Mixed-Reality Learning in the Art Museum Context

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ABSTRACT
We describe the realization of two interactive, mixed-reality installations arising from a partnership of K-12, university, and museum participants. Our goal was to apply emerging technologies to produce an innovative, hands-on arts learning experience within a conventional art museum. *Suspended Animation, a Reflection on Calder* is a mixed-reality installation created in response to a sculpture by Alexander Calder. *Another Rack for Peto* was created in response to a painting by John Frederick Peto. Both installations express formal aspects of the original artworks, and allow visitors to explore specific conceptual themes through their interactions. The project culminated in a six-month exhibition where the original artworks were presented alongside these new installations. We present data that the installations were well received by an audience of 25,000 visitors.

Categories and Subject Descriptors
J.5 [**Arts and Humanities**]: Arts, fine and performing

General Terms
Design, Human Factors.

Keywords
Art, Learning, Mixed-reality, Interactivity, Museum.

1. INTRODUCTION
Many art museums are struggling to identify innovative approaches to engage new audiences in their exhibitions. There is an extensive recent history of interactive artwork and sound installations that pose compelling and unique interactive interfaces within the museum context [1, 2]. While many artists have embraced emerging interactive technologies as a vehicle for expression, these paradigms are to-date underutilized in engaging museum visitors with historical works of art. Nonetheless, curators and researchers have found that interactive media , in addition to active participation by visitors , has been shown to increase audience attendance and appreciation in museum exhibits [3-5]. Science museums have more readily integrated multimedia presentations and interactive paradigms into their exhibitions. However, the typical scope of participation is often limited to few, discrete interactions such as button presses that trigger the playback of multimedia presentations. Dynamic multimedia design poses challenges in the traditional art museum. For example, we must consider how to present a meaningful experience for visitors, how to engage transient visitors [6], and how to design sonic and visual media that can clearly fit with, and not overwhelm, the surrounding artworks. We address these challenges in our work by drawing solutions from existing interactive installations described above.

The traditional art museum is typically viewed as a place of quiet contemplation. This culture can run counter to today's world of dynamic multimedia and it is not always optimal for student visitors and families with young children. Moreover, contemporary research in the learning sciences emphasizes the importance of active learning [7], collaborative learning [8], and constructionist [9] learning.

In our initiative, we confronted this notion of the traditional art museum and worked to reframe visitors' experience in two ways. First, we sought to provide a hands-on experience where visitors can "touch" artwork, and explore the work in ways that would not otherwise be possible. Second, we linked the active process of construction with an understanding of the original artist's process. In this paper we discuss the design and implementation of two installations that address these goals, describing the project structure and presenting evaluation data.

2. PROJECT COMPONENTS
The realization of this work is the result of a nine-month collaboration between Arts, Media and Engineering's [AME] *K-12 Embodied and Mediated Learning* group at Arizona State University [ASU], the ASU Art Museum, and the Metropolitan Arts High School in Phoenix, Arizona. The project builds upon ongoing work in art and learning within the Situated Multimedia Arts Learning Lab [*SMALLab*], a mixed-reality environment that is described below.

The project was undertaken in three phases. During Phase 1, a group of three teaching-artist mentors from AME collaborated with the ASU Art Museum to identify two works from the Museum's permanent collection, Alexander Calder's *Many Pierced Discs* and John Frederick Peto's, *The Rack*. In Phase 2, these teaching-artists made weekly visits to Metropolitan Arts High School in Phoenix, Arizona where they collaborated with teams of three high school student-artists to develop a conceptual framework and design for a new interactive

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installation utilizing *SMALLab*. In Phase 3, the collaboration culminated in a six-month exhibition at the ASU Art Museum. The exhibition featured the original artworks exhibited adjacent to the new interactive installations.

The central technology for the installation is AME's Situated Multimedia Arts Learning Lab [10]. *SMALLab* is a mixed-reality learning environment that allows participants to interact with one another and with sonic and visual media through full-body, 3D movements and vocalizations. Participants manipulate a set of interactive glowballs, and as they move, the body serves an expressive interface that mixes real world elements with digital components. Physically, *SMALLab* is a 15' wide X 15' wide X 12' high space. An open physical architecture supports the following sensing and feedback equipment: a five-element array of cameras for vision-based tracking, a top-mounted video projector providing real time visual feedback, four audio speakers for surround sound feedback, and an array of tracked physical objects. A networked computing cluster drives the interactive system with custom software for multimodal sensing, modeling, and feedback.

We have previously utilized *SMALLab* in a variety of learning environments that include arts and science education. Our approach to education is informed by related research in open-ended educational philosophies that support exploratory and active learning approaches. Constructivism posits that learners construct much of what they learn [11], and emphasizes the necessity of play and exploration in self-guided learning, particularly in mediated environments [12]. *SMALLab* and this set of installations served as a tool for both formal and informal learning within a constructivist learning framework. First, by creating new interactive installations, participating high school students directly engaged topics including interactivity, immersive sound, the intersection of sonic and visual media, and the application of these concepts for aesthetic and educational purposes. Second, *SMALLab* was installed in the ASU Art Museum where it functioned as an informal learning environment for an audience of thousands of visitors.

Once installed in the museum, visitors used a separate panel of buttons to choose among the interactive artworks that could be experienced in *SMALLab*. When a particular work was selected, the appropriate visual and sonic elements loaded, and the interaction framework adapted automatically. Written instructions and docent feedback ensured that visitors understood how to engage the interactive elements.

3. SUSPENDED ANIMATION

Many Pierced Disks (1950) by Alexander Calder, pictured in the left side of Figure 1, is a standing mobile made of sheets of painted metal. With air currents, the piece undulates on its own, slightly changing the position of the disks. Calder (1898 – 1979) made thousands of mobiles throughout his life, and this work highlights the things he loved most in sculpture: motion, action, and the color red. Calder said that his mobiles were "abstractions which resemble nothing in life except their manner of reacting." [13]

Many Pierced Disks served as the conceptual starting point for our realization of *Suspended Animation, a reflection on Calder*. Our team of artists and student-artists were drawn to this work because of the inherent potentials of the mobile structure. There is a tension between the relatively static configuration of the piece in the museum and its clear ability to spin and move if only visitors could act upon it. We posed questions regarding the form of the work such as: *What if the mobile was suspended on springs rather than on fixed rods? How would this reshape the idea of balance and movement? How could this serve an aesthetic goal?*

When considering the conceptual dimensions of Calder's sculpture, the student-artists identified a dominant theme regarding the balance of natural and urban environments. The notion of balance is drawn from the balancing mobile structure itself. Furthermore, the softly curving shapes of the suspended discs suggest an organic, natural origin. However, these discs are crafted from plate steel, a man-made material associated with contemporary urban environments.

The right side of Figure 1 shows our 3D virtual model of a mobile that is inspired by Calder's *Many Pierced Discs*. The virtual structure is interactive and is governed by a set of physics models including gravity, springs, and levers. This 3D scene is projected onto the floor of the *SMALLab* exhibition space. Using two glowballs, one or two museum visitors can simultaneously interact with the virtual structure in real time, empowering visitors to "touch" and play with a sculpture like Calder's. The physical height of one glowball is mapped to control the mass of one side of the mobile model while the height of the other glowball is mapped to the other. As museum visitors raise one glowball above the other, the gravity model exerts a greater force on the mass of one side or the other, thus moving the lever with a force that is proportional to the difference in glowball heights. In addition, the rotational angle (parallel to the floor) between the two glowballs is computed in real time. As this angle is rotated around the central origin, the 3D virtual camera view will shift in real time, sweeping in large arcs above and around the virtual sculpture. Through this interaction, visitors can take the perspective of standing directly above the sculpture, looking underneath it, and spining it around in the virtual space. This interaction provides a means for visitors to explore the formal aspects of Calder's work.

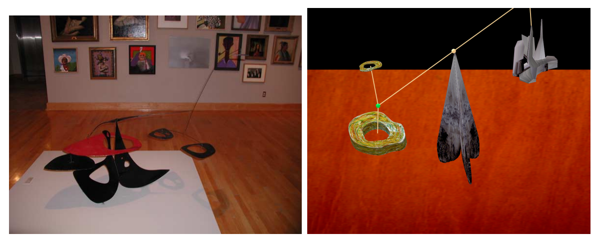

Figure 1. *Many Pierced Discs* by Alexander Calder and the virtual mobile in *Suspended Animation*

The conceptual ideas are expressed through the real time visual, kinetic, and sonic elements of the installation. The left side of the balance visually represents the natural environment. The suspended 3D forms are defined by rounded edges that suggest weathered rocks wrapped with a lush green and red texture. The elements are attached to the balancing linkage by a model of a physical spring with a simulated gravity force pulling the lower object down, and another simulated gravity force pulling the upper object up. As a result, when the balance shifts, these objects glide in a fluid manner that suggests an organic softness. The right side of the balance represents the urban environment. Here, the form of the weight is modeled after an urban skyline. It is covered by a dark texture with stark lines. This object is also connected to the linkage through a virtual rigid rod with a strong gravity force that causes the object to sink and rise with a precise, mechanical quality.

Interactive sound is an important component of the installation. As the mobile balance shifts, objects can hit the floor, and the participants hear sounds relating to the central theme. Specifically, when the "natural" side of the balance reaches the floor, participants here a synthesized sound like a large, soft object landing in a pile of leaves. Conversely, the sharp sound of a deep, resonant attack, like a metal drum, expresses the urban environment. In addition, we composed two soundscapes that are mapped to each side of the virtual mobile. These soundscapes are comprised of urban and natural sounds that are indicative of the regional environments near the ASU Art Museum. As a visitor shifts the balance of the model through their interaction, these two tracks are cross-faded to render an immersive sonic environment that matches the corresponding conceptual theme of the raised side of the model.

4. ANOTHER RACK FOR PETO

The Rack (1882) by John Frederick Peto (Figure 2) is a trompe l'oeile painting [14]. It depicts a number of personal artifacts of the artist, such as letters, newspapers and books that are arranged on a letter rack. *The Rack* is one of a series of similar works created during the Second Industrial Revolution, a period when the modes of production and the urban landscape were undergoing great change. Peto's painted racks were full of ordinary objects that showed wear and the effects of time. They represented the intimate minutia of the rising working and middle classes.

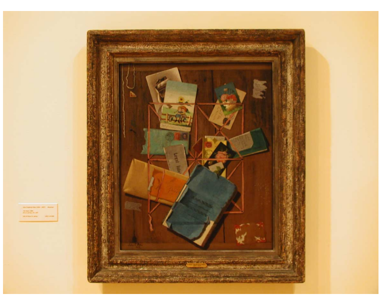

Figure 2. *The Rack* by John Frederick Peto

During our planning and design sessions, student artists considered the context of Peto's original work. They asked questions such as: *Why were certain objects he saved so important? What do these artifacts suggest about the day-to-day experiences of that time?* They considered the work's relevance in our digital age, asking: *What would a 21st century letter rack look like? How could it be manipulated and transformed? What artifacts would it contain?* Inspired by this discussion, the team of artists and student-artists endeavored to create an interactive letter rack, to be situated in the art museum, that would allow visitors to reflect on Peto's work by interactively constructing their own 21st century collages.

The student-artists first generated a large set of images, sounds, and video clips that would constitute the elements of the dynamic collage. Echoing the original work, these media elements were designed to convey a sense of our everyday experience and personal intimacy. For example, the student-artists created composite images that juxtapose drawings by hand with ordinary found objects. They created stop motion videos that combine graffiti-styled text elements with organic materials.

Next, the team designed a set of actions that enable visitors to create collages by transforming media elements within the virtual letter rack. *SMALLab* provides an interface of two glowballs that are tracked in 3D space. These devices were used in this piece out of the necessity of maintaining a standard interface across each of the interactive installations.

Figure 3. Visitor creates a virtual letter rack in *SMALLab*

There are four stages to configuring a media element. First, the visitor holds two glowballs, one in each hand with arms spread apart, standing above a particular visual media element that is projected onto the floor. By bringing the arms together, the visitor can now select an individual element. Second, by moving the glowballs up and down, the visitor can scrub through the set of available sonic and visual elements that are available. Each height is mapped to a particular pair of elements. Once the preferred element is identified, the visitor now spreads their arms apart to initiate the transformation operation to alter the size, position, and rotation of the element within the collage. To enlarge the size of the element, the glowballs are raised higher from the ground. To shrink its size, the glowballs are lowered. To change its rotation, the visitor turns to one direction or another, and the element follows that rotation. To move the media element, the visitor walks a new location, dragging the media element as they go. Finally, once these transformations are complete, the visitor releases the element by bringing the hands together above a desired position.

As pictured in Figure 3, visitors can use this set of operations to create a wide array of virtual letter rack collages. Once a visitor has created a collage, it remains projected until another visitor picks up where the previous visitor left off. In this manner, the installation enables visitors to consider Peto's original artwork through both their own real time activities and the artifacts created by others.

5. EVALUATION

This project culminated with a six-month exhibition at the Arizona State University Art Museum, a leading institution for contemporary American art presentation in the Southwestern United States. Over 25,000 visitors of all ages attended the exhibition. To evaluate the success of the initiative, we collected data through multiple observations of visitors, discussions with Museum staff, and comments noted in the museum's visitor log. Our observational data are principally derived from two sessions. First, we observed several hundred visitors of all ages interacting during the exhibition opening. Second, we observed a visit by approximately two hundred middle-school age students on a school visit three months later.

Visitors demonstrate a willingness to engage the work by manipulating the glowballs individually and in cooperation with other people. Working with *Suspended Animation*, visitors readily circle the virtual model and shift the balance of the mobile by raising and lowering the glowballs. However, we have observed that visitors are reluctant to explore the extremes of the vertical space. While exceptionally inquisitive visitors will engage a full range of high to low movements, most keep the glowballs in at a comfortable waist-level. Thus, a majority of visitors do not discover the more demonstrative sound transformations inherent in the work without additional guidance from docents, museum staff, or expert users.

When engaged with *Another Rack*, we observe a greater difference between visitors of different ages. Younger visitors readily engage the work. Despite its specific demands, most are able to grasp the interaction sequence for manipulating the collage either by glancing at the documentation, responding to docent instruction, or even through trial and error. Older visitors were often more daunted by the interaction and as a consequence, did not as readily engage with this work.

We have observed that many visitors spend an exceptional amount of time interacting with the *SMALLab* installations. While many adjacent galleries were sparsely attended, a persistent crowd of participants explored the work during the exhibition opening. We attribute this fact to an increase in motivation and engagement suggesting that our approach to hands-on learning in the art museum is capable of reaching new audiences in meaningful ways.

Two days prior to the exhibition opening, we presented the project to a group of Museum docents. These docents have little prior exposure to interactive technologies, but expressed great enthusiasm for the work. They were able to explore the work and reported that the interactivity provided a similar level of engagement as related work in gaming. They expressed concern that the technological elements might overwhelm the original sculpture for many visitors, but indicated an eagerness to share this project with visitors.

The ASU Museum staff reported that the work was well received with visitors of all ages. They noted that a number of school groups contacted the Museum to specifically request a scheduled tour of the installation. Young students have been drawn to the interactive technologies and have demonstrated a marked increase in motivation for learning in the gallery as measured by their increased time in the space and informal comments. Through an informal visitor log, we collected comments from visitors that reveal an enthusiasm for the work, particularly with young people. One visitor stated, "Interesting, [I] was part of the art. I could create it immediately with my instant emotion and body movement." Another wrote, "I love the GLOWBALLS exhibit! I brought my mother after camp." While another wrote, "It's totally cool man I'm going here every chance I get! □I loved the museum I will be back great art."

6. CONCLUSIONS

We have described an innovative exhibition framework that is capable of engaging a broad audience of art museum visitors through hands-on, active learning activities. We have demonstrated the efficacy of mixed-reality technology for this purpose, and have shown that the *SMALLab* environment is both flexible and robust. With the integration of sonic, visual, and tangible media in this installation, we have shown that despite some challenges, interactive, multimedia exhibitions for learning can play a powerful role in a traditional art museum context. Additional media documentation of the project is online [15].

7. ACKNOWLEDGEMENTS

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