for the study through direct solicitation of Museum of Science community partners, and by contacting Museum members and volunteers who had identified themselves as a person with a disability. In total, 16 visitors were observed and interviewed as part of this study. Participants represent novice computer users and computer experts, as well as adults from age 17 through 77. The following is a list of the represented disability groups:[3]

- Visitors with low-vision (3)
- Visitors who are blind (2)
- Visitors who are hard of hearing (3)
- Visitors who are deaf (2)
- Visitors with limited upper body mobility (3)
- Visitors who are wheelchair or scooter users (2)
- Visitors with learning or other cognitive disabilities (4)
- Visitors who do not self-identify as having a disability (3)

Each participant in the study is considered to be a separate case study.

Data Collection

Each case study includes data collected during two interviews conducted with the participant, and interactive observations of the participant at each of the three interactive components. The paragraphs below provide an overview of each of these data collection techniques. These techniques were pilot tested with two users who are blind, one

[3]The total number below is greater than 16 as many visitors had more than one disability.

wheelchair user, and a user who is deaf, and the data collection methods were modified accordingly. Both the interviews and the interactive observations were recorded using a digital audio recorder, and the conversations transcribed. In addition, the observer/ interviewer took notes to record observations that could not be captured through audio (this also served as back-up in cases involving technical failure).

Given the time demands of the interviews and the participant observations, data collection took place over two separate events. The first event was an on-site visit that included an introductory interview and interactive observations at the three interactives. The second event took place over the phone within two weeks of the first event and consisted of a final interview in which participants were asked to compare their experiences at each of the three interactives. In some cases (particularly for the visitors who are deaf and required an interpreter to communicate with the observer/interviewer), the final interview took place on-site immediately following the interactive observations. Originally, it was planned that this data collection would take place over two separate site visits. However, due to the lack of public transportation that is accessible for persons with disabilities in the Boston area, many participants reported that it was difficult for them to make two visits to the Museum of Science. Therefore it was decided that the final interview would occur over the phone.

Observations

The original observation instrument called for visitors to be observed using each of the three interactives following a modified think aloud protocol (Ericsson & Simon, 1993). It was proposed that while the participants were using the computer interactives, they would be asked to think aloud and the observer/ interviewer would ask the participant questions that specifically addressed what the participant was doing at that particular moment, the goal he or she was trying to achieve, and his or her thoughts on a strategy to achieve it.

However, the think aloud protocol was received with mixed results by the study participants. Thinking aloud is difficult for visitors who are blind and rely on the auditory delivery of information, for it is awkward to listen and speak at the same time. Therefore, the observer is limited in the number of questions she can ask these participants about their experience while they are using the interactives. The think aloud method is also difficult for visitors who are deaf and need to use their hands to speak, as it is cumbersome to talk and interact with the computer simultaneously. This technique is also impracticable for the participant who has a cognitive impairment in the right hemisphere of her brain. She finds it confusing to concentrate on speaking out loud and engage in the activity at the same time. Thinking aloud is easier for the participant who has a nonverbal learning disability. She states that thinking aloud is a technique taught to students with similar disabilities as it helps them to organize their thoughts.

As a result, the observer modified the methodology as the study progressed and eventually followed a participant observer approach, where the observer sat with the participants and encouraged them to share what they were thinking as they used the interactives, as if talking to a friend. The participants shared real-time thoughts and feelings about the experience, but expressed only those they felt comfortable sharing, and only when they felt comfortable sharing it. Following each interaction, participants were invited to replay their experience at the component, describing what they did (a modified form of a retrospective report). They were also asked to communicate any immediate thoughts they had about the positive or negative aspects of the design.

On-site interview

Before the site-visit began, the observer/ interviewer interviewed each participant to develop a better understanding of his or her educational or professional background, experience using computers, and disability. During this interview, participants were asked whether they would prefer to remain anonymous or have their identity revealed in the final report. Participant responses were recorded using a digital audio recorder, and if the participant preferred to remain anonymous, their names were changed in the report.[4] After the site visit, the observer/ interviewer conducted a closing interview that focused on learning about the participants' perspectives of the interactives. The introductory interviews took place in a quiet, relaxed setting within the museum such as a conference room or the staff cafeteria. The final interview was conducted over the phone, or in the same room as the introductory interview if a phone interview was not possible.

Limitations of the methodology

The methodology described above has a number of limitations that should be considered when reviewing the study's findings. First, participants used the interactives on their own, and were not accompanied by other family members or friends with whom they may normally attend museums. Some participants were accompanied by their personal care assistants (PCA), but the PCA's were asked not to provide assistance when the individuals used the computer interactives. This decision was made in order to better examine the ability of the interface to facilitate an independent learning experience for

[4] It is impractical to receive written permission from the participants as many cannot sign their names (including visitors who are blind and visitors with limited mobility). Asking for permission and recording responses through audio was the most universal solution.

persons with disabilities. However, this resulted in an experience that was not naturalistic and may not reflect a “typical” museum experience for the participants.

Another limitation of the methodology was that participants did not choose the interactives they used. In an informal learning environment, museum visitors choose which experiences they will learn from and self-select those experiences they believe best matches their content interests and learning styles. For this reason, the participants interacted with exhibit components that they might not have typically engaged with if they were at the museum on their own. This may have influenced the final results, and in particular the participant’s opinion of the interactives.

DATA ANALYSIS METHODS

According to Robert Yin, author of *Case Study Research: Design and Methods*,

> *The first and most preferred strategy [for analyzing case study evidence] is to follow the theoretical propositions that led to your case study. The original objectives and design of the case study presumably were based on such propositions, which in turn reflected a set of research questions, reviews of the literature, and new hypotheses or propositions. (Yin, 2003)*

The theoretical proposition guiding this study, and therefore the analysis of the data, is that it is the design of the experience, and not the abilities or disabilities of the individual, that defines whether an individual is able or *disable* to learn. This follows the social model of disability defined by Dr. Carol Gill, in her article *Invisible ubiquity: The surprising relevance of disability issues in evaluation.*

> *…disability is a dimension of human differences (and not a defect), [and] derives its meaning from society's response to individuals who deviate from cultural standards…(Gill, 1999)*

The way museums design their computer interactives reflect the "cultural standards" of the industry and its assumptions about visitors' abilities and how they learn. Individuals whose abilities and disabilities fall outside of this cultural standard are often excluded from the learning experience by the design of the environment. For this reason, the data were analyzed to identify areas where the design of the interactive influenced whether the participant was able, or disable, to interact with the component and learn from this experience.

Another theoretical proposition guiding the analysis is that the design features that enable learning will vary between the study participants, and will depend in part on their experience using computers and the primary sensory ability through which they receive information. As stated by Dr. Rose and Dr. Meyer in their landmark book *Teaching Every Student in the Digital Age: Universal Design for Learning*

> *Traditional views of disability…suggest that a person either does or does not belong to the category "disabled." New understanding about the distributed nature of neural processing shows that the abilities in many domains fall along a very large number of continua. Further, the importance of a particular strength or weakness depends upon what is being asked of the learner. This is why, for example, a youngster with perfect pitch who has difficulty recognizing letters is seen as disabled, but a child who is tone deaf but can read words easily is not.*

This definition of disability led the cross-case data analysis. Traditionally, cross-case analysis is used to identify trends that appear across all cases. While this type of cross-case analysis was conducted (as is commonly known in the universal design field, 'accommodations' made for persons with disabilities are often found to assist a larger audience), it is not sufficient. The theoretical framework described by Rose and Meyer requires that the cross-case analysis should not only identify common themes, but also be used to define the wide-spectrum of ways that the participants receive, interpret, understand, and interact with the learning provided at each interactive.

For the purposes of this study, a successful design was considered to be one that reflected the frequently cited definition of universal design offered by the Center of Universal Design at North Carolina State University, which is "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." Ideas for suggested design features were therefore generated based on this definition, and selected based on the ability for that feature to create an experience that would be accessible to users of a broad range of abilities and disabilities.

Data within each case were coded using ATLAS.ti software and code categories were developed following constant comparative analysis (Lincoln & Guba, 1985). To establish the "trustworthiness" of the study's findings, participants were asked to review the preliminary findings and reflect on the validity (Lincoln & Guba, 1985). Each case study participant was sent a case description summarizing his or her experiences, as well as summary of the preliminary findings, which included a brief description of the cross-case findings (see Appendix B for a copy of this description and examples of the case study descriptions that were sent to the participants). Participants were encouraged to provide the author with feedback on the accuracy of these documents from their perspective, and specifically to recommend changes to the summaries that they felt would better represent their experiences at the Museum of Science and their opinions of the three interactives. Additionally, study findings underwent peer examination where the developers, designers, and evaluators of the interactives were asked to comment on the emerging findings and express how these findings match, or do not match, their experiences testing the interactives with a larger museum audience. (Merriam, 1998)

FINDINGS

This study illustrates the experiences of 16 individuals who collectively represent a broad range of abilities, disabilities, computer experience, ages, backgrounds, and interests. While participants were chosen for inclusion in this study based on their disability, their experiences reflect who they are as individuals, including how comfortable they feel using computers and visiting museums, their conception of what learning is (and isn't), their mental models of how computers behave, and the topics that interest them as informal learners. The profiles listed in Table 2 and described in the summaries below provide insights on the backgrounds, abilities, and interests of each participant and includes information about who they are as individuals that may have impacted how they interacted with each of the interactives included in this study. It is significant to note that while the participants vary with regards to ability and disability and experience using computers, they all share two common attributes: they love to learn, and enjoy visiting museums.

TABLE 2: OVERVIEW OF STUDY PARTICIPANTS					
Participant	**Age**	**Disability?**	**Computer experience**	**Museum habits**	**Interests**
Alice	53	Blind	Frequent user, not expert	Has not visited frequently since losing vision	Reading, music, language, biology, knitting, cooking
Jerry B.	51	Blind	Assistive technology specialist	Frequent zoo and aquaria visitor	Computers, bird “watching”, the natural world
Olivia	55	Low vision	Novice, inexperienced	Frequent visitor	Astronomy, biology, chemistry, fiction
Mark	31	Low vision	Expert user, professional	Frequent visitor	Computers, sports, science
Carol	30’s	Late-deafened	Frequent user	Frequent visitor	Science, particularly biology and math
Leon	32	Deaf	Frequent user since 2000	Frequent visitor	Art, History
Carolyn	52	Hard of hearing	Frequent user, not expert	Frequent visitor	20th century history, fiction, heath/ fitness
Jerry P.	77	Hearing aid, doesn’t self-identify as disabled	Frequent user, but not expert	Volunteer	Running, science, helping people
Kent	67	ADD, hard of hearing	Frequent user, not expert	Frequent visitor, volunteer	Science (nature, evolution, space)
Gail	27	Non-verbal learning disability	Frequent user, not expert	Frequent visitor	History and politics
Yaacov	17	Dyslexia, dysnomia, dysgraphia	Expert user	Frequent visitor and volunteer	Science, metallurgy, medieval history, computers
Linda	60	Low vision, cognitive and mobility disabilities	Frequent user, not expert	Infrequent museum visitor	Knitting, reading fiction, studying the Torah

TABLE 2: OVERVIEW OF STUDY PARTICIPANTS (CONTINUED)					
Participant	**Age**	**Disability?**	**Computer experience**	**Museum habits**	**Interests**
Judy	50's	Wheelchair user, limited finger use	Frequent user, not expert	Frequent visitor	Anthropology, art, natural history
Stacy	50's	Wheelchair user, limited strength	Frequent user, not expert	Frequent visitor	Entrepreneur, Karate, Tai Chi, science
Jen	31	Doesn't self-identify as disabled	Frequent user, not expert	Frequent visitor	Visual arts, sociology, psychology
Vicky	20	Doesn't self-identify as disabled	Expert user	Frequent visitor	Chinese calligraphy, math, abstract topics

Summary of participants

Alice

> *I'm one of these people who says, you get used to anything…It's like with musical instruments, some people have an instrument made for them, and they are just constantly back at the maker, "Change the bridge, move the fingerboard, level this, change the strings, put a different bow here, yadda yadda." And other people take the instrument and they make it their own, the way it is. They work with it. I belong in the second category.*

Alice is a 53 year-old musician and translator who became blind as an adult. She has a seeing-eye dog she takes with her as she travels. As described in the paragraph above, Alice is accustomed to adapting to designs and making them work for her.

Alice enjoys reading and learning. She used to visit museums regularly, and avows, "I love every museum I've ever been to." Unfortunately, Alice doesn't visit museums anymore. When asked, "what changed?" Alice responds:

> *I can't see anything anymore. I mean, I'm not a friendless person, but I go a lot of places by myself. I used to travel a lot by-- I love to travel by myself. And there's not much point if you can't see what's there and there's no one there to describe it to you. So you just sort of don't go...*

Alice proclaims a "love/hate" relationship with computers. She regards herself as an "average Joe" user and not a "whiz" and frequently finds herself frustrated by designs that are not user friendly. However, she uses her computer everyday for reading and writing and asserts computers are "indispensable" for people who are blind.

When using the computer interactives, Alice begins by moving her hands in broad strokes to orient her to the kiosk's design. She listens carefully to the information, and positions her ears close to the speakers if the background noise is high. At Fish Farming where auditory directions are available, Alice listens to the directions first before trying the interactive. At Mammal Skull Mystery and Personal Computers where directions are not available, Alice begins using the computer by pressing the buttons to see what happens, and learns to use the system through trial and error.

Jerry B.

> *My wife read something that said if you use a computer more than 11 hours a week you may be addicted. And she said, 'what if you use it 11 hours a day? I laugh because basically, that would be a good description of what I do.*

Jerry is a 51 year-old assistive technology specialist who has been "virtually totally blind since birth." As one would guess by his profession, Jerry is an expert computer user who is very "interested in making the technology work for me." He uses his computer for a variety of purposes, including storing and playing music and reading information about new topics. Jerry also enjoys computer gadgets and carries a flash drive (a small computer drive the size of a thumb you can fit in your pocket) with him wherever he goes. While Jerry can read Braille and has both a Braille printer and a Braille digital display, his preferred method for receiving information is through speech.

Jerry is an active member of his community, currently serving as President of a local council for persons who are blind and leading workshops on how to identify birds through sound. Other interests of Jerry's include music (especially the guitar), and staying connected to others with similar interests and backgrounds through the Internet. While Jerry does not consider himself to be a frequent museum visitor, his interest in the natural world has recently brought him to numerous zoos and aquaria.

When Jerry uses the computer interactives, he begins by feeling around the kiosk with his hands to explore the interactive's design. He then listens to the information carefully, following the directions precisely to determine what to do. As he continues to use the interactive, Jerry explores the interactive through touch to make sense of the directions and information delivered through the audio.

Olivia

> *Because my main interest is reading-- If I could read 24 hours a day, I would…if I was able to, if I didn't have to sleep and do those boring things like, you know, do laundry, eating, things like that. [Laughter]. I have so many books, I don't know if I'll ever finish all of them.*

Olivia, age 55, is a retired teacher with low vision who enjoys reading science fiction and non-fiction books about history, science, and art. To read information, Olivia uses a variety of media, including print (which she reads with a magnifier), large print, Braille, and audio.

Olivia serves her community through active volunteer work. She is knowledgeable about accessibility and frequently provides feedback on access to various organizations. Olivia considers herself to be "very, very, very near-sighted" and can only see out of her right eye. She has difficulty discerning details, and cannot identify someone by their facial features alone.

Given her thirst for knowledge, it is not surprising that Olivia is a frequent museum visitor who visits multiple museums on a regular basis. When Olivia visits the Museum of Science, she focuses on temporary exhibitions, the Omni Theater and the Planetarium. Olivia does not visit the permanent exhibits, mostly because they are hard for her to navigate and find.

Olivia is not a computer-user. She has heard of the World Wide Web, but has never used it. The only items she uses on a regular basis that she considers to be computers are her Kurzwiel reading machine (a scanner created for persons who are blind that converts text into audio) and digital cable. Through her interactions with these and other everyday items, she has developed an understanding of the types of interfaces that work well for her. Touch-pads are difficult, while buttons that provide tactile feedback are much easier.

When using the interactives, Olivia keeps her head close the screen and quickly moves it back and forth to view the images and text it displays. She closely follows the directions of each activity, and relies on the directions and the process of elimination to determine what to do. Olivia utilizes both the audio and the text, switching between the two modes. If the text is difficult for her to read, she uses the audio. If she needs a visual confirmation of what she hears, or if something catches her eye, she leans in close to the screen to get a closer look at the text and images.

Mark

> *…my favorite channel is the Science Channel, which is cable. I like the History Channel, I like technical stuff like that. I'm a big fan of the Mars Rover or whatever that's out there, been keeping up with that…Polar Ice Caps…I'm kind of an information junkie.*

Mark is a 31 year old with low vision who works in the field of computer system technology support. As one would expect given Mark's profession, he is an expert computer user. A self-proclaimed "information junkie", he is very interested in science, especially astronomy, and watches the Science Channel and reads science publications on a regular basis. He also enjoys sports, jogging, and eating at restaurants. Mark has optic nerve atrophy, a condition that worsens with age. Currently, he has some vision, but is unable to see details in images or read small text. Bright lights can make this problem worse, so Mark wears amber-colored glasses to provide him with greater contrast when reading.

Mark is a frequent museum visitor. Generally, when Mark visits museums, he does so with friends or family members who assist him by reading exhibit labels out loud. Although Mark could read the labels if he gets close enough (especially with the aid of his magnifier), many exhibit labels are difficult for him to access. Even when he can get close to labels, he is often hesitant to do so as he does not want to get in the way of others.

As Mark uses the interactives, he reads the computer screens by keeping his eyes close to the screen and moving his head back and forth at a rapid pace. If necessary, he uses the small magnifier he carries with him at all times to access words written in a small font. Generally, he prefers to use the audio rather than reading as he can hear it faster than he can move his head around the screen. However, he switches between listening and reading while interacting with the same activity, and seems to rely on both.

When operating the computer, Mark learns the system through trial and error, “playing around” with the computer to see what it does. When faced with a system he does not immediately understand how to use, he feels comfortable exploring how it works and allowing the goals and directions to become clearer over time. When confronted with a design flaw, Mark easily circumvents the difficulty it poses by finding an alternative means for interacting.

Carol

> *For me, reading the language is fine. I’m curious what other deaf are going to say...*

Carol is in her late 30’s and is the regional director of a nonprofit organization that provides services for people who are deaf or hard of hearing. Carol is late deafened, and both reads lips and signs. Carol’s professional experience influences her interactions with the interactives. She frequently advocates for groups not represented in the study, such as Deaf Spanish and Deaf Blind. She discusses changes that address not only her own experiences with the interactives, but also how she thinks others might respond.

Carol has an interest in science, particularly biology and math. She minored in computer science as an undergraduate, but admits, “computers have changed so much since then.” She is also a frequent museum-goer who visits a museum every few months. Her favorite museums are the Smithsonian Institutions, which she describes as being “very accessible”.

> *They [the Smithsonian] always have captions on things. They have museum tours with interpreters when you request them. Movies are always captioned. Here [Museum of Science], you have a once in a while show that are interpreted or captioned. Not everything. You can’t just go whenever you want and see what you want…here, it is limited to Saturdays and then the shows are already picked.*

When using the interactives, Carol focuses on the visual aspects of the display. At Mammal Skull Mystery, she looks closely at each line drawing before answering the questions. At Fish Farming, she closely watches the fish and the line graphs. Although Carol does not hear, she pays attention to the audio, frequently feeling the kiosk tabletop and detecting the sound through touch. She feels the sound of the music at Mammal Skull Mystery, the sound of the audio-delivered text at Fish Farming, and the sound of the voice narrating the computer animation at Personal Computers. Each time she senses the sound, Carol wonders, what am I missing?

Leon

> *It’s so visual. That’s the primary reason. There’s a lot of history there, a lot of contemporary art, but I like the fact that it’s a very visual environment. (Leon describing his favorite museum in San Diego)*

Leon is a 32 year-old college student studying psychology who considers himself to be “little d” deaf and has experience working with deaf children. He wears hearing aids and can hear some sounds and noises. Leon’s primary language is American Sign Language (an interpreter was hired to translate our discussions), but he also has limited lip-reading abilities. He is interested in topics such as art and history, but when asked if he is interested in science he replies, “I failed it in high school, so not so much.” Leon is a frequent museum visitor, visiting art museums on a regular basis. A self-described visual learner, Leon appreciates museums that provide visual representations of content and information, as well as diagrams and schematics that provide directions.

Leon feels “quite comfortable” using computers, and has used one on a regular basis since he received his own in the year 2000. When using the computer interactives, his hands moves quickly as he touches the buttons, screen or anything else that is available. He looks closely at the screen, and more specifically the visual images, to see what changes as he touches these various elements. Although Leon is deaf, he is acutely aware of the presence of audio at the computers, visually noticing terms such as “Audio on/off” or “Audio Text,” feeling the vibrations of the sound on sides or tabletops of the interactives, and hearing the sound of the background music at Mammal Skull Mystery.

Carolyn

> *A library works for me. I knew I would have this hearing loss. I’ve had progressive loss since I was in my 30’s. It’s hereditary, a family thing. As a librarian, I can always work because there are so many different, you can work without having to hear…*

Carolyn is a 52 year-old school librarian with a hereditary condition that causes progressive hearing loss. Currently, she has 70% hearing loss in her upper ranges. She is adept at adapting to and selecting environments that best suit her altered hearing.

Although she wears hearing aids, she relies extensively on lip reading to communicate and understand others. She finds it easier to understand phrases when they are expressed in context. When words or phrases are unexpected (such as proper names) it is harder for her to interpret what is said.

Carolyn is an avid read with a strong interest in 20th century history, fiction written by American authors, and topics related to health and fitness. She is a frequent museum visitor, and attends the Museum of Science and other local museums with family on a regular basis. Carolyn feels comfortable using computers since "as a librarian I use one all the time." She describes herself as a "user" who "helps kids and adults find information" but she doesn't "create web pages or do the programming." She feels she needs to move through unfamiliar applications slowly as it takes her a while to operate more advanced functions.

When using the interactives, Carolyn looks closely at the provided information (both on and off the screen) and expresses that she "wants to know more before I start." At Mammal Skull Mystery, Carolyn gathers information through the audio. Later, at Personal Computers she experiments with using the computer with and without audio, and finds the interactive easier to comprehend without audio. At both Personal Computers and Fish Farming, Carolyn thoroughly reads the text on the screen. As she uses each interactive, she notices aesthetic elements such as the "oldish feel" of Personal Computers and the "pretty tones…[of the] wood and color of green" at Mammal Skull Mystery, which she feels influences her perception of the displays.

Jerry P.

> *How would you feel if you were, say, my age about computers?…Mostly everything you have is interactive. And I*

> *wonder how many older generation people really get into that portion of it. I noticed that when I walk around in there, I don't do sit and go through them, I kind of just watch the kids do it. I don't actually try it. I wonder how many older generation people feel the same way I do?…I'm more of a Louvre type… but I do like the interaction, I really do. I think they're great. Maybe I don't have time, maybe it's because we don't want to take the time…*

Jerry P. is an energetic 77 year-old retired engineer who loves to run and enjoys helping and assisting people. Jerry is an active member of his community. He is past-President of a local organization for runners over the age of 65. He also has been volunteering at the Museum of Science for over 12 years. He does not consider himself to have a disability. He mentions that he is losing hearing in his higher frequencies (because of the environment he worked in during his younger years) and is currently experimenting with hearing aids. He jokingly adds, "my wife claims I can't hear." He does not wear the hearing aids when he works at the Museum because the environment is too noisy and the hearing aids amplify the background noise of the crowds.

Jerry has a computer at home that he uses for email, letter writing, storing addresses, and keeping a date book. However, he admits that he doesn't "play tricks with it" and doesn't "know how to do a lot of things." Jerry also feels that his relationship (and possibly understanding) of computers is different from that of younger generations who grew up with the technology.

As Jerry uses the interactives, he closely follows the directions and listens to the audio as he reads the information on the screen. Following the auditory delivery of the information by the computer, he steadily and purposefully presses the buttons to move the computer forward. Occasionally, when the computer does not respond as expected, he reaches up and touches the screen.

Kent

> *Recent retirement opened up a significant window of discretionary time. I decided to use this discretionary time in some constructive way, so I started volunteering at the museum one day a week…I enjoy exploring the entire museum.*

Kent is a 67 year-old retired medical doctor who has "lived a life with what is today called ADD." Over the last five years, Kent has also noticed that he is losing hearing in his higher frequencies ("my wife jests I have developed selective hearing"), although he reports that he still hears reasonably well under 10,000 Hz.

Kent has a strong interest in science, and enjoys reading and learning about the plant and animal life, evolution, space exploration, and the "politically-charged topic of creationism." In addition, Kent also appreciates the arts, particularly music and photography. He is a volunteer and frequent visitor of the Museum of Science and other museums in the Boston area. He passionately enjoys learning about science and loves sharing that information with museum visitors. Kent reports that certain design features, such as handouts describing the geographic layout and directional signage (such as arrows and footsteps) make museums more accessible for him.

Kent rates his comfort level using computers "on a scale of 1-10, about a 7 and a half." He states that unlike the "jet-set generation of today" he did not grow up with computers and he had to grow into it, calling himself a "1937 born vintage genuine antique." Regardless, he does feel "reasonably comfortable" using computers, but admits that occasionally he comes across a problem he can't trouble shoot.

When using the interactives, Kent looks closely at the visual presentations. At Fish Farming, he comments on the amount of information on the screen and reports that he feels "a bit overwhelmed." He carefully reads all of the labels (those on the kiosk and the screen) before starting each interactive. He then follows the directions precisely, and expresses that he wants more precise language and definitions at Mammal Skull Mystery and Fish Farming.

Gail

> *I'm really not a computer person… I was completely computer illiterate until I-- well when I went to college, of course I used e-mail and very basic web searches, but until I started working out of college I didn't really even know how to turn one on…*

Gail is a 27 year-old graduate school admissions counselor who has a non-verbal learning disability (NVLD), which influences her learning preferences in a number of ways. She enjoys learning, especially about history and politics although she is not as interested in science. She is a frequent museum visitor, visiting at least one local museum a year. While she is a frequent computer user, she feels her skills are limited and does not like using it "all the time." Gail is highly aware of her disability, and is well informed about the ways it impacts her learning style.

> *For me it's abstract spatial thinking. For example…geometry wasn't even worth taking for me. I got a lot of help, I'm sure I learned something, but I forgot it all. It's not the type of learning-- makes visual learning difficult. I'm definitely an audio learner, and I need to write everything down…And it also, in me, it can affect different people in different ways. For me, fine motor skills and organizational, sort of executive functioning, are affected.*

When Gail uses the interactives, she tends to read first and act second. She follows the text directions precisely and presumes a literal interpretation of the text. She reads the information aloud as she works and re-reads certain segments when needed.

> *So I read it over twice, because I wanted to make sure I understood it. Had you not been here and I was doing this, I probably would still be reading it out loud. Because that's how I understand it better.*

Gail focuses on the visuals and reacts positively to the "bright…fun" appearance of Fish Farming, while simultaneously feeling overwhelmed by the amount of visual stimulation.

Yaacov

> *I make armor, as in chain mail…I do all kinds of things…I've done pottery, I've done woodwork, I've taken classes at innumerable places…Long and short of home-schooling is that if someone is interested in something and can explain why they are interested in it you are going to have an interesting conversation and learn something and it doesn't matter what the content is. Science, art, whatever…*

Yaacov is a 17 year-old home-schooled student who has dyslexia, dysnomia, and dysgraphia. As part of his home-school education, he regularly visits and volunteers at multiple museums in the Boston area, including the Museum of Science. He is passionate about learning, and takes the time to study many topics at an in-depth level, including art, science, and his most recent passions- metallurgy and medieval history.

Yaacov feels very comfortable using computers. He has done some programming and relies extensively on text-to-speech software to provide him with access to information and experiences that would have previously been inaccessible to him.

> *The major leap was text-to-speech software…that has allowed me to do an enormous quantity of things…it allows me to use the web… it allows me to copy and paste pieces of code back into the programming system and then I can go from there. So yes, I do feel quite comfortable using computers thanks in large measures to the reading software.*

Yaacov not only relies on auditory information at home when using his computer, he also states that the availability of auditory information in museums (whether delivered through computer interactives or handheld audio tours) is an essential element for providing him with access to learning experiences.

Since Yaacov uses the museum as his classroom, he is very familiar with all three interactives and could be considered an expert user for each one. When using them, Yaacov immediately turns on the audio and then listens to it as he looks at both the text and images on the screen. The only time Yaacov does not rely on the audio is at Personal Computers when he devises a way to keep the computer from timing out by pressing the arrow buttons up and down while he slowly reads the screen to himself. Yaacov consistently moves through the interactives quickly, skipping screens if he feels he knows the information well. If he makes a mistake, he hits the go back button or finds another way to correct the error.

Linda

> *Interviewer: I'll let you know when I'm turning the recorder on, and you can also let me know when you want to turn it off. For example, one woman, she's so sweet and wonderful, and at one point, she asked me for a mint for her breath, and then she goes, "oh! I just got that on tape!" It was so funny. So, if at any point in time you want to ask for a mint, or anything else, just let me know, and I'll shut the recorder off.*
>
> *Linda: One mint. [LAUGHTER] I've got a bad sense of humor.*

Linda is a 60 year-old access advisor who enjoys knitting, reading fictional books, and studying the Torah. She has a witty sense of humor, strong connections to friends and enjoys the time she spends serving the community by providing feedback and advice on issues related to accessibility. Linda feels somewhat comfortable operating computers, using her home computer to draft documents, email friends and play games such as Solitaire and Free Cell.

She considers herself to have "post-Linda" syndrome, as she has many disabilities that have worsened over time, including low vision, limited use of hands (no fingers on her dominant hand), cerebral palsy on her right side, stomach disorders, asthma, stressed ligaments in her ankles, difficulty processing information in the right hemisphere of her brain, and seizure disorders that cause her to lose her ability to concentrate. The cumulative impact of all these disabilities on Linda can make her life difficult and overwhelming at times, but she receives help from a personal assistant and receives lots of support from friends and family.

Linda’s personal care assistant accompanies her to the museum, but she does not assist her as she uses the interactives. As Linda uses the interactives, she reads the labels and follows the directions. She also recalls prior experiences with computers (such as working with web sites), using those previous interactions as a guide. She uses the audio on occasion, but frequently becomes confused. During her retrospective reports she has difficulty determining the difference between thoughts in her head, instructions the observer was giving, and the computer’s audio. In addition, her interactions with many of the interactives (particularly Fish Farming) are cut short as elements that are part of the design (the swimming fish at Fish Farming and the spinning skull at Mammal Skull Mystery) or outside of the design (repetitious noises in the *Computing Revolution* gallery where Personal Computers is located) cause her to have seizures.

Judy

> *So when I get stuck I sit there and I’m like, ‘think outside of the box. What could be the other solution?’*

Judy is a 40 year-old university access advisor who, as a result of post juvenile rheumatoid arthritis, uses a wheelchair and has limited use of her fingers. Part of having a disability, Judy tells us, is being able to quickly problem solve and develop new solutions. Although she didn’t want to “go into the stereotypic career” of rehabilitation education, Judy’s personal experiences led her to pursue a career in rehabilitation and disability policy. Given Judy's profession, she frequently provides feedback as to what she expects would be problems for other users, in addition to stating what works for her as a user.

Judy is a frequent museum visitor who loves visiting museums of all kinds including art, anthropology, and natural history museums. She finds it helpful when museums provide visitors with adequate signage to direct them towards services and architectural elements that are wheelchair accessible. Judy does not consider herself a computer expert (and says she has a history of "blowing up" computers), but she is "getting more comfortable all the time."

As Judy approaches each interactive, she takes the time to position her wheelchair so it is optimally placed for her to reach the controls and see the screen. She then looks around for outside information that will provide her with a "general overview." When using the interactives, she frequently adjusts her body's position in the chair, leaning back and moving her head left and right. She then listens to the audio as she reads the information, pausing after the audio is finished to look more closely at the screen.

Stacy

> *All my life I studied Karate, for 16 years. My husband was a teacher. I stopped at 30 when I was diagnosed with MS. Now it is still a big part of my life because of my husband. I've done Tai Chi in a wheelchair. My exercise person has me do Karate punches. It's still in my heart mentally, including the discipline…*

Stacy is a 50 year-old former entrepreneur, teacher, and Karate brown belt who currently works as a customer sales agent from home and takes pleasure in visiting museums. She loves learning, and states that there are very few topics she isn't interested in learning more about. Stacy has MS, which has led her to develop limited upper and lower body strength and requires her to use a wheelchair. She used to attend museums regularly, but doing so has become more difficult over time based on both her physical and monetary situation (she is living on a fixed income). When she visits museums she must do so with a personal assistant as it is difficult for her to wheel around on her own, which means she needs to pay admission for an additional person. Stacy states that she feels comfortable using computers, and uses one on a regular basis to work on a part-time sales job from home.

When Stacy uses the interactives, she wheels up close and presses the buttons with hand, keeping her fingers curled under to provide extra strength as she pushes her body weight behind her action. When she is not interacting with the screen, she rests her hands on her lap, or on the surface of the table. She consistently reads first and acts second, taking the time to read all of the available information both outside and on the computer screen. She tends to feel less comfortable learning a system through trial and error, but will take the time to explore the interface if the instructions are not clear.

Jen

> *I've taken classes with art-related programs like Photoshop and Dreamweaver. I've worked as an assistant web editor for a little while, at one point. Although I don't consider myself to be very techno-savvy…*

Jen is a 31 year-old museum studies student who works at a local university. She does not consider herself to have a disability. She is a frequent computer user, but says she is not "techno-savvy". She enjoys working out, hanging out with her family, and visiting museums. She is also interested in learning about sociology and psychology and her favorite science classes were chemistry and biology. Her passion, however, is the visual arts. She frequently visits art museums, and has taken courses about graphic design and other art-related disciplines.

As Jen uses each interactive, she reads the text, but since she is a visual learner, focuses more on the images than the other elements of the interactives' design. She tends to follow the directions, and is hesitant to explore a system using trial and error. When she attempts to problem solve, she is successful.

Vicky

> *[I've been using a computer] Ever since fourth grade. My dad was a computer science major so very early on we had a computer…*

Vicky is a 20-year-old computer science major at a local institution of higher education who does not consider herself to have a disability. She has an interest in interactive design and education, and is currently taking courses on each. She is also interested in abstract topics such as mathematics and Chinese calligraphy, although she admits that she doesn't have time for hobbies now that she is a student. Given the demands of her college schedule, she's only visited one museum in Boston, the Museum of Fine Arts. However, this is not indicative of her usual museum-going habits. When growing up, she would visit the local children's museum twice a year with her family.

Vicky's computer experience is extensive. She uses her computer to do homework, watch movies, and play games. When asked to describe the set-up of her computer, she nonchalantly mentioned that she uses "a desktop, one that I built with my friend." She also has a laptop, but rarely uses it. When I met her, she wasn't sure whether she wanted to be a computer science researcher or a programmer after graduation.

Vicky uses both hands when operating the interactives. She rapidly clicks the buttons, moving her hand as if she was playing a video game. She does not use the audio, but instead focuses on the text to determine what to do. Vicky also relies extensively on the visual representations and uses them to guide her decision-making at both the Fish Farming and Mammal Skull Mystery interactives.

Cross-case findings

Looking across at the experiences of the 16 different participants, study findings reveal that the Museum of Science button interface is, for the most part, successful at providing physical access for visitors of a broad range of abilities and disabilities. Each participant is able to perceive the information provided at the three kiosks and use the button interface to navigate and input selections with little to no assistance. Tables 3-5 summarize the physical accessibility of the three interactives, including information on the problems the participants encounter and the interventions (if any) the observer applies to move them forward. These findings show that not all of the interactives are fully accessible to all users. In order to make the interactives easier to use for the study participants, design elements beyond the button interface and the use of audio and text to deliver information will need to be incorporated into the design.

TABLE 3: SUMMARY OF FISH FARMING'S ACCESSIBILITY					
	Turns audio on/off?	**Perceives directions?**	**Runs simulation?**	**Perceives changes in fish tank?**	**Changes one or more variables?**
Alice	Yes	Yes	Yes	Yes	Successful after second try, clearer directions requested
Jerry B.	Yes	Yes	Yes	Yes	Couldn't figure out how to go "up" in numbers, clearer directions requested
Olivia	Yes	Yes	Yes	Yes	Yes
Mark	Yes	Yes	Yes	Yes	Yes
Carol	Yes	Yes, after instructed to hit Enter	Yes	Yes	Yes
Leon	Yes	Mistakenly hits Start Over first	Yes	Yes	Yes
Carolyn	Yes	Yes	Yes	Yes	Yes
Jerry P.	Yes	Mistakenly hits Start Over first	Yes	Yes	Yes
Kent	Yes	Yes	Yes	Yes	Yes
Gail	Yes	Yes	Yes	Yes	Yes
Yaacov	Yes	Mistakenly hits Start Over first	Yes	Yes	Yes
Linda	Yes	Yes	Yes	No, moving fish induce seizure	Yes
Judy	Yes	Yes	Yes	Yes	Yes
Stacy	Yes	Yes, after instructed to hit Enter	Yes	Yes	Successful after observer instructs on the order buttons should be pressed
Jen	Yes	Mistakenly hits Start Over first	Yes	Yes	Yes
Vicky	Yes	Mistakenly hits Start Over first	Yes	Yes	Yes

TABLE 4: SUMMARY OF PERSONAL COMPUTERS' ACCESSIBILITY					
	Turns audio on/off?	**Navigates menu?**	**Selects choices?**	**Perceives information?**	**Connects computer to artifacts?**
Alice	Yes	Yes	Yes	Yes, but limited by time-out and background noise	No
Jerry	Yes, after observer instructs to hit twice	Yes	Yes	Yes, but limited by time-out and difficulty hearing	No
Olivia	Observer tells participant about the audio on/off	Unable to detect highlighting without assistance	Yes, but wants directions	Yes, but limited by timeout	No
Mark	Yes	Yes, but thought it was a touchscreen at first	Yes	Yes, but some text too small	No
Carol	Thinks "audio text" = captions	Yes, but thought it was a touchscreen at first	Yes	Yes, but movie captions were hidden from view	Yes
Leon	With some assistance	Yes, but thought it was a touchscreen at first	Yes	Yes, but movie captions were hidden from view	No
Carolyn	Yes	Yes	Yes	Yes, but wanted better captioning for the 1984 movie	Yes
Jerry P.	Needs instructions	Needs instructions on how to use the buttons	Yes	Yes	Yes
Kent	Yes	Yes, but thought it was a touchscreen at first	Yes	Yes (timeout feature was fixed)	Yes
Gail	Yes	Needs instructions on how to use the buttons	Yes	Yes	Yes
Yaacov	Yes	Yes	Yes	Yes, but limited by time-out	Yes
Linda	Yes	Yes	Yes	Yes, but background noise causes processing difficulties	No
Judy	Yes	Yes	Yes	Yes, but limited by time-out	Yes

TABLE 4: SUMMARY OF PERSONAL COMPUTERS' ACCESSIBILITY (CONTINUED)					
	Turns audio on/off?	**Navigates menu?**	**Selects choices?**	**Perceives information?**	**Connects computer to artifacts?**
Stacy	Yes	Needs clearer directions, and increased contrast for menu selections	Yes	Yes	No
Jen	Yes	Yes, but thought it was a touchscreen at first	Yes	Yes	No
Vicky	Yes	Yes	Yes	Yes, but limited by timeout	No

TABLE 5: MAMMAL SKULL MYSTERY'S ACCESSIBILITY							
	Picks a skull?	**Listens to/ reads question?**	**Examines skull?**	**Inputs selections?**	**Answers correctly?**	**Compares computer's answer to #?**	**Connects activity to artifact case?**
Alice	Yes	Yes	Yes	Yes	No, needs a better description of what the different features feel like and where they are found on the skull	No, did not notice tactile numbers	No.
Jerry B.	Yes	Yes	Yes	No, couldn't tell what buttons did	No, needs a better description of what they different features feel like and where they are found on the skull	No, couldn't identify numbers by touch	No
Olivia	Yes	Yes	Yes	Yes	Yes, but first time she thought they were shells	Yes	No
Mark	Yes	Yes	Yes	Yes	No, needs a better description of the features and clearer images	No, contrast too low	Yes
Carol	Yes	Yes	Yes	Yes	Yes, couldn't do it at first, but got it right after 3rd try	Yes	Yes

TABLE 5: MAMMAL SKULL MYSTERY'S ACCESSIBILITY (CONTINUED)							
	Picks a skull?	**Listens to/ reads question?**	**Examines skull?**	**Inputs selections?**	**Answers correctly?**	**Compares computer's answer to actual #?**	**Connects activity to artifact case?**
Leon	Yes	Yes	Yes	No, couldn't tell what buttons did	No, didn't understand activity purpose. Once observer explained, answered correctly	No	No
Carolyn	Yes	Yes	Yes	Yes	Varied, needs a better description of some skull features	Yes	Yes
Jerry P.	Yes	Yes	Yes	No, hits a different button then intended	Varied, needs a better description of some skull features	Yes	No
Kent	Yes	Yes	Yes	Yes	Yes, some skulls required multiple tries. More precise descriptions of skull features would improve activity	Yes, doesn't read numbers, but counts the skulls	No
Gail	Yes	Yes	Yes	Yes	No, needs better descriptors of the features	Yes	Yes
Yaacov	Yes	Yes	Yes	Yes	Yes	Yes	No

TABLE 5: MAMMAL SKULL MYSTERY'S ACCESSIBILITY (CONTINUED)							
	Picks a skull?	**Listens to/ reads question?**	**Examines skull?**	**Inputs selections?**	**Answers correctly?**	**Compares computer's answer to actual #?**	**Connects activity to artifact case?**
Linda	Yes	Yes, reports font too small.	Yes	Yes, sometimes computer registers multiple presses when she hits the buttons	No, activity goal needs to be clearer	No	No
Judy	Yes	Yes	Yes, but not all in reach	No, doesn't understand the buttons' purpose	No, activity goal needs to be clearer	Yes	Yes
Stacy	Yes	Yes	Yes, but some hard to handle	Yes	Varied, activity goal needs to be clearer	Yes	No
Jen	Yes	Yes	Yes	Yes	Varied, more precise descriptions of skull features needed	Yes	Yes
Vicky	Yes	Yes	Yes	Yes	No, more precise descriptions and better visual mapping needed	Yes	No

Participants' perceptions of their experience

As shown in Table 6, the participants' perceptions of their experiences vary across the three interactives. Participants are positive about their experiences at some of the interactives, describing these interactives as fun, challenging, and offering opportunities for learning. In contrast, the participants are less optimistic about other interactives, expressing frustration because the directions are hard to understand or the goals are unclear, or stating that they do not feel that these interactives are educational.

While the participants each express a range of feelings about the three interactives, they do not all agree on which interactives are educational, fun, or difficult to use. Not all participants in the study prefer the same activity, and user preferences for one activity over another are quite strong. Comparing across, 9 participants list Mammal Skull Mystery as their favorite, 5 list Fish Farming, and 2 list Personal Computers. There also isn't uniform agreement as to the interactives that are the most difficult to use (with five participants listing Mammal Skull Mystery, 6 listing Fish Farming and 5 listing Personal Computers) or the easiest to use (with 9 participants listing Mammal Skull Mystery, 5 listing Personal Computers and 3 listing Fish Farming). Interestingly, the interactive the participants consider the easiest to use is not always the one they are the most successful using (as defined by the criteria for success outlined by exhibit developers) nor is it the one they like the best. Almost universally, the participants report that it was the content and the type of activity that determines which interactive is their favorite, and not its ease of use.

TABLE 6: PARTICIPANTS' OPINIONS OF THE INTERACTIVES			
	Likes the best	**Easiest to use**	**Most difficult to use**
Alice	***Mammal Skull Mystery***: "I think it had the most information, and the most kind of things to do."	***Fish Farming***: "It was basically a problem to solve. And if you figured out how it worked, you could solve the problem relatively quickly and that was the end of it."	***Mammal Skull Mystery***: "There was no way to really be certain that in answering the questions you were getting the right information about what you had in your hand."
Jerry B.	***Fish Farming***: "Forced me to think about something and perform a task and see the results of the task I had performed." and "Easy, but it challenged me a little bit…when I'm challenged I tend to remember what I did and feel some satisfaction from it."	***Fish Farming***: "Buttons were pretty intuitive…except for the one thing about the scrolling," "I could hear the results of what I did right away. I like the sound thing where, the descending sound indicated how far down the population was going. I thought that was pretty cool." And "The speaker sounded good, the voice was good."	***Mammal Skull Mystery***: "Confused between the incisors and the canine teeth."
Olivia	***Mammal Skull Mystery***: "I liked the fact that you actually could hold something in your hands, and that made it real." And "I could solve the problems all by myself. That's a really great feeling."	***Fish Farming*** and ***Mammal Skull Mystery:*** Reports both are easy to use.	***Personal Computers***: "Not being able to know what to do," "couldn't see the highlights," and "could have had a little more information about the computers."
Mark	***Mammal Skull Mystery***: "I did learn something. Eyeballs, the way it was structured, whether they were nocturnal or otherwise. I like the fact that I could touch them and get close to the skulls and physically move them."	***Mammal Skull Mystery***: By default, others perceived as more difficult.	***Personal Computers***: "I had to get up to see the monitor better."

TABLE 6: PARTICIPANTS' OPINIONS OF THE INTERACTIVES (CONTINUED)			
	Likes the best	**Easiest to use**	**Most difficult to use**
Carol	***Mammal Skull Mystery***: "It was more of a challenge. Knew at end you would get the names of the skulls. Knew that goal was to find out and you did."	***Mammal Skull Mystery***: "The screen had clear choices with expected answers Yes, No. Buttons, there were only three of them… It was sort of easy to figure out Yes, No… It was also visual."	***Fish Farming***: "It was confusing to figure out what the goal was, what you were supposed to do."
Leon	***Fish Farming***: "You got a little bit of history there, you got some information and facts I actually didn't even know about that I left with."	***Personal Computers***: "The directions were right there. Well actually, not even the directions. The way it was presented, the presentation was easy."	***Mammal Skull Mystery***: "It just left me clueless. It posed a question to me on, How am I going to interact with you?" And "It felt like I was back in school where I had to find out everything and I was going to be tested and given a grade at the end."
Carolyn	***Mammal Skull Mystery***: "Learned from it" and "More like a game. It was really interactive."	***Mammal Skull Mystery***: "Clear questions, clear answers."	***Fish Farming***: "All that math. It's a personal thing for me with math. As soon as I see some sort of problem-solving I think 'Yuck'."
Jerry P.	***Fish Farming***: "Fun," "It was very clear," "I liked the mathematics of it," and "There seemed to be more to do."	***Mammal Skull Mystery:*** "It wasn't asking you to do too much."	***Personal Computers***: "Didn't understand what they were trying to say." And "Past my generation, at my age, we weren't into computers. The language, for me, it is a foreign language."

TABLE 6: PARTICIPANTS' OPINIONS OF THE INTERACTIVES (CONTINUED)			
	Likes the best	**Easiest to use**	**Most difficult to use**
Kent	***Mammal Skull Mystery:*** "It was organized, it led me to be able to build on new knowledge and reach out to push my envelope further." And "I like the algorithm system by which the design of that exhibit enables one to move systematically from a skull to the identification of that skull."	***Mammal Skull Mystery***: "Very clear signage, very straight-forward, focused questions, and I would have to say an overall simplicity of design."	***Fish Farming***: "For me, I was continually confused by seeming inconsistencies in the responses to the same questions leading me to wonder if the exhibit was flawed or whether I was not understanding the goal of the exhibit." And "It's not self-explanatory how to engage with that particular exhibit."
Gail	***Fish Farming:*** "There's something about its content that just interested me. Working between two factors I guess, like negotiating the two factors, that's what I liked."	***Personal Computers:*** "It wasn't requiring you to do anything. Once you figured out the buttons, it was just requiring you to read the information. Or listen to it, if you chose the audio message."	***Mammal Skull Mystery:*** "I feel like the fossil thing was just sort of try it- Tell us what you think, we're going to tell you if you're wrong or right."
Yaacov	***Personal Computers:*** "Despite all of its problems… I like the history of the computers and it in part because that really did have a very high content to time ratio."	***Mammal Skull Mystery:*** "It had fairly clearly how to navigate through it."	***Personal Computers:*** "It times-out on it, it doesn't get the sounds towards you, the angles are strange."
Linda	***Mammal Skull Mystery:*** "The easy one was the best."	***Mammal Skull Mystery:*** "Easy to do, wasn't fast. Easy-going, helped if you knew something about animals."	***Fish Farming:*** "It was stuck in a very open junction." And "I ended up having seizures all evening and difficulty going to sleep."

TABLE 6: PARTICIPANTS' OPINIONS OF THE INTERACTIVES (CONTINUED)			
	Likes the best	**Easiest to use**	**Most difficult to use**
Judy	***Mammal Skull Mystery:*** "I have a natural interest in it. I think it was visually attractive. Not so much easy access, but it had more hands on."	***Mammal Skull Mystery:*** "It's very clear…it's also I think the most attractive... It was easy to use, it had a lot of comparisons that you could make."	***Personal Computers:*** "I realized I had to sit up on top to see the screen. And the print, to be honest, it was a bit faded… And the timing out, just was like, the first time it was like okay, but then it became increasingly frustrating."
Stacy	***Personal Computers***: "I found that the easiest; I like easy." And "I always like to learn new things."	***Personal Computers***: "I remember it was just pretty straightforward, that I knew what I was getting when I pressed the button."	***Fish Farming***: "It took me a while to get the hang of that one. But I wanted to get the hang of it." And "I think maybe the instructions weren't clear."
Jen	***Mammal Skull Mystery***: "The way that you were able to pick up the objects…touch them, and interact. I thought the graphics were nice, the different pictures of the animals. It just kind of sticks out more than the other two in my mind."	***Personal Computers***: "Once I started using it, it was actually very simple."	***Fish Farming***: "I remember being able to use it successfully, but not feeling quite certain that what I was doing was right."
Vicky	***Fish Farming***: "It was more interactive… felt like it was something, that a, that there were choices that I had to make, in order to accomplish something… Sticks out in my memory more because I had to estimate what I thought were the correct inputs."	***Personal Computers***: "It wasn't an interactive display-just looking for information, wasn't very many things to do. If you just wanted to get information out of it, it was a simple system for doing it."	***Mammal Skull Mystery***: "I felt like the layout was hard and ended up pressing the wrong buttons and when I sat down it wasn't clear at first how to go about playing the game."

DISCUSSION

This study provides a lesson on how the design of a learning experience shapes and influences an individual's ability to learn. Examination of the study's findings reveals that each participant has varying levels of success as he or she uses the three interactives and that in some cases, the same individual who is highly able to interact with and learn from one interactive is *disabled* when using another. In addition, it is the presence (or lack thereof) of certain design features that appears to play a pivotal role in the accessibility of the interactive for the participants. Looking closely, this finding exposes the following for museums:

- ***A dilemma***: The design of the interactive influences who is able, and who is disable, to learn from the experience. This poses a dilemma: how can museums design interactives to promote learning amongst users of a broad range of abilities and disabilities?
- ***A solution***: Study findings yield insights on design solutions that can be applied so that interactives are accessible for a broader range of users.
- ***A challenge***: This study reveals that a significant challenge still remains: experiences that are "usable by all people, to the greatest extent possible" are not always "better for all."

The discussion below looks further into these areas and offer interpretations on what these lessons mean for the design of future interactives in museums.

Design shapes who has access to learning

> *If a particular kind of learning is not made socially available to us, there will be no learning to do. (McDermott, 1996)*

Study findings bring to light how the design of the interactives influences the ability of the individual to access the learning opportunity afforded by the experience. Each participant has varying success as they use the three interactives. For example, some participants find it easy to interact with Fish Farming and report that the experience is educational and meaningful, while at the same time stating that Mammal Skull Mystery is difficult to use and hard to comprehend. Other participants find Fish Farming confusing and overwhelming, yet maintain that Mammal Skull Mystery is easy to use and thought provoking.

Whether an individual is able to learn from the experience appears to be a function of the relationship between the design of the environment and the individual’s physical characteristics and prior experiences. This finding challenges us to reconsider traditional notions of disability as defect, considering that persons who are labeled as “disabled” are sometimes more successful using the interactives than the persons who do not have that label, and reinforces the social model of disability where disability is a reflection of the denial of rights for individuals who are perceived as “other.”

Nowhere is this more evident than in the comparison of the experiences of Olivia, an inexperienced computer user with low vision, and Vicky, a computer science major at a prestigious technical institute who does not self-identify as having a disability. Both individuals are highly successful using two of the three interactives, yet each experiences moments of “disability” when using one of the three interactives. For Olivia it is the

Personal Computers interactive that is difficult to use and comprehend, for Vicky it is Mammal Skull Mystery.

Taking a closer look at Olivia

Olivia is a 55-year old retired teacher who has low vision and limited experience using computers, but is very well read on matters concerning science. Olivia interacts with Fish Farming with ease. She is able to perceive the available directions through both sight and sound, and follows them exactly to determine what to do. She observes changes in the fish population, and manipulates the variables to find optimal solutions for preventing the spread of disease in the fish tank. She solves both of the activity's "challenges", which is a significantly positive result as very few visitors are able to complete challenge 1 or challenge 2. During the formative evaluation of this interactive with the Museum's family audience, only 11 of the 55 groups observed using the interactive successfully completed both challenge 1 and challenge 2 (Robertson, 2003). After using the interactive, Olivia reports that she learned something new through this activity about the relationship between the number of fish in the tank and the rate at which the disease is able to spread.

Olivia also experiences success using Mammal Skull Mystery, although this interactive is not as easy for her to use as the first. Olivia learns to use the system during her first attempt, when she fails to use the interactive correctly after mistaking the skulls for shells. Olivia is able to determine the mistake she has made on her own (without assistance from the observer/interviewer) and moves forward with the activity, calling upon her knowledge and interest in the natural world to guide her through her exploration of the skulls. She successfully answers each of the questions and identifies the skulls on the table. Her success leaves her feeling empowered, as evinced through a statement she makes during her final interview about the Mammal Skull Mystery activity,

> *…by just feeling the things and listening to the questions and answers, I could solve the problems all by myself. That's a really great feeling.*

In comparison to her success using both Fish Farming and Mammal Skull Mystery, Olivia is not able to fully access Personal Computers. When Olivia first approaches this interactive, she remarks on the absence of directions to tell her what to do. Through process of elimination, she decides to press the round button to start the interaction. Olivia then moves her head back and forth with her eyes close to the screen as she rapidly searches for directions. As she does this, the computer times-out. However, she does not despair, and again presses the round button. This time she sees the directions, and reads aloud "Select any of the buttons to the right to get started…" Olivia then presses the right triangle and looks for changes on the screen. When she doesn't notice any, she presses the left triangle multiple times, still searching the screen for a response to her actions. She again does not notice the changes on the screen and is unsure how to interact with the interactive. Eventually, the observer calls her attention to the highlighting and explains how to use the menu, and Olivia is able to move forward.

Taking a closer look at Vicky

Vicky is a savvy college student with extensive computer experience and no reported disability. Vicky, like Olivia, excels at using Fish Farming. She reads the directions, perceives changes in the fish population over time, and finds solutions for both of the available challenges. When making choices about how many fish there should be in the tank to prevent the spread of disease, she relies on the visual information of how crowded the fish appear to guide her decision.

> *I know that fish need certain space or, you know, disease always affects us more in small spaces… so I looked at the fish tank to see how populated it was and then estimated a number and gave that estimate a try… I thought the tank was a nice visualization…*

Similar to Olivia's reaction to Fish Farming, Vicky reports that she understands the purpose of the interactive and states in her final interview, "the concept [Fish Farming] was trying to teach, the whole modeling thing, was an interesting approach."

Unlike Olivia, however, Vicky is also able to interact with Personal Computers. She perceives the available information by reading the text, and successfully navigates through the menu options using the arrow keys and makes selections by pressing the round Enter button. Vicky experiences some difficulty accessing the "Simple IC Chip Movie" due to a lack of clear mapping between the buttons on the console and the objects on the screen. However she is able to problem solve and develop a way around this design flaw.

Vicky is considerably less successful when using Mammal Skull Mystery. Here, Vicky is able to look at and feel the skulls, perceive through sight and sound the questions, and read the Y and N beneath the buttons that inform her of the buttons' purpose. However, Vicky is not able to answer the questions correctly and identify the skulls. She reports that the provided verbal and visual clues are not descriptive enough and make it difficult for her to answer the questions with certainty. In addition, when faced with a Yes or No question, the computer provides Vicky with two images to assist her in answering the question. The picture corresponding to an answer of "Yes" is on the left, and the picture corresponding to "No" is on the right. This is the opposite of the placement of the buttons where "Yes" is on the right, and "No" is on the left. As a result, Vicky tells us, she finds herself pressing the Y button when she intended to answer "No", or pressing the N button when she intended to answer “Yes.” The lack of clear mapping between actions and decisions creates a situation where Vicky is dis-able to interact with the interactive and learn from the experience. During the final interview, when asked which component she finds the most difficult to use, it is no surprise that she chooses Mammal Skull Mystery.

Olivia and Vicky- how design shapes ‘ability’

Vicky demonstrates the characteristics of a person who is traditionally labeled “able”: she perceives the world through both sight and sound, and is an experienced computer user. Olivia, in contrast, is traditionally labeled “disabled”: she has low vision and is a very inexperienced computer user. Comparing Vicky’s and Olivia’s experiences at the three interactives, however, reveals that “ability” is contextual. At some activities, Vicky is able to successfully interact and learn from the experience, and at others she is not. The same is true for Olivia. Thus, who is able or disable is not always a consequence of the physical characteristics of the individual, but is shaped by how well the environment has been designed to support the methods through which he or she learns about and perceives the world.

If the design of an interactive plays an important role in determining who is able or disable to learn, it presents a dilemma for museums: how can they design environments that promote learning for visitors of a broad range of abilities and disabilities? Further analysis of the study findings reveals design solutions that provide access to learning for a broad range of users.

Design features that support universal design for learning

Study findings reveal a series of design features that either support or detract from the participants' experiences as they use the three interactives. Summarized below is a list of design elements that should be considered when designing future computer interactives. This list of features was generated through observational data, which provide insights on how the users used the three interactives, and interview data that reveal the participants' perspective about how the design enabled or disabled them as a learner. Because the theoretical framework for this study is that the user is the expert concerning issues of what is and isn't accessible for them, greater weight was given to suggestions revealed through interview data than those derived through observations.

This list is not exhaustive and does not provide a definitive guide for the design of computer interactives for museum exhibitions. Given the small number of users, the results of this study may not be generalized to reflect all users. However, the design features that were chosen for inclusion in this section were selected based on their apparent benefit across users of a broad range of abilities and disabilities. Therefore, it is hypothesized that these design features would benefit a larger audience. Suggested design features include the following:

- The activities' goals should be clearly presented at the beginning of the activity;
- Directions should be clear and simple, and provide participants with a precise description of what to do and the exact order for doing it;
- Monitors should be placed in upright positions close to the edge of the table;

- Images should offer a visual indication of what to do, how to proceed, and the content behind the activity;
- There should be clear mapping between the buttons and the images on the screen;
- Screen text and audio should closely match and provide opportunities for the user to easily switch back and forth between the two modes;
- Users should be provided greater control over the pace of interaction;
- Timeouts should allow time for user feedback before ending a session;
- Buttons should be clearly labeled and provide visitors with both a tactile and visual indication of how they should be used;
- Images should have high contrast and there should be reduced dependence on color-coding for visual cues;
- Precise and descriptive language should be used to assist participants who are blind and aid learning for participants who are sighted;
- Background noise should be kept to a minimum; and
- Images should move slowly on the screen.

The reasoning behind each of these design suggestions, as well as information on the participants who would have benefited from their implementation, are provided in detail below.

The activities' goals should be clearly presented at the beginning of the activity. Review of the participants' interview responses reveals that, for many of the participants, a clear goal and/or purpose greatly influences whether the participants' enjoy an interactive and perceive that it is easy to use. If the participants feel the goals are clear, this generally relates to a positive feeling about the experience. If participants feel the goal is not clear, it leads to negative feelings and in some cases a perception that the experience is inaccessible. The request for a clear indication of the activity's goals is expressed by participants of a broad range of abilities and disabilities,

> *In terms of the ADD challenge, I think this museum does a very good job of keeping the exhibits sufficiently simplified and focused to allow an individual with ADD to remain engaged. But I would certainly share with other museums that for many individuals it is important to keep an exhibit straightforward, well focused, in order to have the interaction continue with engagement by the user. (Kent, describing in his final interview, what he would tell other museums about designing interactives for individuals with ADD)*

> *It was confusing to figure out what the goal was, what you were supposed to do. (Carol, who is deaf, describing in her final interview why she finds Fish Farming difficult to use)*

> *It was basically a problem to solve. And if you figured out how it worked, you could solve the problem relatively quickly and that was the end of it. (Alice, who is blind, describing in her final interview why Fish Farming is easy to use)*

> *Well I liked in the fish farming, I liked the specificity of the task, what they're asking you to do. It's pretty well outlined. (Gail,who has a non-verbal learning disability, describing in her final interview an aspect of Fish Farming that aids her experience)*

> *I just saw a fish in the tank, and then I pressed the arrow. The fish started to go somewhere, I think. You're just saying the number of fish in the tank-- But I don't know, I mean consciously I don't know what I'm trying to aim for. (Stacy, who uses a wheelchair, describing at Fish Farming why she is having difficulty using the interactive)*

> *Maybe I can add why I was frustrated with the third one. Because I came in with an open mind, but I didn't know how to communicate with this exhibit. I wasn't being led. I was saying, "Hey, you tell me my agenda," and it didn't tell me. But with your prompt it gave me a little agenda, or an outline to follow. Then I could follow the road of learning after that. It was that middle ground that prompts from A to C. B wasn't there. (Leon, who is deaf, describing in his final interview why Mammal Skull Mystery is difficult to use and why the observer intervention helps him to understand the activity)*

Providing visitors with a clear indication of the interactives goal is often cited as a "best practice" in exhibition design. As stated by George Hein,

> *Informing [the visitors] explicitly in advance what they are going to see, what they might find, or what the intention of the exhibition is, makes visitors more comfortable, more able to engage with the exhibitions and therefore, better able to learn. (Hein, 1998)*

The importance of providing visitors with an indication of an interactive's goal increases when considering the needs of an audience that includes a broad range of users. For example, as Kent tells us, visitors with decreased attention need a clear indication of the goal and purpose to help them remain focused on the activity. In addition, given the significant link between the goal being clear and participant enjoyment and learning, developers should consider how to communicate this information through multiple media (visual images, audio and text) to be sure that the purpose of the activity, and hence the experience, is accessible to all users.

Directions should be clear and simple, and provide participants with a precise description of what to do and the exact ordering for doing it. The lack of clear directions is a problem for several participants and in some cases, inhibits full access to the learning experience. For certain visitors, the absence of precise directions is particularly problematic. Alice requests clearer directions at both Mammal Skull Mystery and Personal Computers, and appreciates the comfort level afforded by the detailed directions presented at Fish Farming.

> *But I thought the fish one, that explained to you…that told you how to do it. I think that's really the answer. To put directions that say if you want to read how to do this, you know, press blah blah. And if you want to just fumble your way through it on your own go ahead. (Alice, who is blind, in her final interview)*

Olivia describes why clear directions are important for visitors with low vision.

> *You have to be really specific. It doesn't have to be simplified or anything, it just has to be real specific what to do. Because you can't see everything at a glance. (Olivia, at Personal Computers)*

This perspective of having a limited view of the screen at any one point in time corresponds with observations of how Olivia interacts with the computer, viewing the screen up close as she looks at it from the corner of one eye. This process results in a limited view of the screen, and a restricted understanding of the provided visual cues.

Gail, the participant who has a non-verbal learning disability, also expresses that clearer directions would assist her as she interacts with the activity.

> *I think that, if you were talking about my disability, you want directions that are specific and organized in steps. You've got to break down the big picture. You want hints or, I don't know what the right word is, cues that are not only visual but audio in nature… It's important to-- people with this as well as lots of other disabilities have a problem where everything they read they take literally. So if something is to the right it better be to the right. Not so much for an adult who has learned from lots of mess-ups over the years, but for like a little kid with the same thing that's important. Because we all have different compensation levels, and adults usually are a lot more serious with that.*

It is not surprising that Gail's learning needs are equivalent to the needs of the participants who are blind or have low vision. For Gail, it is graphical and other visual information that is the most difficult to interpret and understand, the same medium that is also inaccessible for Alice and Olivia.

Although Carol (deaf) is an experienced computer user and able to use all three interactives with little assistance, she also feels more comfortable when the directions are clear and therefore she doesn't have to rely on trial and error. Carol's desire for directions extends beyond usual text variety– she wants visual indications of what to do.

The need for clear directions that provide the user with an accurate indication of what to do is not a new concept and is frequently listed as a guideline for creating successful interactive exhibits (Kennedy, 1997; McLean, 1993; Serrell, 1996). When designing for an audience that includes a broad range of users, how we provide users with an indication of what to do changes. Here again we see the importance of presenting directions not just through text, but also through multiple media including visual representations and audio so that the directions can be clearly understood by users who perceive information through only sight and those who perceive information through only sound. Designers and developers also need to consider the subtle, visual cues that are thought to guide user interactions and provide the audience with alternative ways (through tactile cues or detailed information delivered through audio) for receiving the same information. In addition, an interactive's directions should be literal and provide unambiguous indications of the steps for interaction that do not leave room for alternative interpretations.

Place monitors in upright positions close to the edge of the table. The monitor's placement varies across the three interactives: Personal Computers' monitor is angled 45 degrees and is imbedded along the same surface as the buttons; Fish Farming's is placed upright and is less than a foot away from the edge of the table; and Mammal Skull Mystery's monitors are slightly tilted upwards, but placed much further back than Fish Farming's screen as it is positioned behind the table that holds the tactile skulls.

Of these three monitor placements, Personal Computers' screen placement is the most awkward and Fish Farming's is the most comfortable. Fish Farming's screen placement is close the 10 to 15 degrees from vertical angle recommended by Jeff Kennedy in *User Friendly: Hands-on Exhibits that Work* (Kennedy, 1997). This screen is also located close to the edge of the table and allows Olivia and Mark (who have low vision) to get their eyes close to the screen to view the finer details of the visual display. In contrast, the placement of the screens at Personal Computers is particularly difficult for Mark and Olivia who need to constantly reposition themselves (fluctuating between standing and sitting as they bend over the kiosk) to get close enough to the screen to read the text.

> *The angle of it-- because I can feel my back getting a little strained when I read that. (Mark, at Personal Computers)*
>
> *I like when things are close so I don't have to lean so far in. If I needed to, I didn't have to stand up and throw myself over the console like I did on the other one [Personal Computers]. This [Fish Farming] is cozier I would say. (Olivia, at Fish Farming)*

The angled placement of the Personal Computers' screen is also problematic for the participants who are wheelchair users. When pulling up to the Personal Computers interactive, both Stacy and Judy spend time adjusting their position, moving forward and back in their seat until the angle is just right. Even then, both Judy and Stacy need to lean forward to see the text at the bottom of the screen.

> *Being in a wheelchair-- of course, my eyesight is a little short…Being a little short, I can't read the bottom of the screen. I was trying to read this article, and the bottom is a little too low for me, well, probably because I'm short, I'm not sure…(Stacy, at Personal Computers)*
>
> *[I had] a hard time seeing something because of the angle…(Judy, at Personal Computers)*

Leon and Carol (who are deaf) also experience difficulty with Personal Computer's screen placement, as it is difficult for them to read the video captions at the bottom of the screen. Both Leon and Carol do not see the screen captions until the observer points them out. Once the captions are identified, both Leon and Carol stand up and bend over the kiosk to view them. Leon takes note of this difficulty and instructs that it would be better if the screen were placed more in his "line of sight."

In addition to decreasing the physical accessibility for users with disabilities, slanting the computer monitor also increases user frustration and detracts from the usability of the interactive. As shown in Table 4, seven of the 16 participants interact with Personal Computers as if it was a touchscreen, trying to touch the menu on the screen to make a selection. This behavior is not surprising given that Personal Computers' design is based on the design of another interactive (in *A Bird's World)* that is a touchscreen. When participants are asked why they think the interactive is a touchscreen, some suggest that the angle of the screen influenced their behavior.

Provide images that offer a visual indication of what to do, how to proceed and the content behind the activity. Functional images are needed to facilitate learning amongst our visual learners, particularly those who are deaf or hard of hearing. Many of the existing guidelines and standards for creating accessible web sites or other software focus on providing verbal access of visual images for users who are blind with detailed descriptions on the exact wording and phrasing that needs to be applied to the verbal descriptions of images**,** equations**,** and other visual representations (Freed et al., 2003; Vanderheiden, 1994; Wheaton & Granello, 2003). While many guidelines mention the need for visual representations of information, they rarely go into deeper detail about the presentation of visual images and guidelines for presenting them in a way that reaches a broad range of users. As Leon tells us, the importance of using visual images to convey meaning and directions should not be ignored.

> *Observer: And if we were going to share information about our computer designs to other institutions, what do you think we should tell them about creating interfaces that would be acceptable for you, or someone else who is deaf?*
>
> *Leon: Tell them to use more visual types of displays. Less narrative, more visual images. And not hokey, just a picture of an animal, no, but descriptors in a visual fashion. Telling me what to do in a visual way, versus just a narrative. (Leon, in his final interview)*

Jen, Vicky, and Jerry, the three participants who did not self-identify as having a disability, also find the images helpful.

> *I thought the graphics were nice, the different pictures of the animals. (Jen, in her final interview describing one reason Mammal Skull Mystery was her favorite activity)*
>
> *I think the visual helped me a lot, I could see what I was doing…(Jerry, describing a feature of Fish Farming he found helpful)*
>
> *I know that fish need certain space or uh disease always affects us more in small spaces so I looked at the fish tank to see how crowded it was and then estimated a number and gave that estimate a try. (Vicky, at Fish Farming describing how the visuals helped her to quickly solve the challenges)*

Carol, who is deaf, relies on images to facilitate her learning, extensively using the line drawings provided at Mammal Skull Mystery and the visual graphs at Fish

Farming. However, Carol feels the visuals could be improved and requests images that are more instructive. For example, Carol informs that the "red" fish in Fish Farming did not appear "sick" and suggests a sad face for the fish, as this would better indicate the disease. At Mammal Skull Mystery, Carol thinks the images on the second screen do not provide her with useful information and wishes that the animals shown better reflected the possible identities of the skulls on the table.

Gail also warns that poorly implemented visual representations could be distracting for visitors with non-verbal learning disabilities. Although Gail finds Fish Farming easy to use, she feels the screen is visually overwhelming.

> *It seemed like there was a lot of visual stimulation. The fish farm was on the one side, and then the graph was over here, and then they gave you challenge questions. It was a lot to take in at once. (Gail, at Fish Farming)*

The use of visual images across the three interactives improves the experience for multiple users. In addition, the absence of instructive images also prevents access for certain users. Leon instructs that when adding images to the interactives, exhibit developers should consider the content, feelings, and direction these images portray, and not just add them for decorative purposes. In addition, Gail alerts us to the danger of adding too many images that will over stimulate the user visually and make the interactive difficult to use. For this reason, exhibit developers should be selective about the images that are included, and work to ensure that the screen provides visual clarity and provide the visitors with guidance on what to do and where to focus their visual attention.

Provide clear mapping between the buttons and images on the screen. One of the "lessons learned" by the Museum of Science staff after years of conducting formative evaluation of computer interactives is the need to present unambiguous mapping between the buttons and the information on the screen (C. Reich & Rayle, 2004). In fact, participant remarks at Fish Farming testify that this strategy is successful as participants comment that the clear mapping between the buttons and the information on the screen makes the interactive easy to use.

While this lesson has been applied to the development of numerous computer interactives, it is not always adhered to. This is not surprising given that the absence of clear mapping is a common design flaw found across a variety of consumer products.

> *Mapping problems are abundant, one of the fundamental causes of difficulties…A device is easy to use when there is visibility to the set of possible actions, where the controls and displays exploit natural mappings. The principles are simple but rarely incorporated into design. (Norman, 1990)*

Some participants struggle when using both Personal Computers and Mammal Skull Mystery because of inadequate mapping between the buttons on the console and the information on the screen. At Mammal Skull Mystery, the picture corresponding to an answer of "Yes" is on the left, while the "Y" button is on the right. This impacts Vicky's, Carol's and Jerry P.'s experience at this interactive. All three of these participants press a button on the console that does not correspond to the answer they express aloud. Both Vicky (who does not have a disability) and Carol (who is deaf) cite this as a source of frustration,

> *Observation notes: Carol looks at the screen, and then studies her skull, feeling the teeth. She pauses. "Yes" she says in a hesitant tone. "This picture is the Y (points to the left picture) and this one is the No…it would be better if these buttons were the other way around." (Carol, at Mammal Skull Mystery)*

> *I felt like personally I had some problems with the skull one, just because I felt like the layout was hard and ended up pressing the wrong buttons. (Vicky, in her final interview)*

The lack of clear mapping between the buttons and the screen choices also negatively impacts the participants' experiences at Personal Computers. The triangle buttons used to navigate the screen point up and down, and for the most part, this position directly corresponds to the presentation of the menu choices, which are presented vertically along the right-hand side of the screen. Occasionally some menu choices are presented to the left of the main menu (such as "See how a simple IC chip works" as shown in Figure 12). Some of the sighted participants could not determine how to select this option, including the participants who were experienced computer users.

> *Now I would like to see how a simple IC chip works, but, I would like to touch that button [points to the area of the screen where the 'virtual' button is located] but I'm not sure how I get to press that. I'm guessing it's going to be by pressing this button [tries hitting the left arrow button, that doesn't work, so she just keeps scrolling through the menu choices until it is highlighted]. Oh, OK. So this is kind of odd because, its kind of strange that you have options here [points to text area of the screen], when this used to be what I thought was where the options were… [Points to the menu tree section of the screen]. (Vicky, at Personal Computers)*

> *We'll make the ...(inaudible) work (selects what makes a PC work). "Integrated Circuit", what kind of circuits do ...(inaudible)? "See How A Simple I-Chip Works"-- I selected it. It took me a second to realize that I had to go over to the right side of the menu once, to see if that left one was more that was being de-highlighted, if that's the right word. (Mark, who has low vision, at Personal Computers)*

Judy, a wheelchair user, also experiences difficulty accessing the IC Chip movie. After several failed attempts, the observer assists her with this action.

> *Judy: How do I get back there? I don't see that.*
>
> *Observer: What are you trying to see?*
>
> *Judy: I'm trying to see how an IC chip works, and I'm not quite sure how to make that happen.*

Observer: See if you can figure it out.

(Judy tries and fails again. She is getting increasingly frustrated and appears uncomfortable.)

Observer: Everyone has problems with this one.

Judy: Do you touch it?

Observer: No. But that's a good thought. Actually you have to scroll over here--

Judy: Oh, okay.

Computer: ...(inaudible) IC chip, ...(inaudible).

Judy: I never would've got there.

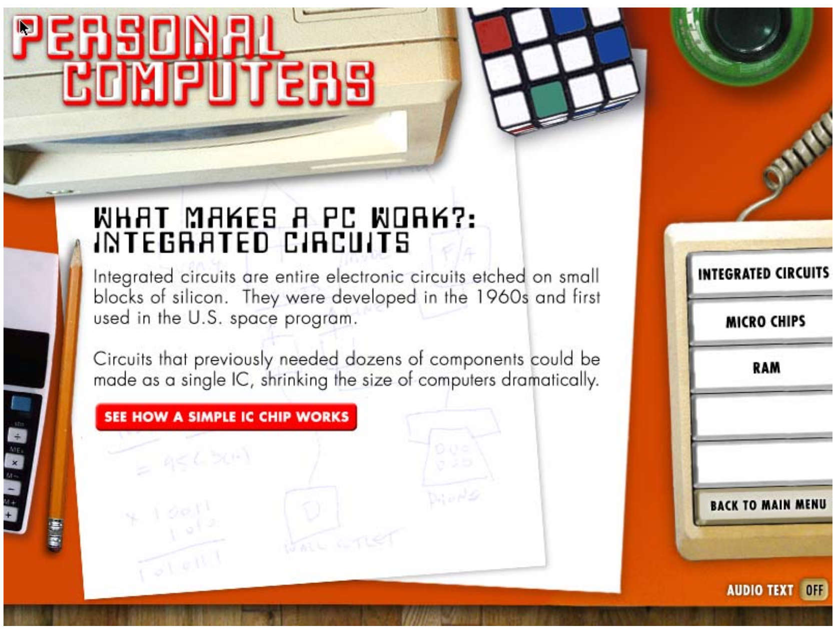

Figure 12: Personal Computer screen that was difficult for participants to navigate

One affordance a touchscreen has that the button interface does not is that with a touchscreen, there is a direct connection between the users' physical action and the selection they make on the screen. In comparison, with the button interface, there is a physical disconnect between the users' physical actions pressing the buttons on the console and the visual feedback delivered by the screen in response to that action. The designers who created both Personal Computers and Mammal Skull Mystery are accustomed to working with touchscreens where clear mapping is not an issue because of the direct relationship between the users actions and selections. However, when working with a button interface, clear and unambiguous mapping between the buttons and the selections on the screen is crucial to the interactive's success.

Screen text and audio should closely match and provide opportunities for the user to easily switch back and forth between the two modes. Observations of the participants using the interactives reveal that many participants, including Yaacov (dyslexic), Judy (wheelchair user), Mark (low vision), Olivia (low vision), Linda (low vision, limited mobility and cognitive impairments) and Jerry P. (no disabilities but wears a hearing aid) listen to the audio while simultaneously viewing the information on the screen. These participants report in their final interview and retrospective reports that the ability to simultaneously listen and read enhances their understanding of the interactives' content and directions. In addition, for Yaacov, the ability to listen and read increases his ability to problem-solve and find a way around the timeout design flaw at Personal Computers.

> *Observation notes: The computer times-out while Yaacov is reading the information on the Microchip screen. "It timed-out on me and shut my audio off." He quickly goes back to the main menu and reselects the Microchip screen. The computer times-out again. "It ends two words from the end. I can only tell because I am following along" …This problem occurs again while he is at the "Altair-how does it compare?" screen. This is a much longer screen and Yaacov realizes that he is missing a significant amount of information because of the time-out. He goes back to the main menu, selects this option again, and then turns the audio off. He reads the screen aloud to himself while simultaneously tapping the triangle buttons so that he can read the screen slowly at his own pace without the computer timing out. (Yaacov, at Personal Computers)*

Leon and Carol also instruct that all information read aloud should be presented on the screen, and that the user should be explicitly informed of this design feature. Both of these participants are deaf and the presence of the audio distracts them since they are concerned that they might be missing information. As an alternative to providing text that states “all audio appears as text on the screen,” Carol and Leon suggest that there could be a visual way to indicate that what is on the screen is also read aloud. Leon, in particular, requests a set-up that is similar to a Karaoke machine where the words on the screen are highlighted in real time as the audio is played.

> *Maybe if the words came up in a bouncing ball, or flashed up in a sequence, that would let me know that the text that's being spoken by audio is coherent, or is, (interpreter is speaking here: what's the word I'm looking for, What's the English word I am looking for)-- connected. Connected with the audio… Yeah, if I had the ability, that's what I would do. To make me feel that I'm not losing anything, versus having this voice that's a committee in the back of my mind. I want that committee out of there, I want to just be able to focus on the screen and focus on what I'm doing. Versus having that committee in the back of my head. (Leon, at Fish Farming)*

One of the dangers of simultaneously receiving and communicating information through images, audio, text, and tactile buttons is that the user could experience sensory overload. As described by Stacy,

> *All that stuff was a little bit much for me. Trying to listen, trying to look, trying to focus on what the question was. Trying to look at the pictures on the left of the screen, trying then to look at the ones on the right... (Stacy, describing her reaction to Mammal Mystery Skulls where the images were not mapped to the auditory directions)*

Providing clear connections between these different elements may help visitors to focus on the medium that best suits their needs.

Greater control over the pace of interaction would assist many of the study participants and enhance the accessibility of the interactives. Participants testify that persons with disabilities need more time to think about, or respond and act, when working with computers. They therefore appeal for more control over moving screens forward or backward. Judy and Stacy assert that persons with limited mobility need more time to implement actions due to their reduced strength. Leon and Carol express that persons who are deaf need more time to read information as English is often not their first language. Vicky and Jen, two of the participants who do not self-identify as having a disability, also request more control over the pace of interaction at Mammal Skull Mystery as they feel they needed more time to answer the questions correctly.

Yaacov, Jerry B., and Alice who are accustomed to using text-to-speech software request that the audio be spoken at a faster rate, although they recognize that the increased speed may not benefit all users. For this reason they advocate providing visitors with a choice for the speed of the computer's speech.

User control over the pace of interaction is a frequently cited guideline for the development of accessible software (Chisholm et al., 1999; Freed et al., 2003; Vanderheiden, 1994), with a recommendation that "programs requiring time-dependent responses in less than 5-10 seconds should have provision for the user to adjust the time over a wide range, or have a non-time-dependent alternative method." Given the difficulty of providing users with the capability of adjusting interactives to meet their own needs in a museum setting, museums should consider ways to create interactives that are "non-time-dependent" so that the experience can be enjoyed by those who need more time to respond.

Timeouts should be lengthened and/ or allow time for user feedback before ending a session. As shown in Table 4, many participants find the timeouts disruptive and feel it inhibits full access to the interactive. When the participants are using the interactives, the computer frequently time-outs and returns to the starting page while they are still reading, listening, or responding. In addition, the timeout feature of Mammal Skull Mystery and Personal Computers do not provide an auditory indication that the computer has returned to the first attract screen. Therefore, the participants who are blind do not know that the computer timed-out unless the observer informs them. Thus, the participants become confused because they do not understand why the feedback they were getting is not the feedback they are expecting. Either the timeouts need to be lengthened to accommodate the abilities of varying users, or participants should be provided with an option for preventing the computer from timing out, similar to the systems implemented in other web applications such as on-line banking where the user is provided with a warning that the computer will timeout unless the user responds within a certain amount of time.

Buttons should be clearly labeled and provide visitors with both a tactile and visual indication of how they should be used. Participants report that well-defined button labels help to provide a clear indication of how the buttons should be used. It should be noted that most participants do not find it difficult to use the buttons, but feel that improved labeling would provide them with more confidence as a user.

The two participants who are blind experience the most difficulty with the button labeling. Neither Fish Farming nor Personal Computers provide tactile indications of the button’s functions. Mammal Skull Mystery has raised letters, but both Alice and Jerry B.

cannot decipher what they stand for. This becomes a significant impediment and prevents them from moving forward. At Mammal Skull Mystery, Alice "guesses" which button is yes and which is no, and she happens to guess correctly. Jerry, in comparison, does not understand what either button is for, which makes the interactive almost impossible for him to use. Since Jerry has never had sight, he finds it difficult to identify letters and numbers by touch and prefers to read Braille. Alice who was sighted earlier in life also feels that Braille letters would be easier for her to use. However, these participants suggest that both raised and Braille lettering should be employed as there are many individuals who are blind who are better at identifying tactile numbers.[5]

Participants with sight express that well-defined button labels also improve their experience. Olivia feels that the buttons at both Mammal Skull Mystery and Fish Farming are well labeled and this makes these components easier for her to use.

> *First of all, they had the letters "N" and "Y", I mean, it wasn't hard to figure out that that was "No" and "Yes". [Laughs] And they were different shapes and different colors, so there wouldn't be any confusion, you didn't have to keep checking to make sure you were pressing the right button. Like if they were the same color and the same shape, you could get mixed up. (Olivia, at Mammal Skull Mystery)*

> *First thing I did was to look at the writing on all of the buttons to see what they are. It was very clear. Especially the ones that said "Enter" and "Audio on/off". Those were very clear. I did that first before I got to do anything. When the instructions said press the Enter button, I did it. Right vaccination, left is the fish, everything was read out loud to me and it was interesting too. (Olivia, at Fish Farming)*

[5] During the two pilot tests conducted with individuals who are blind, these two users also requested Braille numbers and letters stating it was difficult for them to identify the tactile numbers and letters. Like Jerry and Alice, one of the pilot test participants has been blind since birth, and the other lost her sight later in life.

In contrast, Olivia and some of the other participants report that the buttons at Personal Computers are not as easy to use because they do not have labels.

> *A few more clues as to what to do, because the buttons weren't even marked as far as I can remember…I didn't even see any-- They didn't have any instructions on the buttons like the other ones-- the other exhibits-- did. Even though they were big, it doesn't do any good if they're blank. (Olivia, discussing Personal Computers in her final interview)*

> *And then since I wasn't sure what to do with them-- and it wasn't until you pointed it out-- that I looked at the direction of the triangle, and one was up and one was down. It wasn't obvious for me. But maybe it would have been if I had played with it a little longer…(Susan, at Personal Computers)*

> *How to select one- there's no label on it yet. Select, Enter?…(Carol, at Personal Computers)*

These comments demonstrate that adding small labels to the buttons (in Braille as well as text/images) would improve the interactives for multiple users. The labels should not be long sentences, but simple one-word phrases (such as Enter or Select) or universal symbols (such as arrows). Adding these labels would increase visitor comfort with the tactile button interface.

Increase contrast of visual images and decrease dependence on color-coding for visual cues. Increased contrast for the visual images and other elements would greatly improve the accessibility of the interactives for the three participants who have low vision: Mark, Olivia and Linda. In addition, increased contrast would make the experience more comfortable for Stacy and Judy who are wheelchair users[6]. While the contrast and size of text-based information is for the most part accessible for these participants, greater visual contrast is needed for visual cues that are not based on text.

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[6] Wheelchair users are often subjected to increased glare since they are viewing information from a seated position. (American Association of Museums, 1998; Davidson, 2001)

Images the participants have difficulty viewing include the menu highlighting at Personal Computers, the line drawings at Mammal Skull Mystery, and the yellow circle on the vaccinated fish at Fish Farming.

Guidelines for creating accessible exhibitions rarely mention the need for high contrast for visual information beyond that delivered through text, yet, study findings reveal that this was an important factor in the accessibility of the computer interactives for certain users. Guidelines for creating accessible software also do not mention the need for high contrast images, but they do suggest reducing the dependence on color-coded cues for interaction. As stated in the WAI web accessibility guidelines:

> *If color alone is used to convey information, people who cannot differentiate between certain colors and users with devices that have non-color or non-visual displays will not receive the information. When foreground and background colors are too close to the same hue, they may not provide sufficient contrast when viewed using monochrome displays or by people with different types of color deficits. (Chisholm et al., 1999)*

While the use of non-colored related cues would increase the participants' ability to determine which fish in the tank are vaccinated at Fish Farming and which menu item is selected at Personal Computers, this guideline would not increase access to the visual images at Mammal Skull Mystery. Therefore, the need for higher contrast images and visual indicators is still needed.

Precise and descriptive language would assist participants who are blind and aid learning for participants who are sighted. As demonstrated in Table 5, most participants experience difficulty answering the questions at Mammal Skull Mystery. While many participants request the images be revised to more accurately portray the features they should be looking for, some participants ask for more detailed text and audio that describes what one would see and feel on the skull if the answer was "Yes."

This information would be useful for Jerry B. and Alice, both of whom ask the observer for more detailed descriptions of what the facial features feel like before answering the questions. Jerry B. in particular is confused by the use of the term “sharp” to describe the canine teeth. For him, the incisors are “sharp” as the edges feel like knife blades. This is a different interpretation of the term “sharp” then the one used by the exhibit developers who use it to refer to teeth that are shaped like the stakes one would drive through a Vampire’s heart. Given the variety of interpretations for the word “sharp,” the word “pointy” might have served as a better descriptor and decreased the confusion.

Interestingly, the three sighted participants, Kent, Yaacov, and Gail, also request more precise and descriptive language at Mammal Skull Mystery. Gail tells us that what would be important for her as a learner would be information on what the facial feature feels like in addition to what it looks like.

> *For somebody who has a hard time saying, okay visually ...(inaudible) and matching it just by looking at it, they might have clued you into, “Take your finger and feel around. Is there something missing right here, or is it a full circle?” Something like that.*

Similar to the request for clearer and more accurate directions, we again see similarities between Gail’s petition for tactile clues for identifying facial features and those of Alice and Jerry B. This suggests that providing audio descriptions, which are traditionally viewed as an access feature for persons who are blind, may in fact improve the experience for a broad range of users including those with non-verbal and other learning disabilities.

Background noise should be kept to a minimum. The background noise in certain galleries interferes with the experience of multiple participants, and in some cases has a profoundly negative impact on the user. A repetitive sound emanating from one of the components located near Personal Computers distracts Linda as she uses this interactive and she believes this experience may be partially responsible for the seizure she suffers later that evening. When Carolyn, Kent, and Jerry P. (participants who are hard of hearing or wear hearing aids) use the interactives, the Museum of Science is relatively quiet with few other visitors present in the galleries. This makes it difficult to determine how increased background noise would impact their experience, although each report in either their introductory or final interview that background noise tended to be a problem for them during previous experiences at the Museum of Science.

Loud background noises are also problematic for users such as Yaacov (dyslexic) and Alice (blind) who rely on audio to receive information. Yaacov reports in his introductory interview that he has difficulty using the interactives in *Making Models* when school groups are present as the increased noise makes it difficult for him to hear the information provided through audio[7]. When Alice is using Personal Computers, the Theater of Electricity show (which is a very loud, lightening producing show) is also taking place in that same gallery. This makes it impossible for Alice to hear the auditory information delivered through the kiosk, and forces a quick end to her exploration of the interactive.

Decreasing background noise would improve the experience for the participants who are hard of hearing, as well as those participants who relied on audio to receive information, such as Yaacov and Alice. However, this design feature is difficult to put into practice— one of the sources of background noise is the increased number of interactives that provide auditory options for learning. It is interesting that in this case,

[7] On the day I observed Yaacov using Fish Farming, this gallery was relatively quiet and unoccupied.

the design feature that is critical for access for certain user groups (such as visitors who are blind or dyslexic) can also decreases their access to the experience.

Images should move slowly on the screen (including images presented on attract screens) to reduce the risk of inducing seizures. The quick-moving attract screens on Mammal Skull Mystery and Personal Computers, as well as the quickly moving fish in Fish Farming, cause Linda to have seizures and make it impossible for her to sleep the entire night after using the interactives. Even though this design feature was a problem for only one user, the significant physical and psychological impact it has on Linda warrants its inclusion in this report and its consideration in the design of future interactives.

Linda did not advocate for the exclusion of all interactives that include fast moving images. However, Linda requests in her final interview that if fast moving images are required, the Museum should place a warning sign in the exhibition so that persons who experience seizures are not negatively impacted by the design.

> *Put a sign that tells people with head injuries not to use it. Like in Disney "If you have any sort of problems, do not get on this ride." A sign to let you know it's coming.*

Guidelines for creating accessible computer software suggest that quick-moving and flashing images should be avoided. These guidelines define a range that should be evaded (4 to 59 flashes per second (Hertz) with a "peak sensitivity at 20 flashes per second"), and the types of flickering that qualifies such as quick changes from light to dark (Chisholm et al., 1999). Given the severity of the consequences of *not* following this guideline, exhibit developers should review interactives to examine the refresh or flash-rate of the images and avoid even testing the interactives with users who are prone to seizures if the interactives do not fall into this range.[8]

Is designing for ease of use sufficient for providing meaningful learning experiences?

While designing interactives so that they are easy to use for a broad range of users will increase the access to learning they provide, it does not appear to be sufficient for generating meaningful learning experiences. As shown in Table 6, participant remarks during the final interviews reveal that the interactive the participants consider the easiest to use is not always the interactive that is their favorite.

Almost universally, the participants report that it was the content and the type of activity that determines which interactive is their favorite, and not its ease of use or accessibility. In fact, in many cases, the interactive that is the hardest for the participant to use is the one he or she likes the best. For example Alice's favorite interactive is Mammal Skull Mystery, which is also the most difficult for her to use. Despite her struggle, she feels Mammal Skull Mystery provides interesting information and opportunities for learning, where as at Fish Farming (the interactive that is the easiest for her to use) she "didn't really learn that much." A similar dichotomy is exposed in Gail's final interview comments. Gail's favorite is Fish Farming even though she thinks this interactive is "visually too stimulating." Factors outside of the ease of use of the interactive that influence the participants' affective reaction to the interactives include the following:

- The opportunity for tactile interactions outside of the computer screen;
- An experience that matches the participants' conception of learning;

[8] The author is not sure if the interactives tested exceed the flash rate mentioned in this guideline.

- A visually attractive design;
- On-going feedback about accuracy of the participants' inputs when the computer asks a question;
- Content that matches the participants' level of understanding about the topic; and
- Activities that challenges the participants to think and problem solve.

Not all participants in the study preferred the same activity, and user preferences for one activity over another were quite strong. When developing interactives, it is not always possible to create every experience so that it is accessible to all learners. Therefore, some museums (such as the Museum of Science) rely on creating a subset of interactives that are accessible to different audiences. Given the importance of the interactive's content and learning styles, museums should consider whether all learners have access to a diverse range of experiences so that visitors with disabilities can choose activities to learn from that best match their learning preferences.

Is "universally accessible" really "better for everyone"?

Advocates for universal design postulate that designing environments that are accessible for persons with disabilities creates experiences that are "better for everyone." As demonstrated above, for the most part, the three interactives are universally accessible to users of a broad range of abilities and disabilities, and thus, could be considered a universal design. In addition, features that provide access for one audience (such as audio for visitors who are blind) improve the experience for other audiences as well (such as sighted visitors who prefer to listen than to read) and therefore one could state that the design of the interactives was "better" for a broad range of users. However, not every feature is well received by all audiences. In fact, some design features that are mandatory for providing access to the learning experience for some user groups detract from the experience of others.

As a way of examining whether designing experiences for persons with disabilities leads to an experience that is "better for everyone," the descriptions below detail how three design elements that provide access for visitors who are blind are received by the sighted participants who may or may not have other disabilities. These design elements include the button interface, the use of audio to deliver text-based information, and the addition of tactile models to Mammal Skull Mystery.

The button interface

The button interface is accessible and easy to use for all participants. None of the participants find this interface difficult to use nor does it present them with a barrier to learning. Certain participants feel that a push button system is the "best" interface and report that any other interface would be inaccessible. Other participants believe a touchscreen or trackball-based interface would be easier for them to use.

Given that the button interface was derived to provide access for persons who are blind, it is not surprising that Alice, Jerry B., and Olivia (the blind/ low vision participants) report that the button interface is easy to use. Alice and Olivia both appreciate the tactile feedback afforded by the button interface,

> *I mean buttons are obviously very easy. For one thing, most blind people have a pretty good spatial feel. So when they feel-- when they use the buttons a couple of times they sort of want to feel where they are. Then you can basically just reach for it. And you know, I'd say eight times out of ten you're going to hit it square on. (Alice, in her final interview)*

> *Psychologically, I think there's nothing like actually putting your finger on a button and pressing it down, because then you know you did it. (Olivia, in her final interview)*

Alice also expresses that she appreciates the standardization of using the button interface across all three interactives,

> *The fact that all three of them were setup in a similar way. So that if you come into the museum for a day and go around to all the different exhibits, you wouldn't have to spend time at each exhibit trying to figure out what the setup is, how it works. The design was fairly standardized. That's something I think that's extremely important. (Alice, in her final interview)*

In contrast, Jerry B. feels that the interactives did not provide a consistent user-interface across the three interactives, but does appreciate the unfailing use of the one-inch square button to provide audio interpretation.

Sighted participants also consider the button interface simple and easy to use, and think it is better than most other interfaces they have encountered, including Judy and Stacy who have limited upper body mobility.

> *The larger push buttons are easy for someone to use, with and without disabilities. People with various disabilities could use them, including someone with cerebral palsy or who is quadriplegic and can hit them with a closed fist. (Judy, in her final interview)*

> *I liked the buttons. I thought they were easy to use, interact with. (Stacy, in her final interview)*

Other sighted participants without upper body limitations also prefer the buttons.

> *I feel reasonably comfortable with all of the present configurations… [touchscreens, joysticks, touchpads, etc.] I prefer the push buttons to the joystick and the touchscreen…I'm able to keep my eye on the screen and not on my finger…In general, the push buttons seems to be a less unreliable, i.e. more reliable, means of computer activation. The touchscreen sometimes being a little bit quirky, the joystick likewise. I would have to believe that the push button is also substantially less maintenance intensive, which would be a benefit in terms of computer reliability…(Kent, in his final interview)*

> *For my class, I had to design interactives-- and actually, based on the interactives that I did with you-- I kind of was able to get*

> *some hints of how they work and what I felt works the best…The way you navigated was-- I kind of wanted to keep it as simple as possible, so I thought about the computer-- the first one that I did-- because I felt like that was the most simplest, the easiest kind of-- Go from one screen to the next. Pushing the next button, or "Enter." (Jen, in her final interview)*

Gail found the buttons easy to use, and preferred them to other types of interfaces, but stresses the need to be clear about how they should be used since it is not always obvious.

> *I think the buttons, as far as trackballs and mice go, are great. Because people have different fine motor skill issues, and that's very helpful. I think a lot of times we're now becoming to expect the touchscreen. Maybe kids don't as much, but I feel like adults do. So again, like if it's going to be the buttons, be very specific that the buttons below are what you need to use. But I think compared to those other options, it's definitely helpful. (Gail, in her final interview)*

Carolyn (who is hard of hearing) expresses that a touchscreen interface "would be equally good," although she prefers the push buttons for aesthetic reasons.

> *I do like looking at a screen that isn't smeared all the time. (Carolyn, in her final interview)*

However, not every participant prefers the push button system. Mark, one of the participants with low vision, expresses that he would prefer a touchscreen.

> *Touchscreens are a good thing. You see them more and more now. It might have been easier to use a touchscreen to get the options rather than scroll down. (Mark, in his final interview)*

Carol, one of the two participants who are deaf, also expresses that she does not always find the button interface to be easy and intuitive to use. At Personal Computers, she expresses that should would prefer it if the interface was a trackball. At Fish Farming, she finds the labeling of the buttons misleading, and experiences difficulty using them.

However, Carol states that the button interface at Mammal Skull Mystery is simple and easy to use.

> *The screen had clear choices with expected answers Yes, No. Buttons, there were only three of them… It was sort of easy to figure out Yes, No. It was perfect. It was clear. It was also visual. Looked at pictures, does it have canine teeth or something? And that you matched up and then pressed the button. (Carol, at Mammal Skull Mystery)*

Leon, the other participant who is deaf, feels more strongly that he prefers a touchscreen to the buttons. This is not surprising given that Leon's is both a tactile and visual learner.

> *I want to feel connected. Not that I'm distant from the screen, but I want it so that I'm connected to the screen, and actually go beyond ... looking up and down. Otherwise I feel like I'm trying to locate and do some dual manipulation between the mouse and the screen. But if I were to touch the screen, it feels like I'm actually, it's transparent, I'm working within. So that would be nice. (Leon, describing why he wants a touchscreen for his home computer in his introductory interview)*

In summary, all participants are able to access the push button interface and report that in most cases it was easy to use. However, some participants prefer other interfaces such as trackballs, mice, or touchscreens.

Audio

Starting with the first implementation of the Museum's button interface in *Messages,* audio was added as a means for delivering content and directional information for visitors who are blind. Observational data reveal that many participants, including those with sight, listen to the audio while using the interactives. For some participants (such as Jerry and Alice who are blind) the use of audio is essential for providing access to learning since they have no other way of acquiring the provided information. For other participants (such as Olivia and Mark who have low vision, and Yaacov who is dyslexic) the use of audio greatly increases the accessibility of the interactives as it provides them with options for receiving information that might otherwise be inaccessible. For example, both Mark and Olivia use the audio when they cannot read the text.

> *Audio is great, like audio, if I can't use the entire exhibit, it makes up for the fact that I can't read…At the computer exhibit, all of the text on the monitor was read by the computer so you could just listen to the audio and not have to read the text. (Mark, in his final interview)*

> *I couldn't see the chart, but that didn't matter- it was read to me so it was in no way a problem. (Olivia, at Fish Farming)*

Yaacov (who is dyslexic) also tells us that the audio is a critical feature that defines the accessibility of the computer interactives for him as a learner.

> *As I hope I said before, a lot of these I simply would not have done if it wasn't for the audio. (Yaacov, in his final interview)*

Participants who do not have disabilities that require the use of audio also choose to use it because it increases their learning and enjoyment. As an access professional, Judy appreciates that the interactives provide audio for persons who are blind. In addition, she also finds the audio helpful as a learner.

> *I like auditory learning and visual learning at the same time. (Judy, at Personal Computers)*

Jerry P. (an older adult who wears a hearing aid) tells us that the audio helps him to better understand the content and directions at different interactives.

> *When I was looking at that second one and didn't have that audio on, I was completely confused. But once the audio came up, it cleared it up for me. (Jerry P., in his final interview discussing Personal Computers)*

> *I tell you, the audio helped me a lot. She was telling me what to do rather then me reading what I have to do. I don't have the patience at my age to read so the audio portion does help me. (Jerry P., at Fish Farming)*

For some participants, the audio appears to provide a human element to the interactive. Olivia frequently uses the pronoun "she" rather than "it" when describing what the computer tells her to do, just as Jerry P. does above.[9] Mark more specifically states that the presence of the audio at Mammal Skull Mystery makes the interactive seem more like a conversation.

> *It's even more interactive because they're talking to you, it seems like a one-on-one type almost conversation, or interaction. I liked what they did with that. (Mark, at Mammal Skull Mystery)*

Despite the broad range of users who feel that the use of audio to deliver information is a positive design element, audio does not enhance the experience for all learners. Some participants find the presence of the audio distracting, and choose to turn the audio off while working at the interactives. Carolyn (hard of hearing), who originally thought she learned best when the audio was automatically turned on at the Mammal Skull Mystery interactive, later realizes at Personal Computers that she finds the audio distracting and opts not to turn it on at Fish Farming. Gail also purposefully chose not to use the audio.

> *I figured I needed to read it anyway to understand it. I was going to be reading it one way or the other, so reading it over twice is easier for me than to turn the audio on and then read it once on the screen. (Gail, at Fish Farming)*

The fact that Gail prefers to read information out loud as opposed to having the computer read the information for her is not surprising given that, as she states in her introductory interview, reading out loud is a technique that facilitates learning for persons with non-verbal learning disabilities.

> *It's funny that you said-- I'm going to be talking, thinking out loud. Because that's one of the things that's a strength that*

[9] A female voice was used to record all of the interactives' audio.

> *someone with my learning profile always plays to, and it's encouraged in little kids to like work it out, say it out loud. (Gail, responding to the observer's request to "think out loud")*

Even Mark, one of the participants with low vision, does not always have the audio on when interacting with the computer kiosks. Mark frequently turns the audio on and off while using the interactives, alternating between reading the text himself and having it read to him by the computer.

One might assume that the mixed reception of the audio could be solved by adherence to the second principle of universal design "flexibility in use" and that many of the difficulties participants have with the audio could be easily solved by providing users with the ability to turn audio on and off. However, while both Fish Farming and Personal Computers were designed to allow users to control the audio, just the presence of a button that activates audio is a distraction for Carol and Leon, the participants who are deaf. Both Carol and Leon notice the "Audio text button" and could feel the vibrations of the audio as they use the interactives. Both wonder what information the audio supplies that is not available to them as deaf learners. The following is an excerpt from the field notes taken as Carol uses the Personal Computer interactive:

> *Carol: (After the movie, as she continues to use the computer, the audio text is still on since she pressed it during the movie.) What is it? (She feels the sides of the computer and notices the sound vibrations.)*
>
> *Observer: Um, It's reading those options out loud. If you hit this again, it won't do it.*
>
> *Carol: How do I know what it is saying?*

Leon's interaction at Fish Farming also provide insights on how the presence of the audio can distract the user and interfere with learning even when he or she "knows" that the audio is providing the same information that is available on the screen.

> *It was a little bit annoying to me. I felt like something was in the back of my mind telling me, "Oh I wish you could hear that, I wish you could hear that." But later on I realized that whatever was being spoken was on the screen…(Leon, at Fish Farming)*

The continual presence of audio at Mammal Skull Mystery has a profoundly negative impact on Leon. He has difficulty using this interactive, and he assumes that the information he needs is delivered through the audio. This experience leaves him feeling frustrated and "nauseous."

> *But I knew some kind of language or spoken text was happening somewhere around me…And the longer I stayed here the more uncomfortable I got… I wondered if a person who is hearing would press this audio text button, and would get directions actually as to how to use it…? (Leon, at Mammal Skull Mystery)*

Carolyn, who has some hearing, is also frustrated when audio is playing and she can't hear it.

> *I'm wondering, as I always do, would a hearing person be able to hear this? I'm assuming so, so I am a little frustrated. (Carolyn, spoken aloud as she watched the 1984 commercial at Personal Computers)*

After years of interacting with designed environments that exclude learners who do not perceive the world through both sight and sound, it is not surprising that the participants assume that they are not receiving the information they need when they sense the presence of auditory information. Therefore, adding audio to an interactive will not result in a design that is "better for everyone." However, that does not mean audio should be excluded from the interactive as this would decrease access for a broad range of users, including visitors who are blind or are dyslexic.

Tactile skull models at Mammal Skull Mystery

Exhibit developers conceived of the idea for the Mammal Skull Mystery as a means for creating an activity in *Natural Mysteries* that would be accessible for visitors who are blind. In particular, the exhibit developers decided to add tactile skulls to the interactive to increase the enjoyment and facilitate learning for visitors who could not learn from images. Therefore, it is not surprising that three of the four participants who are blind or have low vision select Mammal Skull Mystery as their favorite activity. Both Olivia and Mark cite the ability to physically manipulate the skulls as one of the contributing factors that lead them to choose this activity as their favorite.

> *I like the fact that I could touch them and get close to the skulls (Mark, in his final interview)*

> *Well, I liked the fact that you actually could hold something in your hands, and that made it real. And also, it was something I'm good at; to be able to touch something. It wasn't quite as abstract as when it's on a screen. (Olivia, in her final interview)*

Jerry B. (the fourth participant who is blind) does not cite this interactive as his favorite as he has trouble answering the questions due to inadequate button labeling and the lack of audio descriptions. Despite this difficulty, Jerry recognizes the potential of this activity to provide a meaningful learning experience for visitors who are blind, and in particular, the possibility for it to offer access to the previously inaccessible. In Jerry's opinion, it's the tactile experience that make museums exciting and meaningful places for visitors who are blind.

> *The one with the skulls actually has more potential for being of practical interest to people who are blind…I have as you know a very strong interest in birds, but yet I have very little knowledge of what they actually look like. I've had very few opportunities to actually examine them… in general museums like zoos and other places like that are tough places for blind people to get very excited, because there's just not a lot there to fascinate you when you are walking around amongst things that are behind glass. When I go to the zoo I just go there praying that one of the animals will get mad and make a sound or something. I remember once a friend of mine and I were actually thinking about contacting a zoo and asking them if they would tranquilize a lion and put it to sleep so we could actually examine it because we just really wanted to know 'what does a lion look like?' and all of the visual descriptions in the world really don't*

> *tell you what they look like. You have to get your hands in and feel it to know what it looks like and even then it is hard if it is a real big animal. So with me, it's something that captivates my fascination…Last week I was in Pittsburgh and we visited this placed called the Aviary which is a place where they keep live birds, mostly fairly exotic tropical birds and that sort of thing. But there was a guy there with an owl on his arm (its name was Shakespeare by the way). He was describing it and talking about it and that really fascinated me. But then he handed me a wing, an actual wing from an owl specimen that they had and that really clinched it for me. That caught my attention and I said 'Wow, this is something, this is part of an actual bird. I can feel this." I could feel what a wing feels like and you can see how heavy it is. That's the kind of exhibit that really captivated me. Other than that, I could hear a bunch of unfamiliar birds tweeting, and I could smell the (inaudible) growing in the place, but other than that it was basically a waste of time for me. Actually, it wasn't because I was with my granddaughter, but in a literal sense…*

The opportunities for tactile learning afforded by the Mammal Skull Mystery interactive is also appealing for sighted visitors. Observations illustrate that almost all of the visitors handle and manipulate the skulls while interacting with the activity. In addition, interview data reveal that it is the tactile nature of this activity that made it a favorite for Judy and Jen.

> *The way that you were able to pick up the objects…touch them, and interact. (Jen, in her final interview, describing why Mammal Skull Mystery was her favorite activity)*

> *Not so much easy access, but it had more hands on… (Judy, in her final interview, describing why Mammal Skull Mystery was her favorite)*

Judy's preference for this activity is surprising given that she, Stacy, and Linda (the participants with limited mobility) find it tricky to reach the skulls and hold them in a position that allows them to answer the questions correctly. For these participants, the use of tactile elements does not make the exhibit more accessible, but actually decreases the accessibility of the interactive. Yet, unlike the audio, the presence of tactile elements that cannot be fully manipulated by people with limited mobility does not seem to negatively impact the overall experience for these participants.

Is universal design "better for everyone?"

Juxtaposing the participants' reactions to these three design features that were created for persons who are blind demonstrates that the design features created to provide access for users who are blind improves the experience for users who are sighted. This matches findings from previous studies on universal design where design elements created for users with disabilities were shown to improve the experience for users without disabilities (Danford, 2004; Hein & Heald, 1989; Johnstone, 2003).

Study findings also reveal that design features that are essential for providing access for visitors who are blind, while not creating a barrier for access for other users, do not lead to interactives that are "better" for all. For example, interactives designed with touchscreens and without audio may be "better" for some users (particularly those who are deaf). This finding corresponds with another study on universal design that found that navigational aids designed specifically for users with disabilities were more difficult for non-disabled users to use than the inaccessible designs traditionally employed in public buildings (Danford, 2003). Additionally, the study's oldest participant, Jerry P., warns that digital media itself may not be a universal design as there are many older adults who might shy away from this type of activity because it appears to be for a younger generation, even though he tells us "they really do work for everyone."

These findings do not disprove the idea that universal design leads to better designs for many users. In fact, in the same study that found that the accessible navigational aids were more difficult for non-disabled users also found that the non-disabled users had an overall positive feeling about the building's design and actually thought it was better than most (Danford, 2003). Similarly, participants in the museum interactive study, including those without disabilities, also feel positive about the interactives' designs even when they experience stumbling blocks when using one or more of the design features. While it may be possible to achieve designs that are universal designs according to the definition that they are "usable by all people, to the greatest extent possible, without the need for adaptation or specialized design" (Center for Universal Design, 2002), it may never be plausible to design an interactive that is "better for everyone."

Museums therefore are confronted with a challenge; they will need to consider what trade-offs they are willing to live with, and which they are not when designing for an audience that includes visitors of a broad range of abilities and disabilities.

CONCLUSION

Whether recognized or not, persons with disabilities currently visit museums and are a part of the audience they serve. The 16 study participants are either current museum visitors, or were frequent visitors before they experienced physical changes that made museums inaccessible to them.

How museums design interactive learning experiences significantly impacts who is able, and who is disable, to learn. This idea is best exemplified in a comparison of the experiences of Vicky (a computer science major who does not self-identify as disabled) and Olivia (an inexperienced computer user with low vision). When using Personal Computers, Vicky is able to access the information and learn from her experience, where as Olivia is prevented from learning the content as the design of the interactive does not provide precise directions nor is there enough contrast in the visual images. In contrast, when using Mammal Skull Mysteries Olivia is able to use the interactive with ease, while Vicky struggles as this interactive’s design does not meet her needs as a visual learner. This finding supports the conception that the design of the interactive is not benign and can either support or detract from an individual’s learning process.

There are ways museums can design learning experiences so visitors of a broad range of abilities and disabilities are provided the opportunity to learn. Previous lessons learned in the fields of software and website development, along with the findings from this study, provides suggestions for design features that support learning for users of a broad range of abilities and disabilities. Table 7 below combines this information with what has been learned during the formative evaluation of over 20 computer kiosks at the Museum of Science to create suggestions for design features that should be considered when designing interactives for a diverse audience. As the design features presented have not been tested with a large number of users, this list should not be considered a definitive guide, but a starting point for moving forward.

TABLE 7: INTERACTIVE DESIGN FEATURES THAT PROMOTE UNIVERSAL DESIGN

Feature	**Audience members who benefit**
Screen text that is read aloud and makes sense when heard and not viewed	• Visitors who are blind or have low vision • Visitors who are learning to read • Visitors with cognitive or learning disabilities • English as a foreign language learners
Open captions for videos and non-text based audio	• Visitors who are deaf and hard of hearing • Older adults
Audio descriptions for videos, images, and other visually-based information	• Visitors who are blind and have low vision • Visitors who have cognitive or learning disabilities affecting image reading
Text with a large font, clear typeface, capital and lower case letters and ample space between lettering and text lines	• Visitors with low vision (including older adults) • Visitors who are dyslexic • Visitors at extreme heights (low and high) who may be subjected to glare
Alternatives to color-coded cues	• Visitors with low vision (including older adults and persons who are color blind)
High contrast images and text	• Visitors with low vision • Older adults
Minimized use of flickering and quick-moving images	• Visitors who are subject to seizures
Images that offer a visual indication of what to do, how to proceed and the activity's content	• Visitors learning to read • Visitors with learning disabilities • Visitors who do not speak English (including American Sign Language users)
A short description of activity's goal presented through images, audio and text	• Visitors who have ADD • Inexperienced computer users
Use of the clearest, simplest text that is free of jargon	• Visitors learning to read • Visitors with cognitive or learning disabilities • Visitors whose first language is not English (including those who use ASL)

TABLE 7: INTERACTIVE DESIGN FEATURES THAT PROMOTE UNIVERSAL DESIGN (CONTINUED)	
Feature	**Audience members who benefit**
Clear, simple directions that provide a literal and precise indication of what to do and the exact order for doing it	• Visitors who are blind or have low vision • Visitors with learning disabilities • Infrequent computer users
A clear, consistent and repetitive layout for presenting information	• Visitors with cognitive disabilities • Visitors who are blind or have low vision (and rely on their auditory memory) • Older adults • Infrequent computer users
A limited number of choices presented at one time (5-7)	• Visitors who are blind or have low vision (and rely on auditory working memory) • Visitors with cognitive or learning disabilities (including ADD)
Minimized screen scrolling	• Visitors with low vision • Visitors who have learning disabilities
Design features impacting kiosk design	
A tactile interface, such as buttons, for navigating choices and making selections	• Visitors who are blind or have low vision • Visitors with limited upper body mobility • Visitors concerned with issues of reliability
Control over the pace of interaction, including when a computer "times-out"	• Visitors who are deaf • Visitors who have low vision • Visitors with limited mobility • Visitors who are dyslexic
Clear mapping between the buttons and screen images	• All sighted visitors, especially visual learners
Stools	• Visitors with lower back pain • Visitors with low vision • Young children • Older adults
Monitors placed in an upright position close to the edge of the table	• Visitors who use wheelchairs • Visitors with low vision
Buttons placed on a slanted surface near the edge of the table	• Visitors with limited upper body mobility
Buttons that are clearly labeled with both a tactile and visual indication of their use	• Visitors who are blind or have low vision • Inexperienced computer users
Minimized background noise, when possible	• Visitors who are hard of hearing • Visitors who rely on audio to receive information such as visitors who are blind or dyslexic

Study results demonstrate that design features that are essential for providing access to one audience can lead to improved experiences for other audiences. For example, the use of audio to deliver content-based information was an essential design element that afforded access to users who are blind and those with reading-related learning disabilities, and improved the experience for auditory learners who prefer to listen then read. However, study results also show that not all design features that help persons who are blind lead to experiences that are *better* for all learners. For example, the same audio that is essential for users who are blind can be a distraction for users who are deaf and left wondering, "what am I missing?" Therefore, experiences that are "usable by all people, to the greatest extent possible" are not always "better for all."

The most significant finding from this study is that museums can play a considerable role in defining who in our society is able, and who is disable, to learn. By changing the way they design exhibitions, museums can enable learners of a range of abilities and disabilities to engage in independent learning experiences that do not force them to depend upon others for assistance. When Olivia speaks of the "great feeling" she derives from learning about animal physiology on her own through tactile interactions that are guided by the computers' audio, she speaks for the many individuals who are excited when exposed to new ideas but have so often before been excluded by design from formal and informal learning environments alike. If employed with thought and care, new technologies can offer museums the ability to provide a broader segment of the public with the opportunity to engage in independent learning experiences that foster curiosity and inspire life-long learning.

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APPENDICES

Appendix A: Research instruments

OBSERVATION SHEET FOR PERSONAL COMPUTERS

REMIND PARTICIPANT TO THINK ALOUD

Does the participant…

- ❑ Turn the audio text on
- ❑ Move through the menu choices
- ❑ Select a menu choice
- ❑ Perceive the available information
- ❑ Discuss aloud the delivered content
- ❑ Make connections to the objects displayed in the glass case
- ❑ Which menu selections do the participant chose?

____

____

____

____

____

____

____

Field Notes: What the participant says or does…

Personal Computers Retrospective Report

1. Can you walk me through what you did here at this activity?

   [Probes:
   -How did you determine what to do first?
   -Do you recall what choices you made as you moved through the program?
   -What happened when you made those choices?
   -Were there any moments where you were confused or unsure of what to do next?]

2. What features of this design did you find helpful or useful?

   [Probes:
   -How did you feel about the layout and placement of the buttons?
   -Did the menu choices provide you with a clear idea of what to expect when selected?
   -Thoughts on the provided text and information?
   -Did you find the audio text useful or was it more of a distraction?
   -What about the design of the stool? The kiosk itself?]

3. What features would you change?

   [Probes:
   -How did you feel about the layout and placement of the buttons?
   -Did the menu choices provide you with a clear idea of what to expect when selected?
   -Thoughts on the provided text and information?
   -Did you find the audio text useful or was it more of a distraction?
   -What about the design of the stool? The kiosk itself?]

4. Were you aware there’s a connection between this activity and the artifacts presented in the cases directly behind it?

OBSERVATION SHEET FOR FISH FARMING

REMIND PARTICIPANT TO THINK ALOUD
Observation Information
Does the participant…

- ❑ Turn the audio text on
- ❑ Read/ listen to the introductory role-play scenario
- ❑ Run the simulation in the “control” setting
- ❑ Perceive (through sight or sound) changes in the fish population over time
- ❑ Refer to the challenges that appear on the screen
- ❑ Make a decision on what to change (% vaccinated, # of fish, or both)
- ❑ Change one or both of the variables
- ❑ Run the simulation again
- ❑ Repeat the previous four steps

TRIAL #	1	2	3	4	5	6	7
FISH #							
VACCINE %							

Completed
___Challenge 1
___Challenge 2
___Personal Challenge?

Field notes: What the participant says or does…

Fish Farming Retrospective Report

1. Can you walk me through what you did here at this activity?
   [Probes:
   -How did you determine what to do first?
   -Do you recall what choices you made as you moved through the program?
   -What happened when you made those choices?
   -Were there any moments where you were confused or unsure of what to do next?]

2. What features of this design did you find helpful or useful?
   [Probes:
   -How did you feel about the layout and placement of the buttons?
   -Did you feel you had a clear idea of what actions to take while using the program?
   -Thoughts on the fish farming activity itself?
   -Did you find the audio text useful or was it more of a distraction?
   -What about the design of the stool? The kiosk itself?]

3. What features would you change?
   [Probes:
   -How did you feel about the layout and placement of the buttons?
   -Did you feel you had a clear idea of what actions to take while using the program?
   -Thoughts on the fish farming activity itself?
   -Did you find the audio text useful or was it more of a distraction?
   -What about the design of the stool? The kiosk itself?]

OBSERVATION SHEET FOR MYSTERY SKULLS

REMIND PARTICIPANT TO THINK ALOUD

Does the participant…	1	2	3	4	5	6
Turn audio on						
Pick a skull to classify. Which one?						
Listen to the Q1: ________________						
Look or touch skull for answer						
Compare skull to others for answer						
Make a selection (specify Green button or Red button)						
Notice change in possible answers shown on screen						
Listen to the Q2: ________________						
Look or touch skull for answer						
Compare skull to others for answer						
Make a selection (specify Green button or Red button)						
Notice change in possible answers shown on screen						
Listen to the Q3: ________________						
Look or touch skull for answer						
Compare skull to others for answer						
Make a selection (specify Green button or Red button)						
Notice change in possible answers shown on screen						
Listen to the Q4: ________________						
Look or touch skull for answer						
Compare skull to others for answer						
Make a selection (specify Green button or Red button)						
Notice change in possible answers shown on screen						
Computer's final answer?						
Compare their answer to the computer's						
Make connection to glass skull case						

Field notes: What the participant says or does…

Mammal Skull Mystery Retrospective Report

1. Can you walk me through what you did here at this activity?

   [Probes:
   -How did you determine what to do first?
   -Do you recall what choices you made as you moved through the program?
   -What happened when you made those choices?
   -Were there any moments where you were confused or unsure of what to do next?]

2. What features of this design did you find helpful or useful?

   [Probe:
   -How did you feel about the layout and placement of the buttons?
   -Did the menu choices provide you with a clear idea of what to expect when selected?
   -Thoughts on the provided text and information?
   -Did you find the audio text useful or was it more of a distraction?
   -What about the design of the stool? The kiosk itself?]

3. What features would you change?

   [Probe:
   -How did you feel about the layout and placement of the buttons?
   -Did the menu choices provide you with a clear idea of what to expect when selected?
   -Thoughts on the provided text and information?
   -Did you find the audio text useful or was it more of a distraction?
   -What about the design of the stool? The kiosk itself?]

4. Were you aware there's a connection between this activity and the skull case to the right?

INTRODUCTORY INTERVIEW GUIDE

-Overview of the study
-Schedule for the day
-Schedule for second visit
-Answer any questions
-Permission to use recorder
-Permission to disseminate results
-Anonymity?
Date and time:______________

Name and affiliation:____

1. How familiar are you with the Museum of Science?
   [Probes:
   -When was the last time you visited the Museum of Science?
   -In general, how often do you visit the Museum?
   -Have you advised the Museum of Science on access issues in the past?
   -Have you visited the Making Models, Natural Mysteries or Computing Revolution exhibitions?
   -What was the last exhibition you saw at the Museum?]

2. On average, how often do you visit a museum?
   [Probes:
   -When was the last time you visited a museum?
   -What museums do you visit on a regular basis?
   -How would you describe the accessibility provided by that institution?]

3. What is your occupation [or if a student, what are you studying in school]?
   [Probes:
   -Do you have an interest in science or computers?
   -Do you read about or watch TV programs on science or computers on a regular basis?]

4. How comfortable do you feel using computers?
   [Probes:
   -For how many years have you been using computers?
   -Do you have a computer at home or work?
   -In general, what are the primary reasons you use your or any other computer?
   -What software applications do you use the most?]

5. Would you mind describing for me what the set-up of your home or office computer looks like?
   [Probes:
   -Is there a design feature or a way that is set-up that is unique to you?
   -Do you use any specialized software or equipment?
   -Any other accommodations?]

6. How would you describe your disability?

7. How old are you?

Preferred contact method:________________________________

Alternate contact method:_________________________________

Address:____

CLOSING INTERVIEW GUIDE

Date and time:______________

Name and affiliation:____

1. Which of the three interactives you tried did you like the most?
   What about this activity did you like?
   - Information presented?
   - Ease of use?
   - Level of interactivity?
   - Entertainment value?
   - Educational value?

2. Which of three interactives was the easiest to use?
   What about this activity made it easy to use?
   - Design?
   - Navigation?
   - Interactivity?
   - Content?
   - Accessibility?

3. Which interactive was the hardest to use?
   What made it difficult?
   - Design?
   - Navigation?
   - Interactivity?
   - Content?
   - Accessibility?

4. How do the computer interactives you tried today compare to those you've used at other public institutions, such as bank ATMs or interactives at other museums?
   - Design
   - Ease of use
   - Navigation
   - Accessibility

5. In general, what aspects of the computer interactive's design did you find to be the most helpful and useful?
    - Text size/ color
    - Graphic look and feel
    - Feedback and response
    - Connections to other elements outside the computer
    - Seating
    - Audio instructions
    - Word phrasing
    - Content
    - Captions
    - Images to convey content
    - Pace of content/ interactivity

6. If we were to share information about our computer designs with other institutions, what do you think we should tell them about creating computer interface designs that would be accessible for visitors with similar disabilities?
   [Probe:
   Which design elements should we keep?
   What should be changed?]

7. One of the design features that differentiate our computers from those created by other institutions is the use of a series of buttons as the primary user interface. In your opinion, how effective is this approach?
   [Probe:
   -Did you find these buttons easy or difficult to use?
   -How does this compare to other interfaces you've come across such as touchscreens or track balls?]

8. Is there anything else you'd like to add?

Appendix B: Example documents reviewed by study participants

Alice's case study

Alice is a 53 year-old musician and translator who loves to read. She used to visit museums frequently before she became blind, but now feels they do not have much to offer her unless she is accompanied by a sighted guide. Alice has a seeing-eye dog and takes him with her as she travels.

Alice proclaims a "love/hate" relationship with computers. She regards herself to be an "average Joe" computer user and not a "whiz". However, she does use her computer everyday and stated that they are "indispensable" for people who are blind and would not live without them. She finds herself frustrated by non-user friendly designs and gets tired from everything "talking at her all the time."

When using the computer interactives in this study, Alice would first feel around the kiosk by moving her hands in broad strokes to orient herself to the computer's design and the input devices and tools that were available to her. She would listen carefully to the information presented, positioning her ears close to the speakers if the background noise became distracting. If directions were available, Alice preferred to use them first before exploring the interactive on her own. If directions were not available, Alice would begin using the computer by pressing the different buttons to see what happened, and would learn to use the system through trial and error. Even though she successfully learned how to use the interactives through this method, she requested that the interactives provide more detailed instructions as this would allow her to feel more comfortable using the interactive.

Alice was able to use Fish Farming without help or assistance, and discussed this component in terms of its focus on "problem-solving," which is the educational goal of the activity. Interestingly, this component is the only one that provided separate instructions. Alice required some assistance when using Personal Computers, but only because of the design of the timeouts for this interactive, which happened after a brief stop in usage and without an auditory notification. She felt that despite the difficulty using the interactive, she did learn from it as she acquired new facts about early personal computers. Mystery skulls appeared to be the interactive that Alice found the most difficult to use as she frequently requested clarification on how to use the interactive. The design of the interactive suggested to Alice that the computer knew which skull she was holding in her hand and that is how it determined which questions to ask, when actually the computer was not aware of the skull she had chosen and was selecting questions based on her answers to the previous questions. In addition, the interactive did not provide enough non-visual information on what the different features of the skulls felt or looked like, making it difficult for Alice to determine the correct answers to the questions.

Despite the difficulties Alice experienced when using Mystery Skull, this was her favorite of the three interactives. She felt that it provided the most information and that the experience is one that she could learn from. In comparison, she reported less interest in the Fish Farming component, the interactive that was the easiest for her to use. This suggests that for Alice it is the content of the interactive and the associated learning that was more important for reporting an enjoyable experience than the ease of use of the interactive. This is not surprising, given that Alice stated in her introductory interview that she is the type of person who can adjust to make a design work for her, rather than the type of person who focuses on adjusting the design.

Alice's interactions with the different interactives provide us with insight on how computer interactives could be better designed in the future. The following is a summary of some of the design features that were important for providing Alice with an engaging and enjoyable experience:

Standardization across interactives- Alice found the standardization that existed across the interactives to be useful. She felt that the consistency of the interface allowed her to focus her attention on learning the content, rather than learning the interface. However, she would have preferred if all of the interactives contained auditory directions similar to those provided at the Fish Farming component that are delivered through the hearphone.

Audio information- without the auditory delivery of text-based information, Alice would not have been able to use or learn from any of the three interactives. This feature, therefore, was essential to her learning. In addition, Alice successfully utilized the auditory graph, the decreasing tone that accompanies a real-time line graph on the fish farming screen, to understand how the number of fish and percent vaccinated impacted the final fish population after the spread of the disease.

Buttons- Alice thought the button interface was simple, intuitive and easy to use. She felt that the buttons were comfortably placed within easy reach at each interactive, and remarked that the use of tactile buttons of different shapes allowed her to easily verify that she was making the correct entry. However, Alice did feel that the buttons needed better tactile labels so that she could be clear on the function and purpose of each button, and it would be best if those labels were presented in Braille as opposed to raised letters.

Content- The content of an interactive is very important for Alice, more important than the ease of use. Across all interactives, Alice would have preferred more in-depth discussions of the scientific concepts and suggested that perhaps the computers could provide different levels of content so that visitors could choose how much or how little they wished to learn.

Background noise- A high level of background noise is particularly problematic for Alice as she relies on her hearing to acquire information and instructions. In Computing Revolution, Alice experienced difficulty using the Personal Computers kiosk when the Theater of Electricity show (and its accompanying PA system and cracking lightening bolts) was taking place in the background. When using Mystery Skulls, music projected from a neighboring kiosk also made it difficult for Alice to get the information she needed.

Olivia’s case study (large print version)

> “Because my main interest is reading-- If I could read 24 hours a day, I would…if I was able to, if I didn’t have to sleep and do those boring things like, you know, do laundry, eating, things like that. [Laughter]. I have so many books, I don’t know if I’ll ever finish all of them”. - Olivia, during her introductory interview

Olivia, age 55, is an energetic, retired teacher who is a passionate learner and wants to learn all she can about the world around her. She enjoys learning about history, science and art, and also is an avid science fiction reader. Her favorite science topics are astronomy, biology and chemistry. She is also deeply religious, and serves her community through active volunteer work that consumes most of her time. She is knowledgeable about issues concerning accessibility and frequently provides feedback to various organizations in the Boston area. When working with the Museum of Science on this project, Olivia felt this was part of her responsibility as an educator- to make sure that others learn from her experiences at the Museum.

Olivia considers herself to be “very, very, very near-sighted” and can only see out of her right eye. She has difficulty discerning details, and cannot identify an individual by their facial features, instead she must rely on the sound of their voice. However, she does have enough vision to go to the movies and watch TV and still have an enjoyable experience without using descriptive video.

Given her thirst for knowledge, it is not surprising that Olivia is a frequent museum visitor who visits the Museum of Science, the Old South Meeting House and the Museum of Fine Arts on a regular basis in addition to her volunteer work for the historical society in her neighborhood. When Olivia visits the Museum of Science, she mostly focuses on Special Exhibitions, the Omni Theater and the Planetarium, all of which she learns about by calling the Museum’s phone system and listening to the “tape” to learn about special offerings. She enjoys attending both the Omni Theater and the Planetarium because the visual images are large enough for her to see and enjoy the experience. Olivia does not visit the exhibition halls (beyond special exhibitions), mostly because these are hard for her to navigate and find. When visiting special exhibitions, she will ask the security guard to provide her with detailed directions that allow her to get there on her own. Since she attends both the Omni theater and the Planetarium on a regular basis she has learned how to find both of these theaters without assistance.

Olivia is not a frequent computer-user. She says she has heard of the World Wide Web, but has never used it. The closest items that she uses on a regular basis that she considers to be computers are her Kurzwiel reading machine and digital cable. To receive information, Olivia uses a variety of media, including print (which she reads with a magnifier), large print, Braille and audio recordings. Of these three, Olivia prefers to use large print as this is the quickest medium for her to use to receive information. Second is Braille because this medium still allows her to learn in silence, and third is audio. She does prefer to use audio, however, when she is reading non-fiction.

When Olivia used the computer interactives, she kept her head close the screen and quickly moved it back and forth to view the images and text it displayed. She closely followed the directions of each activity, and had little to no difficulty operating any of the three computer interactives. In fact, her experiences with both Mystery Skulls and Fish Farming were better than most of the other users, including those who did not have any disabilities and were more experienced at using computers. This may be a result of her extensive knowledge related to each of the topics, which made the interactives more accessible for her than for others who were not as knowledgeable about the topics, or it may be an effect related to her inexperience using computers– she did not have any preconceptions about how they were supposed to behave or how to use them, and instead relied on the directions to tell her what to do.

Olivia's interactions with the three interactives provide us with insight on how we can design computer interactives for people who are knowledgeable about science, infrequent computers users and have low vision. Design elements that appeared to provide Olivia with access to learning include the following:

Easy to follow directions that provide the user with a clear indication of what to do. Olivia found Fish Farming and Mystery Skulls easy to use. She felt they each provided the user with a clear indication of how to proceed, including what to do, how to do it, and when.

Audio, in addition to clearly visible text, users with low vision can use as an alternative to reading information on the screen. Olivia switched between reading and listening when using both the Fish Farming and the Personal Computers interactives. When using Mystery Skulls, however, Olivia chose to focus completely on the audio and to almost ignore the visual information that was provided. As Olivia tells us in her final interview, having the choice of whether to receive information through visual or auditory means was an important access feature that greatly improved her experience,

> "I've got to admit, it's much nicer to listen and not have to be straining and trying to see what the screen says. You can sort of ignore the screen if you just want to listen, and you can look at it if you feel like it, so you have a choice. But I can receive information both ways, but if it's something that isn't quite big enough, it's easier for me to listen to it."

<u>Position the computer monitor at a height that makes it easier for the user to place their eyes near the screen from a seated position.</u> Olivia found it difficult to access the screen at the Personal Computers kiosk. It was much easier for her to view the Fish Farming computer user screen, and she did utilize the visuals to understanding the meaning of the interactions. At Mystery Skulls, Olivia relied almost exclusively on the audio as the screens were further away from the stool, although she did not find this to be a problem; the audio helped her to focus her attention on the skull she had in her hand.

<u>Clearly marked, color-coded buttons of different shapes that the user can use to input information into a computer and receive both audio and visual feedback.</u> Olivia found the button interface very accessible. She could easily use it while either listening to the

audio, or while looking closely at the screen. As she stated in her final interview "Psychologically, I think there's nothing like actually putting your finger on a button and pressing it down, because then you know you did it…" This interface also felt familiar to her because it is similar to the interface of her digital cable, except that this system provided auditory feedback about what has been selected.

When possible, provide tactile experiences that connect to the content of the computer interactive. Olivia preferred the Mystery Skulls interactive because of its tactile quality. As Olivia states in her interview:

> "I liked the fact that you actually could hold something in your hands, and that made it real. And also, it was something I'm good at; to be able to touch something. It wasn't quite as abstract as when it's on a screen. And also, just for the fact that by just feeling the things and listening to the questions and answers, I could solve the problems all by myself. That's a really great feeling."

Universal design of digital media research study: Preliminary findings

February 7, 2005

Findings from the study elicited a series of design features for computer interactives in museums that are needed to facilitate learning across users of a broad range of abilities and disabilities. These features include the following:

- The button interface was accessible and easy to use for all of the study participants. None found this interface difficult to use nor did it present a barrier to learning for any of the participants. Participants with certain abilities (especially those who were blind or had limited mobility) felt that a push button system was the "best" interface for them and reported that a touchscreen interface would be completely inaccessible. Some participants felt, however, that a touchscreen or trackball-based interface would be easier for them to use.
- Audio facilitated learning of participants with and without sight, and with and without reading disabilities. For certain participants, such as those who have dyslexia or are blind, audio was an essential accessibility element. For others, it enhanced their experience as they felt using the audio helped them to understand the content, focus their attention and sustain interest. It should be noted, however, that some participants found the audio distracting, especially those who are deaf.
- Tactile models of skulls, originally provided for participants who are blind, were widely appreciated by many participants, yet they were difficult for participants with limited mobility to touch and hold.

- More images are needed to facilitate learning amongst visual learners, particularly those who are deaf or hard of hearing. Images should be used to represent the content, the activity's purpose, and how to use the interactive. However, the images should be presented in such a way that a person knows where to focus his or her visual attention and does not feel overwhelmed by varying visual stimulations delivered simultaneously.
- The language presented should be clear and simple, and provide participants with an exact description of what to do and when, even when they are not looking at the screen and only hearing the information.
- Participants need greater control over the pace of interaction. Participants reported that persons with disabilities need more time to think about, or respond and act, when working with computers. They requested more control over moving screens forward or backward. A few requested that the audio be spoken at a faster rate, although they recognized that the increased speed might not benefit all users.
- The timeout feature needs to be redesigned. Many participants found the "timing out" feature to be very disruptive as the computer would frequently time-out and return to the starting page while they were still interacting with the device. Either the timeouts need to be lengthened to accommodate the abilities of varying users, or participants should be provided with an option for preventing the computer from timing out (as is currently provided in on-line banking).
- Images should move slowly on the screen (including images presented on attract screens) to reduce the risk of inducing seizures and also to increase visibility for participants who have low vision.

- While the contrast and size of text-based information was adequate for participants with low vision, greater visual contrast is needed for visual cues that are not based on text, such as the highlighting of menu options and images that appear on the screen.
- Audio description assists participants who are blind and was also a helpful feature for participants who are sighted. However, in some cases (in particular, Mystery Skulls and Personal Computers) more descriptive text is needed to provide full access for participants who are blind.
- All buttons should be clearly labeled, providing participants with an indication of how they can be used to interact with the device. When possible, labeling should include both visual and Braille labels.
- Background noise should be reduced to the greatest extent possible. Currently, the amount of background noise in our exhibition halls is too high, and prohibits certain participants from fully engaging in the learning experiences provided. Background noise was particularly problematic for participants relying on audio as the primary means for receiving information. The impact of background noise was reduced when the speakers were placed close to the users, as they were in Fish Farming.
- The placement of the monitors can impact the accessibility of the interactive, and also it's perceived use. Many participants thought the Personal Computer kiosk was a touchscreen based on the placement of the monitor, which was on a slanted surface. The slanted surface also made it harder for participants who are deaf to read the captions, and was uncomfortable for participants with low vision who need to get their eyes close to the screen to read it. The placement of the Fish Farming monitor (upright and close to the participant) was generally perceived to be more favorable.

- All participants used the stools when interacting with the designs and most found them comfortable.

The study also revealed additional information about user feelings and attitudes towards the design of computer interactives that may provide insight on how to design better interactives in the future. They include the following:

- Almost universally, the participants reported that it was the content and the type of activity that determined which interactive was their favorite, and not its ease of use or accessibility. In many cases, the interactive that was the hardest for the participants to use was also their reported "favorite." It should be noted that not all participants in the study preferred the same activity, and user preferences for one activity over another were quite strong.
- Participants with sensory-related disabilities were unsure about what information they were receiving, and what information they were not. For example, participants who were deaf would feel the vibrations of the sound and would be unsure of whether the information that was being read aloud also appeared on the screen. Some of the participants found this to be distracting, and interfered with their ability to fully appreciate the experience.
- Many participants feel more comfortable when they are provided with more information upfront about the goals of the activity and directions on how to use it. For some participants, the lack of directions and information about the activity's goals prevented them from fully accessing the activity. Others were able to learn this information through trial and error, but would have felt more comfortable had it been provided.

- Participants appreciated the use of standardized design elements across each of the interactives (such as the standard placement of the audio on/off button and the consistent use of the triangles as arrow keys). They would apply what they learned at one interactive to their interactions at the next. However, the elements that varied between interactives did not negatively impact the user experience, and some felt that this variation made the interactives easier to use as the interfaces were customized to best meet the needs of the specific activity.

NEXT STEPS

- We have already made modifications to the interactives based on these findings, and will continue this effort (changes already made include modifying how quickly the computer interactives timeout, adding a brief instruction to the beginning of Fish Farming about how to start the activity, modifying audio labels to provide more exact instructions);
- We will apply project findings to the development of future interactives here at the Museum of Science;
- We will publish the results of the study and present at annual museum conferences;
- We are pursuing grants to continue this work, building towards design recommendations other museums can use.

Acknowledgements

Universal design of interactives for museum exhibitions is based upon work supported by the National Science Foundation under ESI-0423802. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect those of the National Science Foundation.

This study would not have been possible without the backing of the Museum of Science and its staff (including Christine Cunningham, Ph.D., Betty Davidson, Ph.D., Andrea Durham, Anna Lindgren-Streicher, Robert "Boob" Rayle, Emily Robertson and Susan Sunbury, Ph.D.); the feedback and guidance provided by the Lesley University advisory team (including William Barowy, Ph.D., George Hein, Ph.D., and Nancy Waring, Ph.D.); the generosity of the participants who graciously donated their time, energy and expertise; and the support and assistance of Stephen Reich, the author's husband.