IMPROVING HABITAT DIORAMAS THROUGH THE USE OF AUGMENTED REALITY TECHNOLOGY AT THE GRAND RAPIDS PUBLIC MUSEUM IN GRAND RAPIDS, MICHIGAN

A Thesis

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by

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IMPROVING HABITAT DIORAMAS THROUGH THE USE OF
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To serve the community they intend to represent, contemporary museums must be relevant to both current and future visitors. One such way to retain and attract a visitor base is through the application of simple technology to permanent and temporary exhibits. This thesis examines the impact of adding augmented reality technology to outdated habitat dioramas to improve educational outputs and increase visitor interaction. More specifically, this thesis monitors levels of visitor engagement before and after the addition of augmented reality technology to a dated habitat diorama at the Grand Rapids Public Museum in Grand Rapids, Michigan. At the completion of the study, several conclusions were reached: first, augmented reality can update inaccurate, static, or dated dioramas without physically altering the display; second, augmented reality content can

cover several topics at varying depth through a number of media, ultimately offering more to a wider range of visitor types; third, augmented dioramas can introduce visitors to pressing issues such as climate change, biodiversity loss, and conservation by capitalizing on the inherent vice of aged habitat dioramas, such as outdated ecosystems; and finally, augmented reality is currently a realistic and feasible option for museums of varying size and financial capability looking to improve their exhibits. Ultimately, this thesis not only offers a positive solution to museums struggling to decide the fate of dated habitat dioramas, but also hints at the potential uses of augmented reality within museums beyond habitat dioramas.

CHAPTER I

INTRODUCTION TO THE STUDY

Background

Once the principal mode of exhibition types at natural history museums, the habitat diorama has seemingly lost its holding power. It is now usurped by the growing popularity of interactive exhibits. The carefully crafted nature scenes and fine animal taxidermy that once charmed museum crowds with fantastic notions of pristine environments and charismatic beasts have come to symbolize antiquated representations of long-gone human-environment relationships and perceptions. As an increasing number of museum visitors gravitate towards technology-heavy interactives and exhibits, the ostensibly simple habitat diorama's relevance within museums has decreased. Habitat dioramas have not only become largely irrelevant within museums, they have become inaccurate representations of the natural world and mocking reminders of contemporary biodiversity loss. The idealistic habitats portrayed have indeed succumbed to the demands of habitat loss, and many of the taxidermy animals displayed are either endangered or quickly approaching extinction. As the painted sceneries fade and the taxidermy animals deteriorate, the dissonance between the desires of contemporary museum goers and the actual contribution of the habitat diorama to the visitor's experience is revealed.

Known as the "diorama dilemma," natural history museums across the United States are contemplating the future of the once beloved displays. The dilemma currently

playing out in contemporary museums is a vacillating debate that both praises and criticizes this form of display. Though capable of inspiring biological inquiry, cultivating critical thinking skills, and promoting environmental awareness, habitat dioramas are frequently costly to maintain, static, and rife with outdated, unrealistic, and patriarchal displays of nature.

This thesis posits that Augmented Reality (AR), a form of mobile technology, has the capability to amend these problematic qualities. Coined as a term in the 1990s by Boeing researcher Thomas Caudell, AR technology has evolved significantly (Augmented Reality 2016) since its initial conception. In its infancy, AR was utilized in televised football games, appearing as the yellow "first down" line, and has since grown to dominate consumer, technological, and entertainment markets alike (Augmented Reality 2016). Used in viral mobile games such as *Pokémon Go* and by major products such as Google Glass, it is no surprise that AR has made its way into museums. As a highly versatile technology, AR "integrate[s] digital information [into] the user's environment in real time . . . [it] uses the existing environment and overlays new information on top of it" (Augmented Reality 2016), making it an ideal solution for museums facing the diorama dilemma. AR presents a new alternative without physically altering the diorama, while simultaneously transforming these displays into fertile spaces for diverse narratives, critical conversation, and ignited scientific imagination.

As an admirer of the craft and research that goes into producing a habitat diorama, I became interested in creative preservation solutions after learning about the diorama dilemma. While it is undeniable that habitat dioramas have fallen out of favor

and have been usurped by more interactive displays, total elimination seemed excessive and unnecessary; for this reason, I chose to focus my thesis on a solution that could increase the relevancy of habitat dioramas without altering the display significantly. A technological component was an obvious solution, but the technology had to go beyond simple audio buttons – it had to mirror the fundamental nature of habitat dioramas, which is to say that it needed to be an expression of art *and* science. In this regard, AR fit the requirements; it is creative, artistic, and simultaneously an active and engaging tool for scientific learning.

Likewise, the praise surrounding AR's capability within museums is illustrated through this case study, which closely examined the effect augmentation had on a dated marsh diorama located at the Grand Rapids Public Museum (GRPM) in Grand Rapids, Michigan. Over the course of six months, the aged marsh diorama underwent several observations and alterations. Starting in February 2017, the display was observed over the course of two days in its natural condition to gauge levels of visitor engagement. Following the February visitor observations, the diorama was augmented in March 2017 using the AR platform "Zappar" to improve visitors' interaction with the display. The final stage of the project occurred in June 2017, in which the augmentation was applied to the diorama and visitor's interactions were observed to measure improvements in engagement. Additionally, data from the observations and augmentation were synthesized in June 2017, along with an AR product comparison that measured the feasibility of implementing AR into museums of varying size and financial capability. Succeeding data interpretation and analysis, the findings from the diorama augmentation

suggest a positive future for this form of display, the museums who house them, and the visitors who connect with them.

Beyond the positive implications regarding the future of habitat dioramas, this thesis contributes to museum studies and anthropology. At the crux of the diorama dilemma is the displays' inability to connect with contemporary museum-goers. This dilemma is an important aspect of a larger issue that museums face as they work towards being more inclusive, participatory, and multivocal institutions. In confronting the diorama dilemma, the larger picture comes into focus: dated dioramas are just one example of the contemporary museums' struggle to remain relevant to visitors from all contexts and backgrounds. Therefore, by studying the ways in which dioramas fail and succeed, the findings can be applied on a larger scale. For instance, because the addition of simple AR technology improved visitor engagement without physically altering the marsh diorama, it can be assumed that the addition of non-invasive technologies are capable of transforming static museum elements into vibrant centers for expression, communication, and sharing. In this way, the conclusions reached provide valuable insight into the ongoing transformation of the museum from an authoritative gatekeeper of culture into a space for both formal and informal education.

Likewise, the findings from this thesis contribute to the field of anthropology as they further examine and analyze the complex and ever evolving relationships between individuals and community and community and institution. Ethnographic in nature, the methodology for this thesis employed anthropological observation techniques that studied the motivations of individual museum goers and attempted to represent their motivation-

related desires through the augmented diorama. In presenting an augmented diorama that expressed several motivation-driven desires, the individual held the power to connect with a larger community within or outside of their own motivation-related desires.

In observing the motivations shared between individual and community, a clearer understanding of the social and solitary behaviors that occurred at the marsh diorama could be reached and subsequently used to improve the relationship between community and institution. In the case of this study, social behaviors were dominant and included observing, interacting, reading, discussion, and experience preservation, while solitary behaviors, including observing, interacting, and reading happened infrequently. Thus, a lack of solitary behavior at the marsh diorama suggests that the institution could benefit from added technological elements that address the desires of solitary visitors and their associated community. Therefore, the data collected can be applied two-fold: on a smaller scale, it allowed the GRPM to temporarily offer a more holistic exhibition, while on a larger scale, it revealed the current social makeup of museum goers and illuminated the types of communal-institution relationships that should be formed and nurtured.

Statement of the Problem and Purpose of the Study

A series of key questions concisely summarizes the diorama dilemma, suggests the applicable solution, and guides the progression of this thesis. To start, the root of this thesis seeks to determine whether habitat dioramas should be kept for nostalgic purposes or replaced by more up-to-date exhibits. Proceeding this question, this thesis explores the use of AR within museums and asks if AR can both preserve and

update habitat dioramas in order to meet the desires of contemporary museum goers. Finally, this thesis considers the prospect of employing AR within museums by asking if AR is a realistic and feasible option for museums of varying size and financial capabilities. These questions have been thoroughly explored in order to supplement growing discourse regarding mobile technologies' role in museum education and its contribution to meeting the desires of contemporary visitors by using habitat dioramas as a vehicle for experimentation. Likewise, each of these questions corresponds to a phase of thesis research that is guided by a strong theoretical framework.

Ultimately, this thesis advocates for a shift away from traditional connotations associated with habitat dioramas. By refocusing habitat diorama development on the repercussions of human-environment interactions through the utilization of AR, this form of display can be noninvasively updated, made attractive to a more diverse audience, and become an important tool for engaging the public and inspiring scientific discourse and environmental advocacy. Overall, the thrust of this thesis argues that AR can significantly improve the level of interaction between the visitor and habitat diorama, resulting in increased educational benefits that will work to reshape the visitors' understanding, relationship, and perception of both human-made and naturally occurring environments.

Theoretical Bases and Organization

Four theoretical frameworks contribute to the argument of this thesis. At the core of the theoretical framework is New Museum Theory, previously known as Critical Museum Theory (Vergo 1989; Marstine 2008), which will be supplemented by Visitor Motivation Identity Theory (Falk 2006), Post-Museum Theory (Hooper-Greenhill 2000)

and Mobile Learning Theory (Sharples et al. 2007). Working together, these theoretical approaches embody the movement of the museum towards becoming a more reflexive and multivocal institution and represent the future of inclusive, interpretative, and engaging exhibitions. More specifically, each of these theories confirm the necessity to reform habitat dioramas through the use of AR in order to make these displays compliant with contemporary museums' reflexive and multivocal missions.

On a larger scale, these theories operate within an anthropological context. As museums continue to shed the exclusive and authoritative demeanor commonly associated with them, these institutions must objectively reflect on the relationships they prioritize and the role they intend to play within a community; for this reason, the objective nature of anthropology makes it an ideal field to work within. Like many long-standing museums, the GRPM has grown significantly since its conception as a private collection and continues to do so, however, dated exhibitions slow the progression towards becoming more pluralistic. As the researcher, anthropological methods of observation were critical in understanding the GRPM's visitor base and their associated motivations, behaviors, and desires.

During the February observations in particular, direct, unobtrusive, spot sampling, and continuous monitoring were employed under the guidance of Russell Bernard's (1988) *Research Methods in Anthropology* to establish an ethogram based on visitor's behavioral patterns with the habitat diorama. An ethogram, which is a catalog of observed behaviors, facilitated the analysis and categorization of the GRPM's most and least common form of visitor to the diorama hall. Drawing on theories by Falk, Hooper-

Greenhill, and Sharples et al., meaningful patterns from the data were uncovered, ultimately guiding the progression of the diorama augmentation and post-augmentation data interpretation. In short, the heavy focus on human behavior within a museum context renders this study anthropological in nature.

Setting the tone for the theoretical underpinnings of this thesis is Vergo (1989) and Marstine's (2008) New Museum Theory. New Museum Theory views museums as being contextual and objective, a deviation from early museums which prescribed to fixed and precise interpretation of objects and ideas. With this in mind, New Museum Theory was, and continues to be, a major catalyst in the shifting roles of museums as they transition into more self-reflexive and pluralistic institutions. Likewise, as contemporary museums begin to diversify their narrative to serve a wider community, exhibition styles, object display, and object interpretation have evolved to "represent not just the world views of the ruling classes, but also the . . . culture and histories of non-elite social strata" (Ross 2004:85). More specifically, New Museum Theory guided the incorporation of Anishinabek and Spanish narratives into the marsh diorama, two storylines that were otherwise not present at the marsh diorama.

New Museum Theory is applied here as a framework under which Visitor Motivation Identity, the Post-Museum, and Mobile Learning Theory can be incorporated. For instance, New Museum Theory supports the movement towards more inclusive museum spaces – this might then be tangibly translated into an exhibition in which multiple platforms, one of which utilizes mobile technology, are used to reach a diverse range of visitors in a variety of contexts. Therefore, Visitor Motivation Identity, the

concept of the Post-Museum, and Mobile Learning theories can operate under New Museum Theory, which directs methodological procedures for this thesis.

To start, Falk's (2006) exploration of Identity-Related Museum Motivations "provides a unique window through which we can understand how best to accommodate museum visitor needs; it allows us to better understand the nature of the museum experience and potentially improve it" (Falk 2006: 124). Because a significant portion of this thesis focuses on visitor's experience with habitat dioramas, it is important to reflect on established approaches that are frequently applied to visitor studies.

In *An Identity-Centered Approach to Understanding Museum Learning*, John Falk describes five categories of visitor types that can be used in improving the museum experience. Falk is not the first to categorize visitors, and in fact, several scholars have assigned their own creative categories to describe visitor types and motivations. For instance, Higgins (1884) identified visitors as being students, observers, loungers, or emigrants, Wolf and Tymitz (1978) describe visitors in terms of the commuter, nomad, cafeteria type, and VIP, and Veron and Levasseur (1989) categorize visitors as ants, butterflies, grasshoppers, and fish. Regardless of the names and categories applied, a century's worth of visitor research has made it clear that visitors are not homogenous, and as such, museums should attempt cater to a variety of identities and desires in order to remain relevant.

In Falk's analysis of visitor identity types, he suggests that visitors are explorers, facilitators, professionals/hobbyists, experience seekers, or rechargers; each of these categories is linked to different identity-related motivation factors. For instance,

explorers visit museums for curiosity-driven reasons, facilitators attend museums as enablers of others who want to visit the museum, professional/ hobbyists go to "satisfy a specific content-related objective" (Falk 2006:120), experience seekers visit museums to experience an important or well-known destination, and rechargers are motivated to visit museums to engage in contemplative or mentally/ spiritually restorative activities. Through delineating these visitor types, Falk asserts that identity-related motivations directly relate to the ways in which visitors make meaning within the museum (Falk 2006:121). Therefore, by categorizing visitors, museums can more efficiently cater to visitor's identity-related needs and ultimately fabricate creative ways to reach audiences that may have been previously excluded from museum. However, it should be noted that visitor identities are fluid, multi-dimensional, and highly susceptible to change. Therefore, this thesis employs Falk's Identity-Related Motivation theory for categorization purposes, but recognizes that a well-done, multivocal exhibit wields the ability to transform an enabler into an explorer and so forth. With this in mind, Falk's Identity-Related Motivation concept is highly applicable to this thesis because the delineation of categories guides the augmented content selection for the GRPM marsh diorama. In turn, the carefully selected augmented content is meant to appeal to a variety of identity motivations and invite previously excluded identity types into the museum.

In Hooper-Greenhill's *Museums and the Interpretation of Visual Culture* (2000), the concept of the Post-Museum is discussed. Hooper-Greenhill defines the Post-Museum as taking a cultural approach to objects; rather than communicating "correct" material, the Post-Museum acknowledges that visitors come from a variety of

backgrounds and therefore require more personalized and narrative-based approaches to objects of culture.

The concept of the Post-Museum is heavily dependent upon the contextual model of learning, a framework posed by Falk and Dierking in *Learning from Museums: Visitor Experiences and the Making of Meaning* (2000:10), which draws from constructivist and cognitive learning theories. Contextual learning is described as being both a process and product of personal, sociocultural, and physical contexts, a kind of unending dialogue between person and environment (Falk and Dierking 2000:10). Situated within a museum setting, the contextual model of learning assumes that visitors will be motivated to learn based on their own personal and contextual experiences, resulting in the need to create exhibitions that offer visitors a variety of ways to process and relate to content. Therefore, the Post-Museum is the ideal physical manifestation of the contextual model of learning; it is a highly personalized space that caters to individuals through their past knowledge, interests, and beliefs (Falk and Storksdieck 2005:746).

With this in mind, physical exhibitions within the Post-Museum are only one method of communicating knowledge. For instance, a Post-Museum will cultivate multiple contexts, digital included, that facilitate open interpretation of objects. Hooper-Greenhill (2000) suggests that this multi-platform model affords visitors the opportunity to make their own meaning, and depending on the platform, share their interpretations in a communal space. This vision of a space that supports the visitor's desire to choose and control their learning through multiple mediums both reinforces and is facilitated by the

contextual model of learning (Falk and Storksdieck 2005:746). Thus, the Post-Museum is highly applicable to the theoretical framework of this thesis because it acknowledges the capabilities of technology as a tool that enables multiple narratives within a single exhibition.

Working with Hooper-Greenhill's concept of the Post-Museum, Watermeyer (2012) explores how this model is fertile for immersive learning and public engagement with scientific ideas in technological contexts. In *A Conceptualization of the Post-Museum as Pedagogical Space*, Watermeyer asserts that the Post-Museum should not be an "edifice but an experience of science . . . which rehabilitates and renews the interface between science and its lay communities" (Watermeyer 2012:1). In experiencing science, a visitor's "scientific imagination" is engaged, potentially launching a trajectory in which scaffolded and lifelong scientific learning occurs (Watermeyer 2012:1). Employing "free choice learning" models from Falk et al. (2000), the Post-Museum can offer personalized, multi-platform learning through mobile apps that offer a variety of learning mediums and engage visitors at varying depth, dependent upon their understanding of scientific concepts. Mobilized scientific learning affords visitors the chance to inject scientific narratives into their own cultural contexts, ultimately enabling scientific discourse (Watermeyer 2012: 4). Augmented habitat dioramas are one such channel in which creative encounters with science can be supported and shared within the Post-Museum. Likewise, because AR provides opportunities for social media use within the museum, the gap between the personal and social is bridged. As a result, learning becomes both personal and social, ultimately improving the museum's ability to reflect and harbor

multivocality. Finally, Mobile Learning theory supplements New Museum Theory, Visitor Identity Motivations, and Post-Museum theory by offering a guide as to how concepts such as reflexivity and multivocality can be translated into educational content within museums. In *A Theory of Learning for the Mobile Age,* Sharples et al. (2007:1) explore mobile technologies' influences on contemporary educational theory. As a working definition, Sharples et al. (2007:2) describe mobile technology as being a multimedia experience facilitated by "mobile phones, cameras, music players and portable computers." Sharples et al. (2007:1) posit that the ubiquity of mobile technology marks the need for re-conceptualized theories of learning that are inclusive of powerful technological learning tools and the contexts in which they are used.

Sharples et al. (2007) reflect upon the constructivist theory of learning, which suggests that learning is a result of ongoing, communally practiced knowledge and skill building that is comprised of both personal development and the adaption to change. With this in mind, Sharples et al. (2007:4) regard Mobile Learning as being "the processes of coming to know through conversations across multiple contexts amongst people and personal interactive technologies." Therefore, a theory of Mobile Learning is highly useful in redesigning habitat dioramas to be more reflective of museums as inclusive institutions.

For instance, augmented habitat dioramas can support chat and social media functions in which users can connect and discuss content; through highly accessible, digital conversation, users can "negotiate differences, understand each other's experiences and form transiently stable interpretations of the world" (Sharples et al.

2007:5). Additionally, mobile software connected to the habitat diorama can "provide tools for collecting data and for building and testing models . . . [that will] extend the range of activities and the reach of a discussion" (Sharples et al. 2007:8). Ultimately, mobile technology fosters supportive contexts in which users are continuously able to reflect and engage with narratives outside of their own.

Furthermore, Sharples et al. (2007:9-10) argue that mobile technology itself not only caters to a variety of learning contexts, but often creates contexts for learning by providing the resources for conversation to continue across time and space. Similarly, as users continue to engage and become familiar with mobile technology "new ways of interacting . . . lead[s] to new ways of learning and working" (Sharples et al. 2007:13). For example, through interacting with an augmented habitat diorama, users can not only learn about the scenes on display, but can also practice channels of learning that are otherwise not conducive to traditional learning environments, such as challenging the authority of the curator. Overall, Sharples et al. (2007:13) suggest that mobile technology enables learning that is unbound by context or access to community; therefore, in augmenting dioramas, creators should reflect upon these components of Mobile Learning theory as they are supportive of reflexive and multivocal museum environments.

Reflecting on the organizational structure of this thesis, the collection of data was both guided by the four aforementioned theoretical frameworks and used in the data interpretation process. Because New Museum Theory forms the basis of the theoretical framework, it directs the data collection and analysis that occurred during each phase of

research while the concepts by Falk, Hooper-Greenhill, and Sharples et al. served as supplemental theories applied to specific phases of data interpretation and analysis.

Application of Theories

Considering the first phase of conducted research, which seeks to answer whether habitat dioramas should be kept for nostalgic purposes or replaced by more up-to-date exhibits, New Museum Theory has been applied. Keeping in mind the thrust of the theory, which posits that museums can and should serve diverse communities through the consideration of pluralistic viewpoints, the findings from the visitor studies have been used to determine if the GRPM Michigan marsh display is relevant to its visitor base. Likewise, this theory carries over into the second phase of research by directing the creation of a multivocal augmented storyline.

Interpretation for phase two, which explores whether the use of AR can both preserve and update outdated habitat dioramas in order to meet the desires of contemporary museum goers, applies Falk, Hooper-Greenhill, and Sharples et al.'s theories. These theories work well together and were used to guide the augmentation of the GRPM diorama. To start, observations from the first phase of visitor studies were interpreted through Falk's Identity Theory to pinpoint the most common type of visitor to the display; these findings were then applied to the augmentation process to ensure that the augmented storyline was relevant to the various kinds of visitors who engaged with the display. Similarly, because the Post-Museum concept asserts that museums must have multiple platforms from which visitors can be engaged, and because scientific imagination can be nurtured in this process, the Post-Museum concept therefore

influences the kinds of media selected for the augmented storyline. Likewise, the Post-Museum concept acknowledges the role of mobile technology in achieving these goals, whereas Mobile Learning theory posits that mobile technology itself not only caters to a variety of learning platforms, but also creates contexts for learning by providing the resources for conversation to continue across time and space. With this in mind, the Post-Museum concept and Mobile Learning Theory were reflected upon during diorama augmentation to ensure that the storyline was portrayed through various media that reaches beyond the content available within the GRPM diorama hall.

The third and final phase of thesis research, which considers whether AR technology is a realistic and feasible option for museums of varying size and financial capabilities, is perhaps less dependent on a theoretical framework due to its comparative approach, however underlying concepts from New Museum Theory were applied when determining the overall efficiency and feasibility of supporting AR within museums of all sizes and capabilities. For instance, a major factor used in determining the applicability of an AR platform is its ability to tell several narratives and provide visitors with the agency to explore an object or idea at their chosen depth. Likewise, when considering the comparison points of capability, usability, and price, New Museum Theory was kept in mind as a way to check the feasibility and necessity of implementing AR into the exhibition space.

Limitations of the Study

In the assessment and intervention of alternative museum displays, this study met several challenges. On a broader scale, the theories selected for this thesis carried

their own inherent limitations. Starting with the use of Falk's Visitor Identity Related Motivations, categories posed by Falk were exceedingly useful, but at times also limiting. For instance, the five visitor types identified helped to organize the visitor studies data, but failed to consider the fluidity of these categories. For example, during visitor studies, the two primary visitor types present during the visitor studies were explorers and facilitators, however, sub-categories emerged within these two types, a development that was not built into Falk's theory. With this in mind, this thesis recognizes that the visitor types proposed by Falk are meant to be a jumping off point rather rigid and definitive categories. Likewise, considering Sharples et al.'s (2007) Theory of Mobile Learning, similar framework limitations emerged. In particular, Sharples et al. (2007:4) states that the investigative focus of a Theory of Mobile Learning is "not the learner, nor their technology, but the communicative interaction between these to advance knowing." Therefore, because this thesis heavily focuses on the visitor as well as the type of technology used, the theory could not be used as a whole. As a result, applicable elements concerning the "communicative interactions" between person and technology were pulled from the theory and utilized throughout this thesis when appropriate.

On a smaller scale, limitations of this study are primarily hinged upon the relatively sparse amount of literature addressing AR as a solution to the diorama dilemma, the small sample size, the singular research location, and the thorough testing of only one AR platform. To partially address these limitations, a reflexive approach has been taken. Starting with the lack of published studies that examine the effectiveness of AR on habitat dioramas, this thesis reflects upon foundational studies such as Gambini et

al. (2014) and Marques and Costello (2015) to help guide the progression and organizational structure of this study. In reflecting on these studies, this thesis tests these cited solutions within the alternate context of the GRPM, a medium-sized institution. Considering the time limitations which ultimately resulted in a small sample size, singular research location, and use of only one AR platform, a reflexive nature has been applied in attempt to alert readers to the need for additional research. Although the sample size, singular location, and singular AR platform produced results that are supported by the findings from the limited pool of relevant literature, a larger, multi-locational study that tests several AR platforms might yield more concise results.

However, in spite of the study's limitations, the interventionistic nature of this thesis offers salient findings, regardless of the aforementioned confines. Irrespective of the small sample size and singular research location, the data from the study are clear – visitor engagement with the GRPM marsh diorama significantly improved post-augmentation. As a result, the marsh diorama acts as a representational model that can be applied to institutions of all sizes that possess dated dioramas. Therefore, it is likely that a reproduction of this study would yield similarly positive results, regardless of the sample size, location, or exhibition choice.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

To address the three key questions outlined in Chapter I, a basic overview of habitat dioramas is necessary. Following a brief overview of habitat dioramas, their history, and their function, the positive and negative aspects of these displays will be discussed. Finally, the literature review will further address the positive and negative aspects of habitat dioramas while simultaneously highlighting the benefits of technology, specifically AR, within museums.

Though dioramas are a well-known element in natural history and other types of museums, the parameters used to define these displays are somewhat ambiguous. Ranging from miniature scenes constructed from paper to large and intricate spectacles involving real animals, dioramas come in a variety of sizes and scenes (Kamcke and Hutterer 2015:7). Likewise, dioramas have fulfilled a number of roles over time including entertainment, educational, storytelling, and conservational functions (Poliquin 2012:4-7).

Meaning "through that which is seen," or "to see through," the term *diorama* was first coined by French inventor Louis Daguerre in 1822 (Chicone and Kissel 2014:73). Daguerre's dioramas, which were not fabricated for or installed in museums, took on a form much different from contemporary dioramas. Used primarily for entertainment purposes, Daguerre's carefully painted landscapes played out nature scenes

with the use of light, sound, and occasionally, live animals (Sivak 2014:1). Captivated audiences were invited to sit in a rotating theater and view the translucent paintings as lights changed the scene from night to day, instruments queued up thunderstorms, and appropriate animals, such as goats, roamed around in the background (Sivak 2014:1; Kamcke and Hutterer 2015:10). Because Daguerre's dioramas were a form of entertainment, they were subject to cultural trends and were eventually phased out. During the eighteenth and nineteenth century, long painted scenes known as panoramas took on the role of the diorama (Kamcke and Hutterer 2015:12).

Panoramas came in a variety of forms, were produced using slanted planes to create the illusion of depth, and attempted to portray reality. Panoramas became exceedingly popular during the late nineteenth century (Kamcke and Hutterer 2015:8-9). In tandem with the popularity of the panorama, biological groupings of animals became a common display method within museums. During this period, natural history museums in particular had become grandiose repositories for volumes of natural specimens, and in fact, by the late nineteenth century, roughly one thousand new plant, animal, and insect species were being identified annually (Ritvo 1997:10). This significant increase in specimen identification spurred the need to give order to the natural world, resulting in group displays of specimens organized in rows according to size, color, gender, and geographic location (Poliquin 2012:113). For instance, a flock of birds might be gathered together to show the variation of mating pairs, chicks, eggs, and nests (Kamcke and Hutterer 2015:12). Occasionally, these biological groups, which were typically of the avian variety, would be placed inside a case with the painted panorama in the background

(Kamcke and Hutterer 2015:13). According to Quinn (2006:14), habitat dioramas are a result of biological groupings paired with an appropriate panorama for context.

However, what is considered to be the first habitat diorama was not created until 1889 by Carl Akeley, a well-known taxidermist, sculptor, hunter, and graduate of Ward's Natural History Establishment, the world's leading supplier of natural history specimens at the time (Poliquin 2012:102). Individuals such as Akeley were at the forefront of revolutionizing the ways in which museums displayed zoological specimens, ultimately challenging "the dominant exhibition philosophy of the time by giving scientific legitimacy to the new artistic techniques of [display]" (Wonders 1993:112). His scene of a muskrat group in a recreated marsh was one of the first dioramas in what would become a golden age for this type of display. Museums in both Europe and North America embraced the habitat diorama during the nineteenth century and quickly moved from small-scale bird displays to large mammal installations (Kamcke and Hutterer 2015:17).

Following the opening of the 1891 buffalo group display at the National Museum of Natural History in Washington, D.C., competition for visitorship soon erupted both within and between museums (Kamcke and Hutterer 2015:17). Museums sought to draw visitors by continually upping the quality, size, and variety of taxidermy animals on display, while internally, scientific museum staff fought for fiscal resources, citing that funds should not be wasted on exhibits with such minimal educational value (Kamcke and Hutterer 2015:18). During this period, spectacle was prioritized over

intentional educational output, and the resulting habitat dioramas were dramatic scenes depicting a pristine natural world (Poliquin 2012:95).

While it is true that informative diorama tables, maps, and graphs remained small so as not to take away from the display (Kamcke and Hutterer 2015:19), key educational and conservational elements resulted from these displays. Likewise, dioramas were used at the 1904 St. Louis World's Fair, and again at 1933 Chicago World's Fair to demonstrate the theme of science and progress (Allen 2004:1; Ganz 2008:73). In particular, living dioramas, such as the 1904 Igorot village and the 1933 Pueblo Indian display, were reflective of the Victorian need to understand natural order, including perverse notions of human order and categorization (Allen 2004:1; Ganz 2008:67). In this way, the living dioramas at the World's Fair were ethnographic versions of habitat dioramas, ultimately offering viewers the opportunity to reflect on the spectrum of life and their own order within nature; the same can be said of habitat dioramas at the World's Fair (Poliquin 2012:140). Among the several dioramas that showcased exoticized culture groups and the spoils of industrialism at the 1933 Fair, habitat dioramas, such as a Galapagos Island display, allowed visitors to observe the sea lions, gulls, and iguanas that led to Charles Darwin's theory of evolution by natural selection (Ganz 2008:73-74). Due to the ability of the display method to effectively illustrate progress and science, dioramas became recognized as a highly influential tool in shaping the minds of the public (Ganz 2008:74).

With the opening of large diorama halls, such as the Akeley Hall of African Mammals in 1936 at the American Museum of Natural History in New York, animals

and environments that were once only reachable to a select few became widely accessible to the public. By bringing lifelike scenes of nature into the museum, visitors could examine, engage, and learn about the natural world. Additionally, the inquiry sparked by the dioramas resulted in further scientific research. For instance, a diorama at the American Museum of Natural History showcasing two male lions that had been modeled after the famous "man-eating lions" that killed and ate Indian workers during the construction of the Kenya-Uganda Railroad, resulted in the pursuit to better understand carnivorous dietary habits (Poliquin 1993:99-100; Hutterer 2015:29).

Furthermore, the resonating sense of wonder and awe created by habitat dioramas alerted the public to issues of environmental degradation. During the nineteenth century, the beginnings of environmentalism in the United States highlighted the fact that "wilderness was not an unlimited resource . . . and that ultimately humans played the decisive hand in preserving or diminishing nature's rich diversity" (Poliquin 2012:103). In some cases, this increased sense of awareness resulted in the creation of nature reserves. For example, the Pelican Island diorama at the American Museum of Natural History spurred the establishment of the first federal bird reserve in 1903 on Pelican Island in Florida during Theodore Roosevelt's presidency (Kamcke and Hutterer 2015:14). Similarly, Roosevelt's commitment to conservation is reflected in the American Museum of Natural History's Hall of North American Mammals in which federal parks such as the Grand Canyon, Yosemite, and Devils Tower, Wyoming, are depicted in diorama form (American Museum of Natural History 2016). Thus, the habitat

diorama functioned two-fold as a tool that inspired conservation and showcased the boon of newly enforced conservation policies.

Ultimately, although the entertainment, educational, and conservational attributes of habitat dioramas helped to draw, inspire, and maintain museum visitors for many decades, this form of display eventually fell out of fashion and started to decline during the latter half of the twentieth century (Quinn 2006:10). Frequently criticized for having minimal educational value, production of habitat dioramas became almost negligible in the late twentieth century due to a number of additional factors such as cost and the desire to build displays that were more easily maintained and altered (Fletcher 2008:18). Likewise, as human awareness of the environment evolved, the scenes depicted within aged habitat dioramas failed to match visitor's perceptions of the natural world (Poliquin 2012:95). As a result, these dated installations from the early and mid-twentieth century now require a considerable amount of redevelopment to maintain relevancy within contemporary museums, including the costly preservational aspects of maintaining these exhibits as they slowly deteriorate from long-term exposure to dust, light, pest infestations, and other agents of deterioration.

Positive Functions of Habitat Dioramas Within the Contemporary Museum

Although the construction of new and updated habitat dioramas has largely decreased, these displays often remain a central component of the museum layout (Chicone and Kissel 2014:75). Though habitat dioramas sometimes appear aged or tired,

their appeal continues to attract visitors and, furthermore, numerous studies have demonstrated the educational benefits of these displays (Chicone and Kissel 2014:75).

Taking the form of three-dimensional representations of animals in their natural environment, habitat dioramas easily draw visitor attention. Though habitat dioramas can have animatronic or two-dimensional animals (projected images), the standard display is generally a collection of posed taxidermy animals set within a context that demonstrates accurate flora, accompanied by a painted background that uses techniques of scale to create the illusion of depth (Kamcke and Hutterer 2015:7-14). Occasionally, glass casing is removed from the front of the diorama, allowing visitors to become further engaged (Chicone and Kissel 2014:75). Unlike zoological parks, in which visitors frequently catch only glimpses of wildlife, habitat dioramas give visitors "the opportunity to 'stop and stare' and to observe and make connections with the animals and their environment which is otherwise not possible" (Tunnicliffe and Scheersoi 2015:138).

This snapshot of nature is perhaps the habitat diorama's most potent educational tool; given the chance to study the display up close, visitors, primarily children, can inquire, construct meaning, and sharpen their critical thinking skills as they connect the animals to their environment and to their own personal experiences (Chicone and Kissel 2014:75). More specifically, habitat dioramas allow children to explore the field of biology and likewise, these displays act as tools for biology education (Tunnicliffe and Scheersoi 2015:141). Habitat dioramas allow for a unique learning experience as children break away from rigid teaching methods, observe wildlife that might otherwise be inaccessible, and socialize with other children and educators as they

engage with the display (Tunnicliffe and Scheersoi 2015:141). Active exposure to biological education at a young age may help increase interest in the field at a later age.

Likewise, habitat dioramas help to dispel unrealistic perceptions of wildlife, to a certain extent. Animals used in marketing and advertising for children's shows, toys, clothes, and other products typically depict a highly anthropomorphized version of the animal (Ross et al. 2011:1; Tunnicliffe and Scheersoi 2015:140). An excellent example of this is the anthropomorphic narrative commonly associated with chimpanzees. Frequently showcased as charismatic pets or performers in movies, television, and advertisements, the conservation status and general temperament of chimpanzees is highly distorted in the eye of the public (Ross et al. 2011:1). Although the aim of habitat dioramas is not to frighten, these displays show a less anthropomorphized version of wildlife by showcasing accurately sized animals armed with sharp fangs, claws, and occasionally hunting prey. By exposing children to more realistic versions of animals, a more cautious, accurate, and respectful attitude towards wildlife can be cultivated. Likewise, this cautious respect for nature and wildlife can be nurtured within a safe space, unlike a zoo in which live animals pose a potential threat. It is worth noting that habitat dioramas are frequently guilty of departing from reality by creating scenes that neglect the less picturesque facets of nature such as death, birth, injury, and malnourishment (Morris 2015:65).

Negative Functions of Habitat Dioramas Within Contemporary Museums

Although habitat dioramas are frequently a centerpiece to museum nostalgia and education, criticism regarding the displays' overall effectiveness and upkeep in

comparison to other forms of museum displays have resulted in their dismantling and destruction (Tunnicliffe and Scheersoi 2015:138).

Keeping in mind the habitat dioramas' tendency to edit out upsetting realities such as death and sickness, these displays further slip away from accurate portrayals of reality in a number of ways. To start, habitat dioramas capitalize on the most exciting events that occur in nature such as lions attacking a zebra or a male gorilla beating his chest; these occurrences turn the dioramas into soap operaesque scenes (Reiss and Tunnicliffe 2011:447-459). Humans are mostly absent from habitat dioramas, introducing and widening the perceived separation of humans from nature (Reiss and Tunnicliffe 2011:447-459). Considering current anthropomorphic issues of environmental degradation and biodiversity loss, pristine displays of nature are a far cry from habitat realities. Unfortunately, these displays, which were originally crafted to inspire conservation and respect for nature, are now outdated representations of ecology that ultimately conflict with contemporary scientific discourse (Marandino et al. 2015:256).

Beyond inaccurate and idealistic depictions of nature, these aged displays are subject to changing social connotations and are sometimes catalysts for controversy (Livingstone 2015:195). For example, considering that the majority of habitat dioramas were created in the early and mid-twentieth century, undertones of patriarchy have gradually become more visible overtime. In a 2004 essay by Donna Haraway, casual patriarchy within habitat dioramas at the American Museum of Natural History is illuminated and discussed. Haraway (2004) posits that male animals tend to dominate the visitor's gaze and the chosen poses for the taxidermy animal, originally fashioned by a

male taxidermist, maintains a similar patriarchal vibe (Haraway 2004: 151-157). Furthermore, a visitor study performed by Phaedra Livingstone (2015) in the Akeley Hall of African Mammals at the American Museum of Natural History, supports Haraway's assertion of male-centric dioramas. In the study, Livingstone asked visitors to photograph a particular element within the diorama hall that captured their attention the most. In the study, 23 out of 30 photographs were either specifically of the male lion, juvenile male lion, or the male lion standing over the female. In this way, habitat dioramas suddenly become less accessible to half of the population when it becomes apparent that they were created by, and perhaps for males and male ideologies.

Finally, habitat dioramas take an enormous amount of time, skill, and money to create and maintain (Morris 2015:36). For instance, each diorama requires years of research and development; during the golden age of habitat dioramas, creators would travel to the physical location in order to collect specimens and take in-depth notes about the surrounding environment, a practice that is as equally time consuming as it is expensive (Reissman 2017:1). Although the practice of traveling to the physical location is no longer exercised by contemporary creators, the research and creation time required to build a habitat diorama is still immense. Research alone requires the assessment of scientific journals, videos, satellite imagery, and consultation with botanists, zoologists, and archaeologists to ensure that every miniscule detail is accurate (Reissman 2017:1). The fabrication of the actual diorama is a tedious process in which realistic, panorama backgrounds are painted, leaves are individually molded and hand-painted, and animals skins are mounted (Reissman 2017:1). For instance, the physical creation of a taxidermy

animal is equally as time consuming – between sculpting the body, grooming the fur, and setting the eyes just right, a taxidermy animal the size of a deer can take up to six months to complete (Morris 2015:36). When antiquated taxidermy animals are used in habitat dioramas, they must be conserved to repair tears and damages from light, dust, and insects, a necessary element of diorama maintenance that is often outsourced to costly conservation companies (Trophy Care International 2017). Aged taxidermy specimens often contain toxic chemicals such as arsenic, lengthening the creation or maintenance process as each specimen must be handled with extreme care (Reissman 2017:1).

Likewise, antiquated dioramas have become a work of art in their own right; these displays are a unique blend of science, art, and history, and illustrate the dying artistry of diorama development and fabrication (Hutterer 2015:30). Although in recent years habitat diorama fabrication has experienced some revival, such as the 2015 crowdfunded Hyena display at The Field Museum which raised $155,165 to create the exhibit, this is fairly uncommon (Reissman 2017:1). With this in mind, it is costly, time consuming, and perhaps even inappropriate to alter or destroy these kinds of displays as they are representative of a portion of American museum culture and heritage. Yet this difficulty (or inability) to update and alter habitat dioramas is precisely the reason why the diorama dilemma threatens to dismantle these displays.

Habitat Diorama Function and Proposed Technical Solutions

Despite the need to address this dilemma, current literature on habitat dioramas remains investigative and therefore non-conclusive; however, this area of

research has experienced a growth in interventionistic literature in recent years. Regardless, because the growing body of prominent and interventionistic studies are still in infancy, the general absence of resounding and conclusive literature that actively supports or dismisses habitat dioramas has caused museums such as the National Museum of Natural History in Washington, D.C. and the California Academy of Sciences in San Francisco to replace their dioramas with interactives and stand-alone taxidermy animals (Kutner 2015:1). Yet, the current body of literature that confronts and questions the relevance and educational benefits of habitat dioramas within museums is overwhelmingly positive.

Common trends within diorama-related literature include qualitative visitor studies that focus on the types of interactions that result from observing habitat dioramas and measuring the educational benefits of a child's engagement with this form of display. Additionally, a handful of museums, such as the Oakland Museum of California, have conducted surveys that evaluate the visitors' overall opinions of the museums' habitat dioramas. Although much of the related literature praises the learning initiatives and positive functions of the habitat diorama, few sources actively discuss detailed methods that will bring habitat dioramas up-to-date and increase the impact of their learning objectives; within these few, actively voiced articles, technological innovation is a common theme. With this in mind, because technology, specifically mobile devices, are ubiquitous among contemporary museum-goers, this literature review will explore the beneficial components of mobile technology within museums and delve into both the

observed and hypothesized benefits of AR and its relevance to improving habitat dioramas.

To start, the overarching theme observed within the body of diorama-related literature details the positive learning objectives derived from these displays. For instance, Reiss and Tunnicliffe (2011) posit that habitat dioramas are valuable tools for helping children develop an interest in biology while Scheersoi and Tunnicliffe (2009) similarly find that habitat dioramas spark interpretation and scientific inquiry in visitors of all ages. Likewise, a 2005 visitor study conducted by Dana Nietzel (2005) at the Oakland Museum of California shows that upon interacting with the diorama, parents and children engaged in dialogue based upon their observations and comparisons of the scenes on display.

In a similar vein, Doris Ash (2004:89) praises the focus on observation that dioramas promote, suggesting that observation is more likely to result in verbal exchange and inquiry than physical object manipulation would. This focus on verbal exchange and inquiry is highly beneficial to a child's development of interpretation skills and critical thinking. Finally, Jane Insley (2008) suggests that even seemingly outdated habitat dioramas are important tools in illustrating contemporary issues of biodiversity loss, habitat alteration, and climate change. Ultimately, a review of diorama-related literature appears to highlight the educational benefits of this form of display.

A second observable theme in the body of diorama-related literature expresses common visitor critiques of habitat dioramas, which ultimately highlight areas for

improvement. In particular, exit surveys and visitor interviews at the Oakland Museum of California provide more specific insight into issues that require attention.

Interviews conducted by Nietzel in 2005 are particularly telling of the ineffective qualities touted by habitat dioramas; these interviews highlighted common questions pertaining to the actual location being portrayed in the diorama and provoked curiosities relevant to the accuracy of minute details such as flora and foliage coloration (Nietzel 2005). While some of these questions could be easily answered by reading the associated diorama labels, a visitor study done by Scheersoi and Tunnicliffe (2009) suggests that visitors rarely bother to read the labels.

There are various reasons visitors might fail to read diorama labels, which include length, content that is personally uninteresting to the individual, and aesthetic appeal, leading to the likelihood of labels failure (Screven 1992:183). For instance, a 2008 study by the Garibay Group at the Oakland Museum of California suggests that diorama labels look "outdated" and are therefore unappealing to visitors (Garibay Group 2008:24).

Critiques gathered by the 2008 Garibay Group study at the Oakland Museum of California are particularly telling of common elements that tend to deter visitors from effective engagement with the habitat dioramas. The exit survey asked visitors to rate their experiences with the habitat dioramas, and, while 37 percent of respondents said they enjoyed the immersive feel of the exhibit, 11 percent likened the dioramas to "dead zoos" that were "disconcerting" (Garibay Group 2008:24). Similarly, 10 percent of visitors expressed ethical concern for how the taxidermy animals were killed or collected

(Garibay Group 2008:24). Additional visitor critiques suggested that the displays seemed "out of date," "passive," and lacked "interactivity" (Garibay Group 2008:24).

Although it is likely that the visitor critiques gathered from the Garibay Group study are applicable on a larger scale, the relatively small body of literature restricts garnishing overarching and meaningful observations in regard to the effectiveness of habitat dioramas. Ultimately, this inability to observe the success (or failure) of habitat dioramas on a more extensive scale hinders the studies inconclusive, therefore obstructing the creation and advancement of methodologies and frameworks that aim to improve the overall effectiveness of these displays. For this reason, this thesis steps away from the traditional investigative style of research so present in diorama-related literature, and takes on an interventionistic role. In short, this thesis first investigates the diorama dilemma, as is traditional, and then goes one step further by implementing a solution and studying the results.

Focusing on the "passivity" of habitat dioramas brought up in the 2008 Garibay Group study, issues of reality and authenticity are brought into play. Reiss and Tunnicliffe (2011) examine a few of these elements that could be covertly disengaging to visitors while simultaneously producing and reinforcing inaccurate portrayals of nature. For instance, while diorama development carefully considers accurate displays of animal behaviors and scenery, Reiss and Tunnicliffe (2011) suggest that selected taxidermy animal poses, such as a Silverback gorilla beating his chest, only represents a rare and infrequent behavior. Likewise, the absence of humans, anthropomorphic changes to

natural habitats, and the display of diseased or malnourished animals depicts an unrealistic and idealistic version of nature.

Considering the current literature on habitat dioramas, it seems that there is a definite struggle to reach a balance between visitor's interest, realistic displays, and the "disconcerting" elements of the dioramas. Unfortunately, a significant portion of available literature is simply investigative and fails to directly address the aforementioned imbalances. As a result, methodologies or frameworks to improve the function and appeal of habitat dioramas within museums are somewhat rare. However, museums such as The Field, the Oakland Museum of California, and the University of Milano-Bicocca Museum have produced interventional research that outlines the processes and successes of improving dated dioramas with supplemental technology; examining the various ways these museums have attempted to update their habitat dioramas is one way to bring greater insight into the discussion.

For instance, habitat dioramas at the Field Museum in Chicago, Illinois, were experiencing a decrease in visitor interest due to their lack of interactivity. To combat the outdated nature of the displays, Willard Boyd of the Field Museum added "field stations" outside dioramas comprised of computer technologies and interactives. These interactives help to address contemporary issues of biodiversity by divulging interesting facts about the animals and habitats being represented in the exhibit (Boyd 1999:213). Similarly, in the article *Using Technology to Deepen and Extend Visitors' Interactions with Dioramas* by Loveland et al. (2015) the methods and benefits of updating habitat dioramas at the Oakland Museum of California with technological interactives is discussed. The habitat

dioramas, which focus on California ecosystems, were enhanced with "audio, video, online media, and scientific visualization technologies" that give visitors an in-depth opportunity to engage with the places and people of various California ecosystems (Loveland et al. 2015:96-97). In particular, the Mt. Shasta diorama was updated with a talk from Mt. Shasta region ecologists who discusses the food web, the health of the ecosystem, and ways to improve the health of the ecosystem (Loveland et al. 2015: 96-97). Through the addition of technology, visitors to the Field and Oakland Museum can now engage with the once static displays. Thus, technology can be used to combat visitor critiques of "passivity" and lack of "interactivity."

Additionally, software development, such as the "Digital Diorama Project" described in Gambini et al. (2014), aims to capitalize on the visitor's desire for interactive technologies (Tirrell 2000:15). The Digital Diorama Project works by creating accessible, multimedia interfaces that allow participants of all ages to engage with the diorama in varying depth (Gambini et al. 2014:470). Working with the University of Milano-Bicocca in Italy, the research team digitized a number of dioramas by translating the learning objectives of the diorama into an interactive technology that can be accessed by "PCs, tablets and interactive whiteboards" (Gambini et al. 2014:471). Visitors and school groups can then explore the dioramas at various levels – portions of the exhibit can be enlarged for a closer look, and pop-up guides ask visitors to imagine the sights, scents, and sounds of the habitat (Gambini et al. 2014:473). For a more extensive level of interaction, users can discover biological and ecological components of the display by way of diagrams, videos, and images (Gambini et al. 2014:473). According to Gambini et

al., digital technologies increase the longevity and richness of learning objectives while simultaneously increasing accessibility and environmental sustainability awareness (Gambini et al. 2014:474). Ultimately, a higher level of visitor engagement, interest, and learning are the primary benefits of incorporating technology into habitat dioramas. Developments such as the Digital Diorama Project are relatively new, limiting the study of their effectiveness; however, this thesis attempts to mimic the Digital Diorama Projects' interventional style of research by not only investigating the diorama dilemma at the GRPM, but by also implementing digital aspects into the diorama and measuring its effectiveness.

The success of mobile technology as a learning tool within museums is well documented and is therefore highly valuable when considering the feasibility and effectiveness of updating habitat dioramas with AR technology. Though mobile technology has permeated our culture for several years, mobile apps for museums did not gain traction until 2009 (Economou and Meintani 2011:1). According to a 2011 survey conducted by the American Alliance of Museums (AAM), a third of all museums in the United States intended to incorporate a mobile technology platform into their institution (Rodley 2011:35). Furthermore, the AAM survey emphasized the use of smartphone apps, citing that mobile platforms will experience the fastest growth rate in coming years (Rodley 2011:35). Regardless of the slow introduction into the museum space, the question is no longer if mobile technology *should* be in museums but rather *how* it can "be used to develop a richer, deeper and more immersive visitor experience" (Tomiuc 2014:33).

An Exploration of Mobile Technology in Museums

Looking into the literature, several studies praise the capabilities of mobile technology within museums; these studies posit that mobile museum apps provide a more efficient channel of communication between the visitor and the museum, personalize the museum experience, reach a larger and more diverse population, bring multiple narratives and interpretations to a single exhibit, improve various types of visitation purposes, cater to various learning styles, advance learning in semi-informal settings, invite visitors to interact and engage with objects and ideas at a deeper level, and create memorable experiences (Raptis et al. 2005; Goodin, 2006; Kahr-Højland 2007; Katz et al. 2010; Sanchez 2010; Zimmerman 2010; Economou and Meintani 2011; Goldman 2011; Rodley 2011; Mason 2012; Rung & Laursen 2012;Tsai and Sung, 2012; Tomiuc 2014).

Economou and Meintani (2011), Rodley (2011), and Tomiuc (2014) suggest that the popularity of mobile devices allows museums to connect personally with visitors both inside and outside of the museum. For example, Tomiuc's exploration of the Stedelijk Museum in Amsterdam notes the success of an AR app that placed works of art in a local park (Tomiuc 2014:42). The "ARTours" app allows individuals to hold up their devices to marked locations in the park and view selected pieces from the Stedelijk's collection on the screen of their telephone. As a result, visitors are able to personally interact with museum collections outside of the museum on their own time and at their own pace.

In personalizing the experience, museums have the opportunity to reach new audiences, expand their geographical reach, and more specifically, appeal to younger

individuals (Kahr-Højland 2007; Sanchez 2010; Tomiuc 2014). Similarly, Rodley (2011) suggests that the more personalized experience provided by a mobile app helps to attract and retain new audiences while simultaneously affording visitors a "new way to deepen their engagement with the institution," ultimately making the museum "more immediate, accessible, and relevant" (Rodley 2011:35). Following the New Museum theory in which museums are for somebody rather than about something (Weil 2007), the use of mobile devices can be advantageous in drawing a more diverse audience, and as a result, mobile apps can cater to multiple perspectives, learning styles, and visiting styles. More specifically, the use of mobile technology affords museums the opportunity to include bilingual narratives without having to physically produce new labels; this is an extremely important component of mobile technology within museums. The 2013 study by Yalowitz et al., *Institutional and Intergenerational Experiences with Bilingual Exhibitions*, highlights how bilingual exhibits grant Spanish speakers the ability to switch between Spanish and English at leisure, allows non-bilingual Spanish speakers to take on a more active roles as an explorer or facilitator, and ensures Spanish speakers that the museum values their community.

According to Raptis et al. (2005:1), as contemporary institutions, museums "should be contextualized and personalized according to personal needs." With this in mind, mobile apps invite visitors to create their own meaning by interacting with objects through a variety of formats. In creating their own meaning, visitors can take "ownership over learning experiences," allowing for a more potent and engaging museum visit (Katz et al. 2010:348). For instance, Mason (2012:61) outlines how mobile apps can combine

elements of text, images, video, sound, interviews with experts, 3D models, and games to "support the visitor's learning process." Consequently, in allowing the visitor to take charge of the narrative and depth at which they explore the object or idea, the museum becomes a fertile space for engagement, learning, and meaning making (Tomiuc 2014:42).

Furthermore, Tsai and Sung (2012) posit that beyond personalizing the museum experience, mobile apps can be "tailored toward different visitation purposes ranging from research to leisurely weekend visits" (Tsai and Sung 2012:1). Due to the appeal and accessibility of mobile apps, studies by Goodin (2006), Kahr-Højland (2007), and Tsai and Sung (2012), suggest that the use of mobile apps both improve interactions with the exhibits and contribute to increased learning potential in semi-formal learning settings. For instance, Zimmerman (2010: 267-268) advocates that mobile technology in museums makes the informal learning experience highly personalized, and because it "occurs in short time units discontinuously across time and space, it does not require specific sequences of content, and is based on curiosity, intrinsic motivation, and . . . choice of topic." As a result, learning no longer needs to be confined to a physical space, because mobile technology can foster continual learning in a variety of locations, such as a museum (Zimmerman 2010:279). Ultimately, mobile technology assists informal learning in museums through a combination of "social interactions…and free choice [learning] opportunities" (Zimmerman 2010:268). Likewise, Rung and Laursen (2012:39) postulate that the increased interaction and learning functions as "a memory of a good and meaningful visit to the museum."

Although there are several benefits linked to the use of mobile technology within museums, there are a few shortcomings that should be mentioned. Perhaps the biggest issue raised about the use of mobile technology in museums is the fear that it will take away from the experience of the museum by distracting the visitor from interacting with the more hands-on components of the exhibit. However, Kahr-Højland (2007), Rodley (2010) and Norman (1989:195) propose that mobile devices are so ubiquitous within our culture that they turn into a "transparent medium" that is unlikely to distract from the excitement of the exhibit. *In Looking Around vs. Looking Down: Incorporating Mobility into your Experience Design,* Rodley (2011:35) bolsters this claim by suggesting that interactions between users of mobile apps at museums are more likely to have "profound learning impacts than hours of silent, solitary looking."

In a similar vein, Tomiuc's (2014) exploration of mobile technologies within museums suggests that due to the cost of creating software for a museum exhibit, smaller museums are less likely to be able to afford the creation of a mobile app (Tomiuc 2014:37). Likewise, Goldman (2011:64-65) suggests that beyond fiscal restraints, smaller institutions lack visitor demand to create mobile platforms. These implications by Tomiuc (2014) and Goldman (2011), are further supported by a 2012 Fusion Research and Analytics survey for the American Alliance of Museums. The survey, titled *Mobile in Museums Study: A Survey of American Alliance Museums (US) and Museums Association (UK) Members*, collected information from 740 institutions and explored the use of mobile technology within museums (Fusion Research and Analytics 2012). Among the institutions that claimed they did not employ mobile technology platforms

within their museums, 55 percent listed budgetary constraints as a major reason, while 33 percent listed lack of visitor demand as a primary factor (Fusion Research and Analytics 2012:42). However, as technology becomes more efficient, the cost associated with app development is likely to decrease overtime, making mobile apps more feasible for smaller, resource-strapped museums.

With the potency of mobile technology expressed in the literature, a more specific look can be taken at AR apps within museums. A review of literature on AR technology within museums highlights successful case studies while outlining a wealth of potential uses for the technology as it continues to evolve and improve.

An Exploration of Augmented Reality Technology in Museums

To start, AR is defined by Azuma (1997:43) as "a medium combining the real and virtual, interactive in real time, [and] registered in 3D." Unlike virtual reality in which the user is completely immersed in a computer-generated environment, AR is supplemental to reality and "allows the user to see the real world, with virtual objects superimposed upon or composited with the real world" (Tomiuc 2014:43). Additionally, Tomiuc (2014:44) suggests that AR in museums is practical because it "allows invisible content suited to different users to be embedded in galleries and accessed by users on demand," a feat that would otherwise not be possible due to label and space limitations. In *Is Augmented Reality the Ultimate Museum App? Some Strategic Consideration*, Schavemaker (2011:52) continues Tomiuc's line of thought by suggesting that the

layered capabilities of AR allows for an endless amount of information and communication to take place in a single exhibition space.

Additional benefits of AR use within museums as outlined by Schavemaker (2011:54) includes the generation of increased interpretation and contextualization, the creation of a new platform for artistic expression, and the establishment of a space for innovation and collaboration in both virtual and analog spaces. Likewise, there are several studies that highlight the successful use of AR apps within museums such as the Exploratorium in San Francisco, the British Museum, the Tate Modern in England, the Stedelijk Museum in Amsterdam, and the National Museum of Natural History in Washington, D.C. (Tsai and Sung 2012; Tomiuc 2014; Marques and Costello 2015).

Tsai and Sung (2012), Tomiuc (2014), and Marques and Costello (2015) posit that AR apps such as "Get Surreal" at the Exploratorium, "ARTours" with the Stedelijk, and "Skin and Bones" at the National Museum of Natural History attract a large number of visitors and allows them to seek out personal points of interest and learn through numerous mediums, at varying depth. Art-based apps such as, "Get Surreal" and "ARTours," facilitate the interpretation of art and sculpture, while "Skin and Bones," a science-based app, "enables deeper thinking about the anatomical principles" of the skeletons on display in the Hall of Bones exhibit (Marques and Costello 2015:11). The capability of these AR apps to offer visitors a personal, immersive, and memorable experience supports the contemporary museum's responsibility to build interpretative and meaningful exhibits that serve individuals from diverse backgrounds (Kahr-Højland 2007:14).

Taking a closer look at Marques and Costello (2015), the usefulness of AR technology within museums is exemplified. The "Skin and Bones" app works by permitting the visitor to hold their device up to a selected skeleton and view the animal as though it were still alive. Additionally, the app gives users access to high quality video, animation, quizzes, and games that provide additional information about the specimens' life and habitat (National Museum of Natural History 2015). With this app, users can observe the skeleton of a swordfish acquire its scales or watch a vampire bat skeleton take flight (Marques and Costello, 2015). In *Skin and Bones: An Artistic Repair of a Science Exhibition by a Mobile App*, Marques and Costello (2015:5) document the repair of the outdated and densely technical exhibit into a more "artistic, accessible, and engaging exhibit without physically altering the original display.

The original display, which was virtually unchanged since its installation in the 1960s, was riddled with lengthy and heavily technical language, void of photos, and overall lacking in any "narrative, visual interest . . . and interaction" (Marques and Costello 2015:4). As a result, visitors passively walked through the exhibit. By capitalizing on the ubiquity of mobile devices, the "Skin and Bones" app communicates updated science and stimulates curiosity in both children and adults alike (Marques and Costello 2015:11).

In its current state of implementation in 2017, AR technology offers visitors personalized experiences that "enhance the level of interpretation, provide interaction with objects that otherwise would not be possible, and transform the visitor's experience both inside and outside the museum" (Tsai and Sung 2012:1); however this is not the full

extent of the technology's capabilities. In *Augmented Reality: Beyond the Hype*, Mannion (2014) explores the potential uses for AR technology inside (and outside) museums. Mannion (2014:1) breaks the technology down into four categories of use: "outdoor guides and explorers," "interpretive mediation," "new media art and sculpture," and "virtual exhibitions"; for each category, an example of current or potential usage is explored.

An example can be seen in "outdoor guides and explorers," which direct users to points of interest around a city and then juxtaposes archival photos next to landmarks or buildings. In "interpretive mediation," costumes and masks from the museum collection can be superimposed onto individuals as they view their reflection in a mirror through their phone screen. "New media and sculpture" can allow artists to insert their own artwork into otherwise exclusive museum galleries and challenge curatorial hegemony while "virtual exhibitions" allows student-made, interpretive videos, slideshows, or images to appear when mobile devices are pointed at certain objects (Mannion 2014:1).

Additionally, because AR technology uses all of the functions that are available on a mobile device, interactive potentials are highly varied (Mannion 2014:1). Though AR is still a growing technology, it has the potential to show large objects to scale, such as ships or buildings, bring skeletons or taxidermy animals back to life, or offer multiple, virtual narratives within a single exhibit. Though many applications are in a "proof-of-concept" stage, Mannion (2014:1) asserts that the incredible and budding capabilities of AR technology are not diminished.

Overall, the current literature on the effectiveness of habitat dioramas within contemporary museums illustrates a gradual shift away from this form of display. While multiple studies suggest that habitat dioramas actively engage visitors of all ages by inspiring scientific inquiry, dialogue, and an interest in biology and the natural world, this form of display continues to decline within museums. Although there are multiple reasons for the general retraction from the use of habitat dioramas, such as burdensome financial obligations, outdatedness, and lack of interactive technologies, the literature indicates a predominantly positive data set that is supported by qualitative visitor studies and evaluations. However, the relatively small body of literature on this topic does not provide a means for the assessment of both positive and negative aspects of habitat dioramas as a whole. Additionally, there is an absence of suggested methodologies and frameworks that aim to further improve these displays.

Taking into consideration the recent push in museums to provide visitors with interactive installations, the diorama dilemma would benefit from further exploration into the topic, as well as the incorporation of AR into these types of exhibitions. Fortunately, literature on the use of mobile technology within museums is widely documented and is overwhelmingly positive. Likewise, literature on the use of AR technology within museums expresses a similarly positive trend. Because literature discussing the diorama dilemma with AR as a solution is, for the most part, absent, additional, investigative and interventional studies are needed to determine the potential benefits of incorporating this form of technology into habitat dioramas. This thesis attempts to address this gap in the

literature, contributing to the growing discussion of AR within museums, and its role in redefining the habitat diorama.

CHAPTER III

METHODOLOGY

Design of the Investigation

Methodology for this thesis employs a number of approaches in order to engage the three key questions outlined in Chapter I, which address whether habitat dioramas should be kept for nostalgic purposes or replaced by more up-to-date exhibits, if AR is capable of preserving and updating these displays in order to meet the desires of contemporary museum goers, and if AR is a realistic and feasible option for museums of varying size and financial capabilities.

To effectively address the research questions posed in this study, the timeline for this thesis was broken down into three phases, as shown in Table 1. The first phase

Table 1. Thesis timeline.

Phases and Dates	Location and Actions
Phase I: February, 2017	Grand Rapids, MI: A two day visitor study at the GRPM.
Phase II: March and June, 2017	Grand Rapids, MI: Marsh diorama research, augmentation, implementation, and visitor studies at the GRPM.
Phase III: June, 2017	Chico, CA: AR platform research and product comparison.

occurred during February of 2017, and involved the creation of a quantitative/qualitative data set through direct visitor observations in the GRPM's diorama hall. During the second phase of research, which took place during March and June of 2017, the marsh

diorama augmentation was created and a visitor study was conducted at the GRPM, post-augmentation. The final phase of research was completed in Chico, California in June of 2017, and involved researching and comparing AR software to test for their feasibility of use within museums of varying sizes.

Considering the first phase of this project and the methodology associated with the first question, which poses whether habitat dioramas should be kept for nostalgic purposes or replaced, I utilized direct observation at the GRPM. By Bernard's (1988) *Research Methods in Anthropology* as a guide for my research, I applied a mix of unobtrusive, continuous monitoring, and spot sampling that I conducted in the diorama hall of the GRPM during high volume hours, which typically occur in the early afternoons on weekends. Following completion of the Human Subjects in Research application and approval from the GRPM, two separate afternoons in February, 2017, were spent observing visitor's behavior and interactions with the habitat dioramas, specifically a display depicting a Michigan marsh. During these observation periods, I recorded coded data pertaining to visitor behavioral patterns with the ultimate goal of creating an ethogram. The ethogram, which took the form of a table, helped to quantify the otherwise qualitative data set. The ethogram is strongly linked to anthropological methodology as it aids in the categorization and interpretation of human behaviors that occurred within the museum. Ultimately, the ethogram is the first step in parsing out meaningful behavioral patterns from the data set.

More specifically, my observations of visitor's level of engagement with the Michigan Marsh display provided the opportunity to observe visitor reactions,

conversation, and approximated length of time spent engaging with the diorama first-hand. Due to the unobtrusive nature of direct observation, the actions of visitors are assumed to be free of performance. In observing reactions and creating an ethogram of commonly occurring behaviors, I was able to pinpoint elements that do and do not work within the Michigan marsh diorama. The data I collected from the observations were then applied two-fold within the study. First, data was used to further support the body of literature that suggests habitat dioramas have positive effects on visitor experiences. Second, the data was used to complete the second phase of research: augmenting the marsh diorama to test the effectiveness of AR in updating habitat dioramas and catering to a more diverse audience.

At the core of the second phase of the project, which focused on the second research question of whether AR can preserve and update outdated habitat dioramas in contemporary museums, I used Zappar software to develop and design an augmented experience to be integrated into the marsh diorama. The augmentation process included picking an AR program, extensively researching the habitat, plant, and animal species comprising the Michigan marsh display, and writing a storyline for the diorama that considered multiple interpretations. Furthermore, I employed several mediums to support an array of learning styles, and selected and developed the audio, visual, and written components to tell the story of the diorama. Guided by Marques and Costello's (2015) outlined augmentation process in *Skin and Bones: An Artistic Repair of a Science Exhibition by a Mobile App*, the augmented storyline I developed aims to discuss the environment on display by using multiple viewpoints and to focus on the ways in which

the scenes in the display, though seemingly simple, are highly complex and interconnected. By focusing on the dissonance between the display and reality, the intersection of negative human-environment relations is highlighted using video, audio, photographs, and game content. Each step of the augmentation process was recorded and reflected upon in order to assess if AR is an effective solution for updating outdated displays and making them more compliant with the needs of contemporary museum visitors. Following the completion of the augmented diorama in March, visitors were asked to interact with the display in March, and then again in June. I concluded the study by measuring the effectiveness of the finished augmented diorama.

The third and final phase of the project centered on the third research question, which asks whether AR technology is an option for museums of varying size and financial capabilities. Currently, because of its relative infancy, AR technology is heralded as being a technological luxury only accessible to large museums (Tomiuc 2014:37). Yet, due to the speed of technological innovation, AR is becoming increasingly common and affordable. Presently, there is a range of AR software that vary in both price and capabilities, and as such, the technology should be diverse enough to serve small, understaffed museums with tight budgets as well as well-funded, and heavily staffed large museums. However, the question remains: is the time spent developing augmented exhibits reasonable for understaffed, smaller museums or will this technology continue to remain a realistic option only for larger institutions?

To assess the feasibility of AR technology in museums of all sizes, I conducted a comprehensive inventory of three AR software products currently available

on the market. In this research, I compared points of price, capability, and ease of use. The three AR platforms chosen were Aurasma, Zappar, and Layar, as they had the most competitive prices, best technological capabilities, and user-friendly interfaces. The findings from the AR product survey was compared against the augmentation process from phase two, taking into account triumphs, tribulations, and the amount of time needed to augment a single diorama. While each program offers users the ability to build augmented experiences, Zappar was selected for use in this thesis due to its user-friendly interface, performance in low lighting conditions, and ingestion system which supports several file formats. An in depth description of each AR software along with their advantages and disadvantages will be described in the latter sections of this chapter.

Research Location and Sample Population

On the edge of the Grand River in Grand Rapids, Michigan, an attractive expanse of a curved building is in striking contrast to the glass-paneled skyscrapers that inhabit the rocky river bank. Through tall gallery windows, the skeleton of a whale can be seen hanging from the ceiling; it greets visitors as they enter and as a result, this massive suspended specimen has become a kind of mascot for the museum over the years, much like the whale at the Museum of Natural History in New York. Though perhaps one of the most grandiose artifacts in the museum's possession, the Grand Rapids Public Museum, shown in Figure 1, boasts a collection of over 250,000 items, making it an important research and education facility within the region. However, the museum has not always been so significant to west Michigan, and in fact, comes from small beginnings, much the like the city of Grand Rapids itself.

Figure 1. The Grand Rapids Public Museum (GRPM). Image courtesy of John Eisenschenk, 2012.

Founded in 1854, the Grand Rapids Lyceum of Natural History, as it was originally called, was a modest museum, comprised of the standard "cabinets of curiosity" of prominent local collectors for the time period. After merging with the Grand Rapids Scientific Club in 1868, its collection expanded and was relocated to Central High School, effectively moving the collection from private parlors into the public sphere (Grand Rapids Public Museum 2017).

The growth of the collection continued, and by 1903, the museum moved into a Victorian mansion near the city center. The museum remained at this location until 1940, when a new building was built using Works Progress Administration funds. The building, which remains in the museum's possession to this day, was described by Museum Director Frank DuMond as being as "accessible as a dime store and friendly as

your next door neighbor," making it a "radical departure from most contemporary museums" (Grand Rapids Public Museum 2017). Although the museum eventually moved into its current location on the banks of the Grand River in 1994, the former museum building became a storage and research facility, and was briefly reopened to the public in 2012 when artist Alois Kronschlaeger transformed 27 of the abandoned habitat dioramas into works of experimental art.

At present, the museum collection is showcased on three floors of exhibit space and is complete with a planetarium, carousel pavilion that houses a restored 1928 Spillman carousel, theater, cafe, and museum store. Several permanent exhibits are housed in the building and cover topics such as Grand Rapids history, west Michigan habitats, the museum's expansive collection, immigration to west Michigan, the Anishinabek of the Midwest, and the Grand River. The museum also hosts temporary and traveling exhibits, and has displayed blockbusters such as *The Discovery of King Tut*, *Dinosaurs Unearthed*, and *Titanic: The Artifact Exhibition*.

Additionally, the museum maintains jurisdiction over six sites in and around Grand Rapids. These sites include the Community Archives and Research Center, the former 1940s museum building, an 1836 Greek revival building known as the Calkins Law Office, the James C. Veen Observatory, an 1895 carriage house known as the Voigt House, and the Norton Hopewellian Burial Mounds, a national historical landmark comprised of 17 mounds just outside Grand Rapids.

As the state's oldest and second largest museum, the Grand Rapids Public Museum is an iconic institution throughout Western Michigan that aims to "inspire

passionate curiosity and a deeper understanding of the world around us" (Grand Rapids Public Museum 2017). This vision is achieved through acting as a "living monument of artifacts, ideas and stories told through exhibitions, events, and educational programming designed to inspire, motivate and celebrate our human bond" (Grand Rapids Public Museum 2017). This mission makes the museum intimately connected to its community as these offered experiences are presented within a "uniquely Grand Rapids context" (Grand Rapids Public Museum 2017).

A prime example of this claimed relevancy to the community is exhibited on the third floor of the museum in the form of sprawling habitat dioramas featuring environments and animals native to west Michigan. The life-like displays offer visitors a chance to view aquatic specimens found in the Grand River and Lake Michigan, the animals and plants that inhabit the fragile dune ecosystems of the Lake Michigan shoreline, the migratory birds that frequent inland marshes, fringe species that dwell in the land between forest and farmland, and the boreal snowscapes of northern Michigan which have, in the past, harbored packs of grey wolves. Flap panels and push buttons are sprinkled throughout the dioramas, allowing visitors to feel and hear the plants and animals they encounter, but beyond these elements, interactives, particularly those with a technological thrust, are scarce. It is the relative absence of technological interactives within the diorama hall that make it particularly applicable to this thesis.

The GRPM Diorama Hall

Located on the third floor of the Grand Rapids Public Museum, a collection of habitat dioramas and taxidermy animal displays entertain a large volume of visitors each

year. The dioramas on display depict the plants, animals, and environments of west Michigan; though the displays come from a variety of eras, a theme of conservation and education is evident throughout the hall, which ultimately weaves the diorama hall into a single cohesive unit. Upon entering the far wing of the third floor, visitors are first greeted by a series of stand-alone taxidermy animals mounted in grandiose glass cases that reach to the ceiling. A case featuring baby animals invites visitors to push buttons and hear the calls of the various young displayed in the case, while further down, an expansive case contains over 200 taxidermy birds ranging from tiny hummingbirds to plump geese.

Entering into the diorama hall, the first room is a jam-packed cluster of oddities stored in fine wood cabinets; it is a self-reflexive display that transports the visitor back to the GRPM as it was in 1910. The cabinet-of-curiosity style room is filled with sparkling gems, rough corals, a variety of taxidermy birds arranged by color, animal skulls, and a full mastodon skeleton, making the room both charming and chaotic all at once. Exiting the buzzing room, the next room is decidedly calmer, featuring low blue lighting and four medium dioramas depicting an opossum carrying her babies on her back, grey wolves stalking prey on a winter night, two adult moose with a calf snuggled up to its mother, and a red fox bringing a rabbit to her pups. The dioramas are original pieces from the old GRPM and were created in the 1940s. Much like the first room of curiosities, this second room is meant to show the evolution of the museum and the ways in which the displays have changed over time to meet the desires of visitors. Labels are

lengthy and positioned above the dioramas, and as a result, visitors seem likely to pass through without reading any text or noticing the labels at all.

The next room gives visitors a break from the dioramas and features an updated and hands-on room dedicated to the fur trade. Moving from the fur trade exhibit, a narrow and winding path takes visitors through a double-sided, underwater diorama featuring a variety of aquatic life found in the Great Lakes. Low blue moving lights and sounds of crashing waves create the illusion of being underwater, making it the most immersive display in the hall. Looking closely into the glass cases, invasive species such as zebra mussels can be spotted, affording the museum the perfect opportunity to discuss the impacts humans have on the beloved lakes that surround the majority of the mitten-shaped state. Created in the 1990s, this diorama, along with the rest in the main diorama hall, feature lengthy labels, faded and discolored photographs, and minimal interactives. Regardless, the diorama hall remains a popular space that is almost always bustling with adults and children alike.

Leaving the aquatic diorama and entering into the main hall, the space is shrouded in low blue lighting and the number of displays is at first not apparent. The hall is spacious and curved, adorned with comfortable seating along the wall, and a variety of large and small displays; it frequently serves as a space for parents to sit and relax while their children explore. A half moose sticks out of the wall near the entrance of the main hall and often prompts a quick photo opportunity before visitors approach a large diorama featuring the sand dunes that line the shores of Lake Michigan. A precisely painted background gives the illusion of standing on the top of a dune looking down onto

the lake below. In the foreground, the diorama is packed with trees, plants, birds, small mammals, and reptiles. The intricacies of the display present visitors with the opportunity to hunt for the taxidermy animals that appear to be hidden within their environment at first, but slowly become more evident after a moment or two of focused searching. Panels line the front of the display featuring labels, a magnified replica of sand grains, a sand drift interactive, a tree ring counting activity, and a push-button board featuring the songs of several birds found in the display.

Opposite of the dune diorama, three cases built into the wall feature a variety of stand-alone taxidermy animals that are organized according to three themes: "Layered Life," "Invasion of the Aliens," and "Adapted to Where They Live." Labels associated with these commonly found Michigan creatures are small and seem to be generally ignored by visitors. Likewise, a slim glass case discussing the life histories of Michigan birds and reptiles seems to garner the same amount of fleeting attention. Time paid to these displayed is often usurped by the displays in the center of the hall – a glowing orb featuring the magnified life found in a drop of marsh water, a large marsh diorama, and a children's play area featuring a tree house and puppet theatre.

Due to the flashy nature of the glowing orb, visitors often move directly to the display, circling it with a mixture of amazement and repulsion as they examine the alien-like microbes found in marsh water. Departing from the orb, the next visitor stop is the marsh diorama, the second largest diorama in the hall. In general, the display has similar label panels and interactives as the dunes display and will be discussed at length in the following section. Moving past the marsh diorama, the treehouse and puppet theatre are

the main appeal to children, making it the focal point of the diorama hall. After prying the younger visitors away from the play area, visitors come upon the last two dioramas in the hall – a small display featuring a magnified look at the insects that creep along the forest floor, and the largest display in the hall, an expansive Michigan woodlands diorama.

The woodlands display is very attractive to visitors with its glowing gold lighting that gives the appearance of a sunset, an abundance of familiar animals, and a concentration of interactives such as flip panels and push buttons. Moving along the edge of the display, visitors can touch tree bark, spy familiar animals such as white tailed deer, examine soil layers, and push sound buttons to hear the calls of the various animals featured in the display. As visitors near the end of the diorama hall, they come upon a tent to sit in, a small glass case featuring taxidermy Michigan birds perched in brush (reminiscent of the original style of habitat dioramas), and a series of drawers featuring preserved specimens such as butterflies and caterpillars. Exiting the hall, the bright overhead lights of the museum pull the visitor out of the nature-infused calm of the diorama hall and into the bustling and echoic third floor that overlooks the Grand River and main gallery below.

As a former gallery guard at the GRPM who spent (perhaps) an unbalanced amount of her shift in the diorama hall, it is not inaccurate to say that, beyond the traveling exhibits, the diorama hall is one of the most attractive exhibits in the museum. Even on slow days, the exhibit is slow to empty at closing time. Used as a place to both explore and relax, the hall provides visitors with a wealth of scientific information, opportunity to explore, and the chance to spark conversation and curiosity. While these

activities certainly occur within the hall, it is apparent that the learning objectives presented by the displays are frequently commandeered by the appeal of abundant seating, relaxing lighting, and children's play area. This is, of course, not an issue restricted to the GRPM; in spite of the draw of charismatic and familiar animals, visitor engagement remains low in habitat dioramas across the country (Knutson et al. 2016:340).

Michigan Marsh Baseline Condition

Revisiting the Michigan marsh display briefly mentioned in the section above and shown in Figure 2, this diorama acts as a model representation of the diorama

Figure 2. GRPM Michigan diorama. Image by the author, 2017.

dilemma, making it an ideal display to test out the AR solution proposed by this thesis. The display itself is a welcoming scene placed at the center of the diorama hall; well-lit and large, the environment portrayed is that of a marshland rife with life. Similar to the

dunes and woodland dioramas, taxidermy animals are abundant in the display, and one only needs to focus on the exhibit briefly before the seemingly hidden specimens to start to appear. Leading up to the display, footprints cast into cement of birds and beavers lead the visitor to the edge of a marsh on a clear summer's day. A bright blue sky with puffy white clouds serves as the backdrop, and in the foreground tall grasses, reeds, and cattails house dragonflies, sparrows, timid frogs, and a reclusive muskrat hiding in a den. A recording of a marsh plays on a constant loop, featuring the clicks and chirps of the inhabitants while a ceiling fan provides a soft wind that subtly rustles the tall grasses.

To the left of the display, a small wooden house is inhabited by wood ducks, and a Banded Kingfisher swoops into the tall grasses. To the right, Great Blue Herons preen on the muddy shores, a Red-Winged Blackbird perches on a cattail, and visitors get a look into the solitary corridors of the stick-and-mud muskrat den. In the center of the marsh, an osprey perches upon an old wooden rowboat surrounded by lily pads, and front and center, a looking glass is positioned at the bottom of the display, allowing visitors to examine the life under the marsh waters, as shown in Figure 3. This window into the murky water acts as the main draw to the exhibit, enticing adults and children alike to drop down and point out the snapping turtle, crayfish, fish, and the head of a duck dabbling underwater for a meal.

Lining the edge of the display, labels introduce the water purifying functions of the marsh, provide basic identification labels for the fifty plus fish, birds, reptiles, mammals, insects, and plants featured in the diorama, as shown in Figure 4, and explain the water cycle.

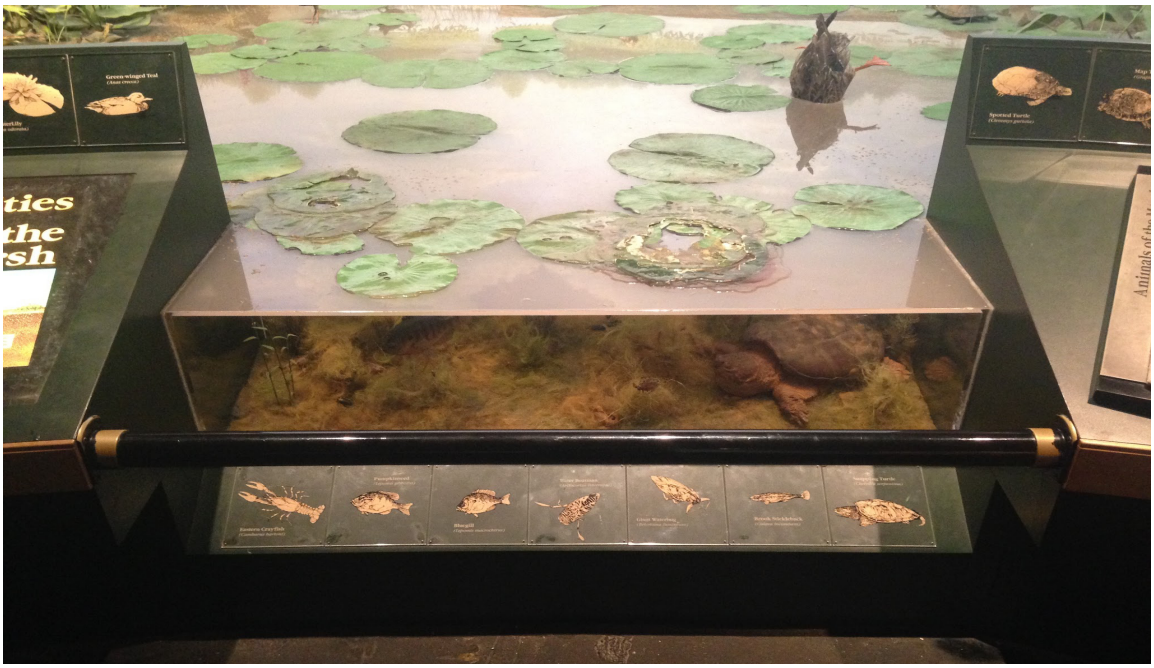

Figure 3. GRPM marsh diorama plexiglas interactive. Image by the author, 2017.

Figure 4. GRPM species identification labels. Image by the author, 2017.

Two flip books provide detailed information about select plants and animals, as shown in Figure 5, a push button interactive plays the songs of frogs and birds, shown in Figure 6, and a panel dedicated to the differences between muskrats and beavers gives visitors the chance to touch the animals' skulls and feel a beavers' pelt as shown in Figure 7. The display is busy with information, yet visitor interaction is kept to a minimum, often manifesting into little more than a slow walk by and a peek into the underwater viewing panel; it is for this reason that this display, with its potential, was chosen to augment.

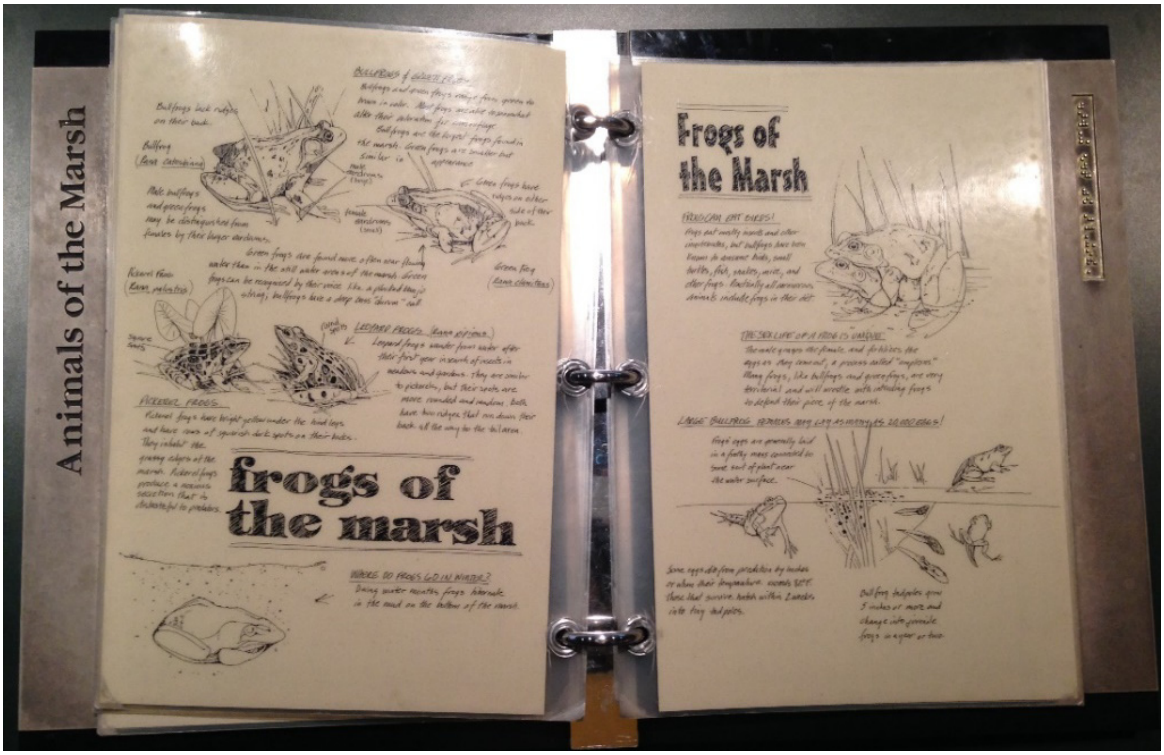

Figure 5. "Animals of the Marsh" flip book. Image by the author, 2017.

Beyond the central location of the diorama within the hall that thusly draws a large number of visitors, plant and animal species presented offer an opportunity to blend

Figure 6. Marsh sounds push button interactive. Image by Lauren Allen, 2017.

Figure 7. Beavers and muskrats interactive. Image by the author, 2017.

conservation narratives into the display, a component that is somewhat absent within the displays' labels. Furthermore, this display is ideal because of its inclusion of human life. Though overlooked, the wooden rowboat at the center of the display provides the opportunity to tie elements of human-environment interactions into the augmented narrative. However, before the augmentation process, visitor studies needed to be performed in order to identify which elements of the display where most attractive to visitors, and which elements needed improvement.

Research Sample

Participants chosen for this study were selected as a convenience sample, which tended to hinge on visitor attraction to the marsh diorama. For instance, during the February, March, and June visits to the GRPM, adults and adults accompanied by children who approached the marsh diorama were either observed or asked to partake in the study. While visitor volumes varied depending on the day or time, the flow was typically calm enough to record and/or interact with the majority of individuals who approached the display. Through analysis of the sample population, two "types" of participants dominate the research sample.

The first type is the parent or adult chaperone, who was visiting the museum as an enabler. In general, this visitor had approached the marsh diorama because their children were interested in the display. This type of participant primarily took a passive role in the study both pre- and post-augmentation, often standing back and observing the children rather than interacting with the display. The second type of participant in the sample were children aged three to twelve. These individuals make up the majority of the

participants and were visiting the museum either with parents or as part of a school field trip. This type of participant was continuously very active both pre-and post-augmentation, and for this reason, observations made during the February, March, and June visits are centered on the actions of these individuals. In general, the main difference between these two sample types, other than age, are the roles they took in the study. The parents and adult chaperones make up a small majority of interactive observations as well as recorded remarks, whereas the children, though they were not personally engaged by the researcher, make up the majority of recorded observations and comments.

Treatment of Study

As previously described throughout the thesis, three key questions were identified that summarize the diorama dilemma, suggest an AR solution, and guide the progression of research. Likewise, each of the three questions was assigned a phase of research that attempted to answer the research questions. The following section details the chronological order in which data was collected during phases one and two and three; starting with the February visitor observations at the GRPM, progressing to the augmentation process and post-augmentation visitor studies in March and June, and ending with the AR software comparison, this section describes the data collection process in detail and offers insight into data interpretation and analysis.

Phase I: Visitor Observations

On the weekend of February 10, I arrived in Grand Rapids, Michigan, to perform a visitor study on the marsh display. Spread over the course of two days, I

unobtrusively observed over 200 visitors interact with the display with the ultimate goal of creating an ethogram that helped to decipher the strengths and weaknesses of the diorama. This observation period admittedly only examines a fraction of the interactions that take place on an annual basis, however, I feel several general conclusions can be made from this brief visitor study. Within this section, these observations are detailed, categorized, and later used to guide the creation of a narrative-driven AR experience.

Observations from February 10, 2017

It was a semi-slow day at the GRPM, a museum that averages nearly 300,000 visitors annually, when I started my visitor observation around 1:00pm (Grand Rapids Public Museum 2015:3). The diorama hall was largely empty with only a few families and couples meandering through. I sat in a chair opposite of the marsh diorama, giving myself a full view of the display and waiting with a pen and paper. Though calm at first, the hall eventually started to bustle with activity as a group of elementary school children came through on a class trip. The children seemed well prepared for their trip, running up to the marsh diorama and immediately pointing out the *amphibians*, a term that was clearly new to them; I heard the term used frequently, accurately by some children and inaccurately by others. The children stayed in groups of three or four with a parent chaperone who asked the children to point out reptiles within the display.

One element of the display that was particularly fascinating to the children was the underwater viewing window featuring the snapping turtle. Children excitedly pointed and called to their friends to come and see the "turtle," and on occasion, some children corrected their peers by informing them that it was, in fact, a "snapping turtle."

This type of species identification continued throughout the children's interaction with the display – the osprey was pointed to several times, and on one occasion, two children agreed that it was a "hawk," similar to ones they had seen before. Likewise, the children were quick to accurately identify the bullfrogs and seemed to be most interested in the push buttons featuring the croaks of various frog species.

The labels and flip books rarely captured the school children's attention while the sound buttons were frequently pushed and the beaver pelt was commonly touched. This theme continued after the school children left, with adults and children rarely engaging with the labels and flip books, but taking an interest in the underwater viewing window, push buttons, and beaver pelt. Visitors seemed happy to point out animals they recognized, such as the snapping turtle, but largely showed little interest in the various other species featured in the display, particularly the birds and plants. By the end of the first day of visitor studies, I observed roughly 50 individuals interact with the marsh display, most of them being children.

Observations from February 11, 2017

Observations from the second day of visitor studies started out on a much busier note; when I arrived at 1:00pm, the diorama hall was already full of families, couples, and individuals. Right away, similar trends from the previous day started to emerge – children and adults were most interested in the underwater viewing panel with the snapping turtle, the frog species sound buttons, and pointing out animals which were familiar. Children called for their friends to come and see the "turtle" and parents asked their children to point to frogs in the display. On average, most interactions didn't last

much longer than a minute, with visitors peering in the underwater viewing panels, remarking about the snapping turtle, pushing a sound button, and moving to either the glowing orb featuring magnified marsh life or the enticing treehouse and puppet theatre.

However, unlike Friday, there were more couples and single visitors interacting with the display, ultimately providing the study with more variation. Single adults seemed more likely to stop and read labels while couples frequently paused to discuss an animal that was familiar to them. Visitors photographed elements of the display such as the snapping turtle and the osprey on the boat, whereas others reflected on and shared previous experiences they'd had with animals in the display. Unsurprisingly, the glowing orb and children's play area located close by usurped much of the display's attention, yet in spite of its location to these attractive elements, the display still provoked excitement, conversation, and curiosity; at one point, a mother finally gave in to the wishes of her toddler who, for the third time, left the play area to stand in front of the marsh display. By the end of the day, I had observed roughly 150 visitors, leaving me with a sufficient amount of data to aid in the augmentation process.

Phase II: The Diorama Augmentation Process

The augmentation process followed the completion of the visitor study performed at the GRPM and the corresponding data analysis. Originally, the marsh diorama was to be augmented using an AR platform called Aurasma, however after trial runs it was determined that Aurasma would perform poorly in the low-lighting conditions present in the diorama hall and was replaced by the AR platform Zapper, a software with similar capabilities and low price, but with superior low-lighting performance.

Considering the data analysis, key points of visitor interest and disinterest were identified. Elements of interest included the underwater viewing panel, water-cycle label, and the amphibians and reptiles in the display. I feel these elements were valued by visitors because of the familiarity of the species, the excitement of discovering the underwater panel, and the appearance of motion on the water-cycle label. The elements of disinterest included the plants, birds, insects, and label about the marsh. Considering the level of disinterest visitors expressed for these elements, I believe it was caused by a combination of unfamiliarity with the species, a lack of motivation to stop and look for the camouflaged species, and the small and lengthy nature of the non-interpretive marsh label.

A mix of plant, animal, and informative labels that were both of interest and disinterest were then chosen for augmentation to attempt to draw on visitor interests and increase attention to commonly overlooked elements within the display. The following elements were chosen for augmentation: purple loosestrife, wood duck, snapping turtle, western painted turtle, bullfrog, northern water snake, great blue heron, osprey, mallard duck, watermilfoil, water cycle label, and marsh functions label. Table 2 details which elements were of interest/disinterest to visitors.

Following the selection of the 12 diorama elements, extensive research was carried out on each component, and expressive media was chosen to create a compelling augmented narrative. Chosen media was acquired through public domain resources such as Creative Commons and Wikimedia to ensure proper copyright usage. The narrative was then arranged into a storyline and presented to education and exhibit staff at the

Table 2. Marsh diorama elements of interest and disinterest.

Elements of Visitor Interest	Elements of Visitor Disinterest
Snapping Turtle	Purple Loosestrife
Western Painted Turtle	Wood Duck
Bullfrog	Great Blue Heron
Northern Water Snake	Mallard Duck
Osprey	Watermilfoil
Water Cycle label	Match Function label

GRPM for approval. The full storyline can be located in the appendices of this thesis, but a brief overview of the content will be described below.

Narrative 1: Purple Loosestrife

Due to visitor's lack of interest in plant species, purple loosestrife was chosen for its attractive colors and interesting narrative concerning local indigenous communities. The purple loosestrife, as shown in Figure 8, is displayed in full bloom and is thus a vibrant purple flower that stands out among the brown and beige foliage in the marsh display. Following extensive research, four brief labels were written about purple loosestrife detailing its introduction to the United States and its impact on local plant species. The first label identifies the plant by its vibrant purple color and invites visitors to find it within the display. The label then discusses how purple loosestrife was introduced to the United States from Europe as a medicinal and decorative plant before it spread and became an invasive species.

The second label introduces the concept of an invasive species and explains how purple loosestrife has destroyed Manoomin crop, a type of wild rice that is sacred to local Anishinaabe tribes. The connection to local Anishinaabe tribes is valuable in that it

Figure 8. Purple loosestrife and great blue heron diorama elements. Image by the author, 2017.

provides a contemporary example of humans interacting with a marsh ecosystem and similarly draws attention to the Anishinaabe exhibit that is located next to the diorama hall on the third floor of the museum. The Manoomin label explains how the crop is used in healing and cultural ceremonies and leads into the third label, a folktale describing how Manoomin was gifted to the Anishinaabe peoples by the creator. The final label discusses how Manoomin has been protected from invasive plant species and is still harvested by Anishinaabe communities today.

The purple loosestrife storyline was then supplemented by a variety of media including audio, video, and images. The backbone of the purple loosestrife narrative are

the four written labels that have been read out loud and recorded so that visitors do not have to read text. This was done for two reasons. First, Zappar does not support text well, and second, the audio allows visitors to look around the display as they listen to the audio. Additionally, the four labels were translated and recorded in Spanish to engage a larger audience. A 2016 demographic report of Grand Rapids estimated that Hispanic or Latino populations accounted for 15 percent of the city's residents, making them the third largest ethnic group (Suburban Stats, 2016); thus, it is important to cater to the linguistic needs of a diverse visitor base.

Additional media includes a four-minute video of a Manoomin harvest from The Ways, a group promoting culture and language stories from native communities around the central Great Lakes. The video gives visitors the chance to see how the crop is traditionally collected, while images of purple loosestrife show the plant in a marsh setting and provide up-close photos of the flower so that visitors can more easily identify this invasive species. Likewise, images of Manoomin and a Manoomin harvest give visitors an idea of what the rice looks like and how it is gathered. The ultimate goal of the purple loosestrife storyline is to alert visitors to the harms of invasive species and make a local connection to the Anishinaabe peoples, who still harvest Manoomin in the Great Lakes Region.

Narrative 2: Wood Duck

Located in the upper left-hand corner of the marsh display, as shown in Figure 9, the two taxidermy wood ducks perched inside and on top of a wooden nesting box garnered little attention from visitors. The wood duck narrative starts by asking visitors to

Figure 9. Wood ducks in the GRPM marsh diorama. Image by the author, 2017.

locate the colorful birds and learn more about their relationship to humans. Similar to the purple loosestrife narrative, four labels were composed to form a historical story that details the successful conservation of this avian species. The first label starts by describing the beautiful plumage of a male wood duck, and then leads into the second label which discusses how wood ducks became endangered after being over-hunted for their meat and opulent feathers. The third label then introduces the conservation efforts that were enacted to preserve the nearly extinct wood duck, while the fourth label expresses the positive outcome of the conservation effort and invites visitors to build wood duck nesting boxes to further help the repopulation effort.

Each label was then read out loud in both English and Spanish and recorded as an audio file so that visitors can listen to the tale of the wood duck while observing the birds within the display. Images of both male and female wood ducks provide visitors with an opportunity to view the birds up close while a video of a male wood duck swimming and preening allows visitors to watch the bird in action. Additionally, visitors can listen to the unique *jeeb!* call of a wood duck and be directed to a web page that gives step-by-step instructions on how to build a nesting box. The ultimate goal of the Wood Duck narrative is to alert audiences to the concept of endangered species, encourage conservation, and inspire interest in constructing a nesting box.

Narrative 3: Specific Species

The specific species narratives cover eight plant and animal species and give visitors an introduction to a few of the most popular animals in the marsh display as well as some of the less popular species in the diorama. These narratives are secondary to the purple loosestrife and wood duck narratives, because they are less in-depth and more strongly rooted in visual media.

As the most popular element in the display, the snapping turtle, shown in Figure 10, was given a narrative that included audio, images, and video. The audio component is composed of two short labels that draw attention to the jaws of the snapping turtle and inform visitors about its snapping abilities. Images show the turtle up close and give visitors a look at its beak-like mouth. A short video shows a snapping turtle swimming in a pond, giving visitors an idea of the speed of the turtle while in the water.

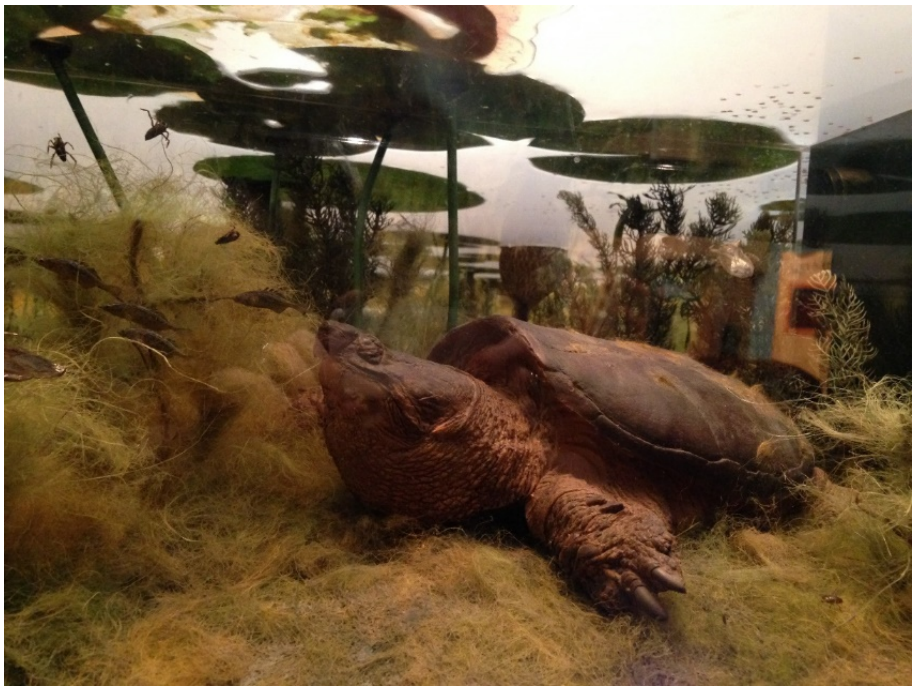

Figure 10. The snapping turtle interactive. Image by the author, 2017.

The western painted turtle was chosen because it is Michigan's state reptile and drew a decent amount of attention from visitors. Audio informs visitors about how these gentle reptiles should not be captured as pets or released into the wild if they are already a pet, and several images show the colorful designs on the turtle that give it its namesake.

The bull frog, which was frequently identified by visitors, has a small text label that informs visitors about how the bull frog got its name (from its deep, cow-like croak), while a brief audio clip describes the surprising diversity of a bull frog's diet. Several images give visitors the chance to examine bull frogs up close.

As another popular species in the display, the northern water snake storyline contains a brief but important message. Audio details how these snakes are frequently

mistaken as being venomous and killed; the audio informs visitors about the differences between venomous and nonvenomous snakes. Images of the northern water snake help visitors to better identify the species, while a video shows a northern water snake sunning itself on a rock to give visitors an idea of the size of a mature adult. Additionally, a brief three-question quiz tests visitors' knowledge about venomous and nonvenomous snakes.

Located near the front and center of the display, the great blue heron, shown in Figure 8, garnered a relatively small amount of attention from visitors. One of the taxidermy birds is posed in a preening position, giving the perfect opportunity to discuss bird behaviors. Brief audio details the benefits of the great blue heron's spear-like beak, while a video shows the bird wading through a stream and striking at prey. A second audio clip introduces the concept of preening to the visitor and a video of a bird preening its feathers gives visitors a better understanding of this daily and necessary behavior. Several images of great blue herons allow visitors to view its sharp beak while an audio clip gives visitors the chance to hear this bird's deep and haunting call.

Frequently referred to as a "hawk," the taxidermy osprey perched upon a wooden rowboat in the center of the display, shown in Figure 11, received regular attention. Similar to the wood duck narrative, the osprey is an excellent example of conservation success. An audio clip draws attention to the rowboat and explains how things left behind by humans can sometimes have harmful side effects on wildlife. The audio clip then goes on to discuss how osprey populations rebounded following the ban of DDT. Images show this bird of prey up close while a video shows its unique hunting technique in which they dive into the water to catch prey.

Figure 11. Osprey and mallard duck diorama elements. Image by the author, 2017.

Similar to the great blue heron, the mallard duck, shown in Figure 11, which can be seen front and center, provides the perfect opportunity to introduce visitors to bird behaviors. The taxidermy duck is posed in a dabbling position in which its head is underwater and its tail is bobbing above water. This pose drew a lot of attention from visitors, who noted that they had observed this behavior in the wild before, but nonetheless found the "bottom-up" position to be amusing. The interest in the duck's pose resulted in an audio clip that explains dabbling behavior. Likewise, images show this familiar duck up close and a video of a duck dabbling allows visitors to identify this behavior in the wild.

The mallard duck narration is linked to the watermilfoil storyline because of this invasive plant species' impact on waterfowl. Images of watermilfoil give visitors an idea of what the plant looks like while audio describes why this invasive species is harmful to native plants and animals. Additionally, the audio directs visitors to peer through the underwater viewing panel and look for the head of the dabbling mallard through the thick layer of watermilfoil, shown in Figure 12.

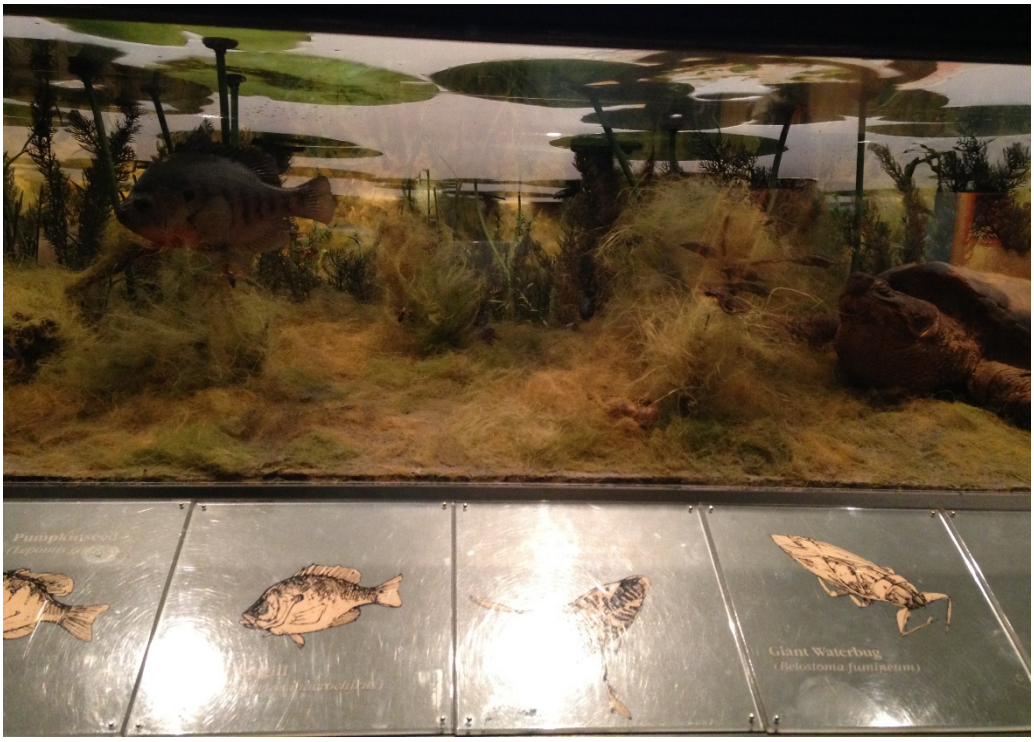

Figure 12. Watermilfoil diorama element. Image by the author, 2017.

Narrative 4: Diorama Marsh Labels

Two final storylines include both popular and unpopular labels, one depicting the water cycle and one describing the functions of a marsh. The popular water cycle label, shown in Figure 13, is a simple picture expressing the movement of water with a

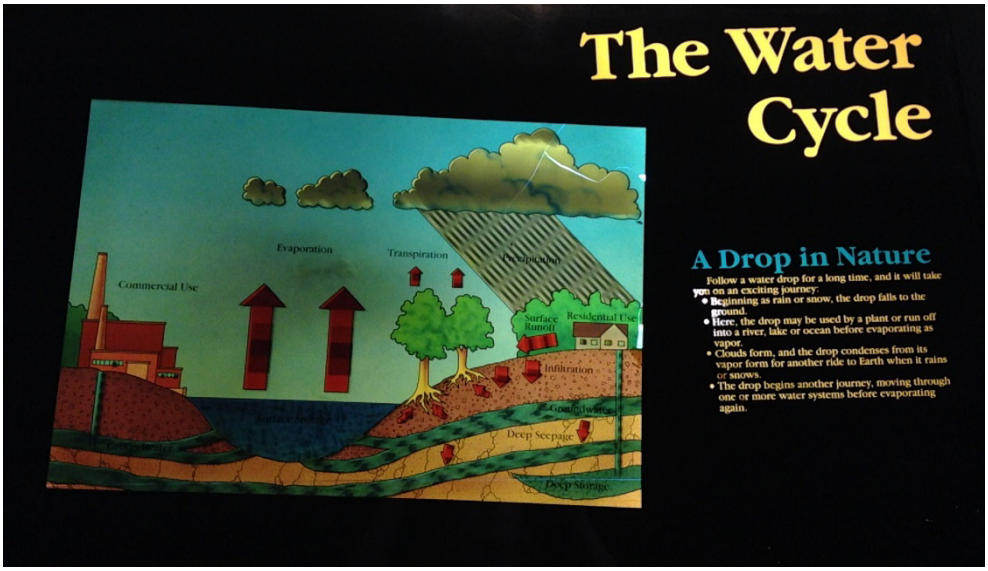

Figure 13. The water cycle label. Image by the author, 2017.

backlight that shows subtle movement. Visitors frequently touched the label, assuming it was an electronic interactive and it is for this reason that the label was given a video which shows the progress of a water molecule through the water cycle. The label detailing the function of the marsh, shown in Figure 14, was frequently ignored due to its small text and significant length. To improve visitor interaction with this label, a simple audio clip details the function of the marsh and a video featuring a busy marsh invites visitors to look and listen to a lively marsh in Sacramento, California.

Augmenting the Michigan Marsh Diorama

Following the completion of the augmented storyline, the actual augmentation process was undertaken. Originally, the AR platform Aurasma was selected for this thesis due to its powerful capabilities, ease of use, and free price. However, after testing Aurasma in low-light conditions it became evident that a different AR platform would

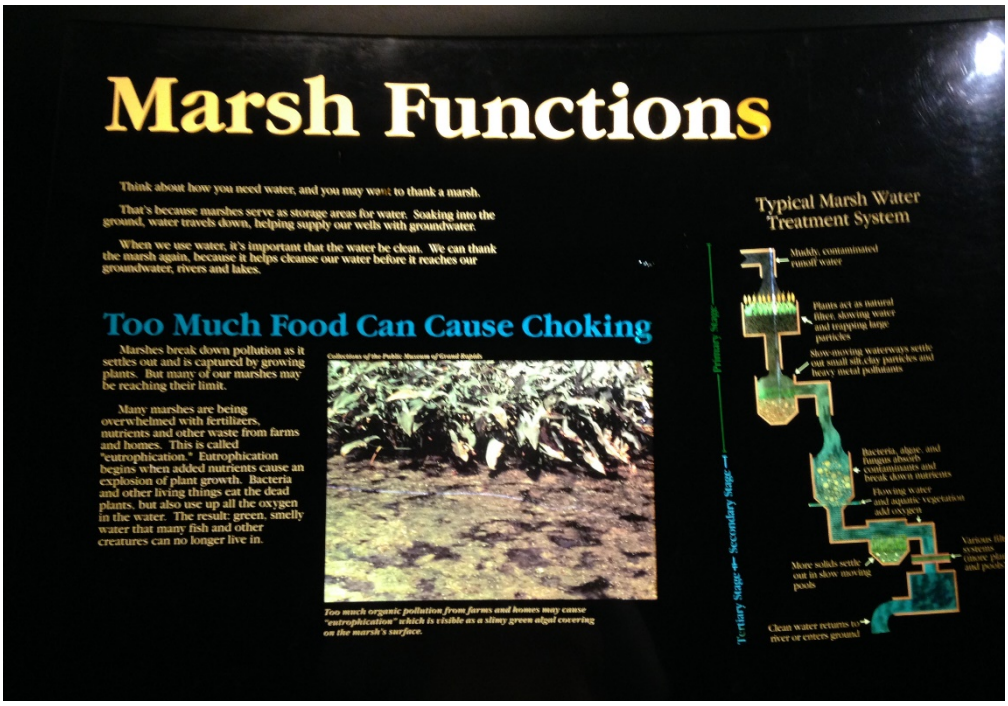

Figure 14. Marsh functions label. Image by the author, 2017.

need to be used to function properly in the darkly-lit GRPM diorama hall. Zappar, an alternative AR platform comparable to Aurasma, was selected for its capabilities and ease of use. However, a major drawback for Zappar is the price of a yearly subscription. At $237.00 annually for an Education account, Zappar is an affordable option for most medium or large institutions but may pose a financial strain on smaller museums. Due to the research-oriented nature of this thesis, I was able to augment the diorama under a free personal account; however this loop-hole is most-likely not available to museum personnel.

Beyond the price increase of Zappar, a second significant change to the augmentation process occurred due to the AR platform switch. Aurasma functions by using object identification, or, a “trigger image,” meaning that augmentation would have

to be completed at the GRPM. However, because Zappar functions by using "zapcodes," a kind of code that can be affixed to a surface and scanned by a smart phone, the augmentation process was allowed happen away from the GRPM. For example, working with Aurasma would require the researcher to be present at the research site to select a trigger object, take a photo of said object so that the program can recognize it as the trigger, and then attach its associated media to the object. In working with Zappar, the reverse of this action occurs; the researcher is able to upload the associated media to the AR platform first, which creates a zapcode that can be printed out and then physically affixed to an object or surface. As a result, the augmentation process was able to occur in Chico, California, without physically being at the research locale, inarguably a positive attribute of Zappar.

Over the course of a week, the augmentation process was completed using Zappar's Zapworks Studio, a powerful yet easy to navigate platform. First, 12 separate zapcodes were created, one for each species element identified in the augmented storyline. The media content associated with each species was then uploaded to the individual zapcodes; this was a fairly effortless step as Zappar accepts a wide range of audio and video files so no format conversion was necessary. The actual augmentation process was incredibly simple. Because Zappar is a fully functioning platform, the individual responsible for the augmentation only needs to drag the content to its associated zapcode and the Zappar platform does the rest of the technical work such as arranging the content into an attractive and interactive display. In fact, the most difficult step in the augmentation process did not concern Zappar: finding high quality, public

domain media was significantly more time consuming than actually augmenting the diorama.

With this in mind, the media sourced for this thesis was primarily obtained from Fair Use sources such as government archives and Creative Commons. Thus, all of the videos, photographs, animations, and some recorded audio of animal calls were from Fair Use sources. For the most part, Fair Use media was invaluable to the success of this thesis, however, having to work within Fair Use limits put significant restrictions on the amount of media chosen and its quality. For example, locating high-quality, open-source media related to lesser known species such as northern water snakes, watermilfoil, or ospreys was exceedingly hard to come across, and as a result, the augmentation process was significantly lengthened.

Due to the lack of Fair Use media pertaining to specific species, some elements of the exhibit had less media content or less polished media than others. For instance, finding an interactive water cycle video or game to improve the static water cycle label was very difficult, and while there were excellent water cycle videos and animations available online, they did not fall under Fair Use. As a result, the water cycle video was sourced from NASA, which falls under Fair Use guidelines because of its status as a government agency, but unfortunately, the video had no audio. Ultimately, museums considering AR, especially those without the funds to pay for copyrighted material, should assess the content of their exhibits in advanced – are the topics obscure and unlikely to have a wide variety of Fair Use media or are the topics more mainstream and therefore more likely to have a wealth of content?

Although the majority of media composing the augmented storyline came from Fair Use sources, a quarter of the content was self-produced, which is also a viable options for museums with a tight budget. As part of the storyline, brief labels were written for each element, however, I wanted participants to hear the labels rather than read them and so self-produced audio was a necessity. For this part of the augmentation process, I asked ten individuals to read the labels out loud while I recorded them with the audio recorder on my iPhone. The iPhone is obviously not the most preferable tool for audio recordings, however the finished product had surprisingly good sound quality. Likewise, the labels being translated into Spanish were given to Spanish speaking individuals who translated the content and were then recorded speaking the labels. Overall, the media selection and creation for the augmented storyline was by far the most time consuming facet of the process.

Once the Fair Use media had been collected, it was downloaded into Zappar, where the program did the rest of the work arranging the media into the zapcodes. After the media had been uploaded into the zapcodes, the zapcodes were "published," meaning that content is available to anyone who has access to the physical zapcodes, and images of the zapcodes were downloaded, re-sized to fit the marsh diorama, and printed. Zapcodes can be resized to be as small as 8mm, but for this particular project a 1.5 inch size was used, as shown in Figure 15, so that the codes could be affixed to the small species identification labels that border the marsh diorama. Once printed out, the zapcodes were heat-mounted to foam core and then cut them out. The end result was twelve, small, circular zapcodes that would be temporarily affixed to the species

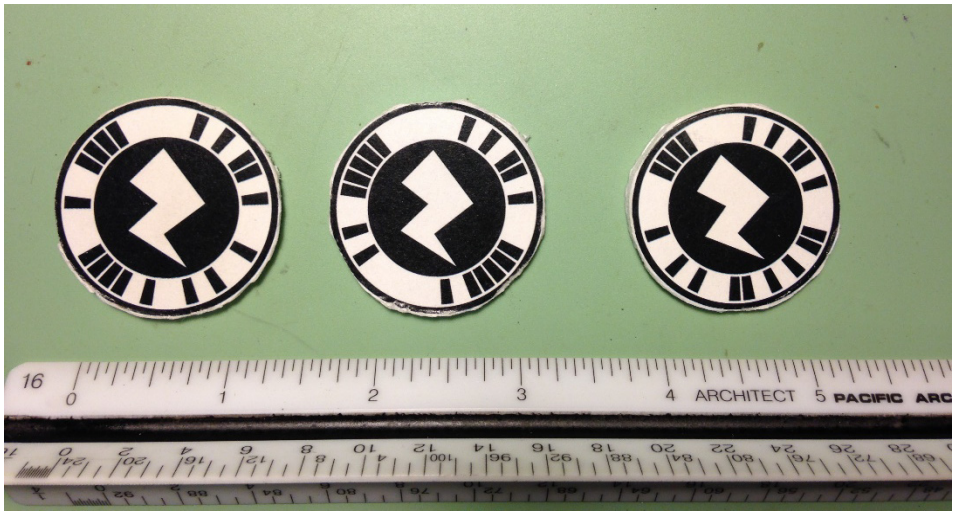

Figure 15. Zapcodes. Image by the author, 2017.

identification labels using blue painter's tape. The temporal nature of this thesis made the blue painter's tape an affordable and innocuous method of zapcode attachment, however, long term placement of zapcodes would require the use of a stronger adhesive or perhaps even re-printing of labels that have the zapcode imbedded into them.

Once the zapcodes were published, printed, cut into shape, and affixed to the display, the content was readily available to anyone with the free Zappar app. The Zappar app is very simple, and only requires the user to scan the zapcode using their smartphone - once the zapcode has been scanned, users are free to interact with the content that appears on their phone screen. In the case of content malfunction or inaccurate information, the zapcodes can be edited and then republished without needing to download, print, and cut out a new zapcode. Additionally, each time a zapcode is scanned, the Zappar platform records the number of times the content has been accessed and the length of time the content is interacted by a museum visitor. This feature, known

as “zapalytics,” was highly useful in determining which zapcodes could use content improvement and will be further explained in Chapter IV.

Summative Survey Creation and Intent

Before the March GRPM visit, as part of the second phase of research, a summative survey was created to gauge visitors’ experience with the augmented diorama. The summative survey, which was to be administered to visitors post-engagement with the augmented marsh diorama, was intended to measure the success of the augmented display. Consisting of four open-ended questions, the survey asked visitors to rate their experience with the augmented diorama, express their opinion about habitat dioramas, consider if their opinion of habitat dioramas had changed post-augmentation, and offer critiques and feedback regarding the augmented content and overall experience. The confidential surveys were meant to highlight areas in which augmented content required improvement. The data from the survey would then be used to make suggestions as how to improve future habitat diorama augmentation endeavors. To increase the ease of taking the survey, a specific zapcode was created so that participants could fill out the survey on the iPad after finishing their interaction with the augmented display. The summative survey can be viewed in the appendices of this thesis.

Launching the Augmented Diorama

Following the completion of the augmented storyline and summative survey, the final stages of the second phase, diorama augmentation and visitor observations at the GRPM, could occur. The study took place on March 10-12, 2017, and was a valuable test that highlighted several obstacles that might addle the path to a successful diorama

augmentation. While this visitor study was meant to be the final visit to the research site, significant technological issues prohibited the study from proceeding, resulting in a secondary trip to the GRPM in June 2017. Technological setbacks from the March 2017 visit to the GRPM and their solutions will be described in detail in the paragraphs below in order to ease the process for future diorama augmentation.

Upon arrival to the GRPM, a brief meeting was held between the researcher and the Education and Exhibit staff on March 10. During this meeting, a mock-up was performed in which the zapcodes were affixed to their proper locations in the display, and the staff was asked to download the Zappar app and interact with the content. Additionally, an 8" x 10" sign instructing visitors to download the Zappar app and interact with the diorama was positioned in front of the display. Using the private staff Wi-Fi network, the staff was able to successfully interact with the augmented display. However, it became immediately apparent that the museum's unlocked and free visitor Wi-Fi did not have a strong enough signal within the diorama hall. As a result, visitors trying to download the Zappar app or interact with the display while connected to the free museum Wi-Fi would experience significant delays in internet speed and in some cases, the Wi-Fi signal was completely unavailable. Because of the poor signal, visitors who were asked to interact with the display where unable to download the app and were resistant to downloading the app using their personal data plans. Furthermore, the signage at the front of the display instructing visitors to download the Zappar app was largely ineffective. The majority of visitors passed by without glancing at the sign, indicating that the launch of an augmented project might require significant advertisement to garner

visitor attention and interest. As a result of these setbacks, no visitor studies were conducted during the March 2017 visit.

To combat these setbacks, several solutions were reached following the March visit. To address the lack of visitor interest in downloading the app on personal devices and the poor internet signal, the GRPM agreed to provide their own iPads to be used during the visitor test. By using the museum iPads, visitors would not need to download the app on their smartphone and could simply interact with the display without using data. Likewise, using the GRPM iPads meant that the devices could be connected to the private staff Wi-Fi, eliminating the issue of poor internet signal. Finally, though an advertisement plan would be desirable for an augmented diorama launch, it was not realistic for this particular small-scale study; however, to improve visitor's awareness of the augmented diorama, volunteers were assigned to work with me during the June visit as a way to garner more visitor participation. Although the March visit did not produce the anticipated results, the setbacks ultimately improved the outcome of the June visit.

Post-Augmentation Observations

I arrived at the GRPM on the weekend of June 2, to implement the augmented content at the Michigan marsh diorama, conduct visitor observations, and circulate a four-question summative survey. During this period, detailed notes concerning conversations with parents were taken in addition to observation notes. Taking into consideration the setbacks from the March GRPM visit, several changes were made which ultimately resulted in a successful data collection trip. Over the course of two days, June 2 and 3, 46 visitors, most of whom were children ages 3 to 12, interacted with the

augmented diorama. This particular visit provided me with the qualitative and quantitative data needed to make suggestions and conclusions regarding the effectiveness of AR in improving habitat dioramas.

During the first day of observations, 32 participants interacted with the augmented diorama. Being a Friday, it was a fairly busy day, and likewise, several school groups with children in fourth and fifth grades passed through the diorama hall. Before the start of the observations, I was joined by a volunteer with whom I briefly explained my study and trained them on how to use Zappar. I came prepared with my own iPad, and the GRPM provided the volunteer with her own iPad. Both iPads were pre-loaded with the Zappar app, connected to the staff Wi-Fi, and were functioning properly at the start of the study. After affixing the zapcodes to their appropriate identification labels around the edge of the marsh diorama, the study began.

The volunteer and I started by approaching either parents of children or the adult chaperone of school groups and asking if their children wanted to interact with the diorama. The majority of adults gladly accepted and we handed the iPads to the children, as shown in Figure 16, giving them a brief explanation of how to access the content.

Once given the iPads, the participants would locate a zapcode, point the iPad camera at the zapcode to unlock the content, as shown in Figure 17 (left), and then chose from the content that appeared on the screen, as shown in Figure 17 (right). For the children, using the iPads was very intuitive and in some cases, the children showed the adults how to use Zappar after having only used it for a few minutes themselves! Because there were only two iPads, school group children gathered around the iPads and

Figure 16. Participants using Zappar at the GRPM. Image by the author, 2017.

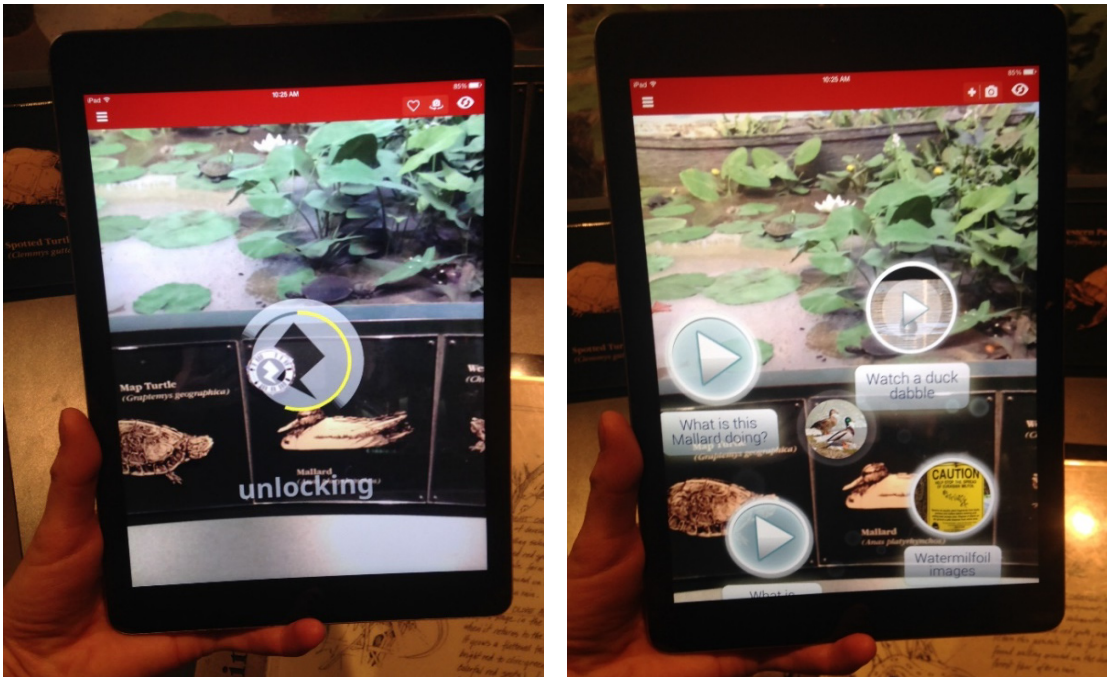

Figure 17. Zappar unlocking content (left) and content (right). Images by the author, 2017.

instructed whomever was holding the device to zap certain content. To the children, their choices seemed to be less based on a particular animal they wanted to learn about and more so about finding all the zapcodes and opening them all. In this way, the process of locating the zapcodes became almost a game in itself.

By the end of the first day of the study, a few general but significant observations could be made. First, diorama elements that were less popular pre-augmentation received a dramatic increase in attention from visitors post-augmentation. Second, video, photograph, and game content were significantly more attractive to participants than audio content. Third, participants used the app on both an individual and group basis, the only difference being that group use tended to generate more conversation and inquiry. Fourth, Zappar tends to work best with newer editions of iOS devices; the newer iPad ran smoothly while the older iPad tended to lose sound after several minutes of use, requiring the app to be closed out of and then restarted. Finally, it was decided both through observations and via adult suggestion that a case mounted to the exhibit would be the best; children tended to be suddenly engrossed by the content and then just as suddenly not, resulting in the iPad being casually set down wherever the child had lost interest. In the future, a hard protective case attached to the diorama via elastic cord might be the best solution to the wavering attention span of the primary participants.

During the second day of observations, 14 participants interacted with the augmented display. Because it was a Saturday, visitors were primarily parents with children. It should be noted that Saturdays tend to vary in visitor volume, and on this

particular day, the Grand Rapids Festival of Arts was being held just a few blocks away from the museum; because of this, visitor numbers were significantly decreased. Regardless, the 14 participants exhibited behaviors that supported the observations made on the first day of the study. Again, less popular elements such as the wood ducks and purple loosestrife sections received an increase in attention; the video, photos, and games were more attractive than the audio content. Both individual and group use occurred, the older device occasionally struggling to handle the app. Children continued to set down the iPad wherever they lost interest, sometimes on the exhibit, sometimes on the floor.

During the two-day study, children were not asked about their feelings towards Zappar, but the adults accompanying the children were. These questions took the form of an informal conversation revolving around a variation of a simple question: "Do you think this [program/ app] increases the interaction your child has with the exhibit?" The majority of parents believed the app had helped increased the amount of time the children spent in exploring the diorama, especially considering the play area directly adjacent to the display. Additionally, parents commented that the iPad made the interaction more relatable to the children. In one instance, the parent of an autistic child commented that she loved the idea because for her son, technology is often the only way that he actively gets involved with others. Ultimately, while there is room for improvement, the findings from this study suggest that augmented content does increase visitor engagement with habitat dioramas. These findings will be discussed in further detail in Chapter IV.

Phase III: AR Platform Product Comparison

The final phase in the thesis, which was completed in June 2017, involved the investigation and comparison of AR platforms to determine their feasibility of use within museums. Considering the growing popularity of AR, a fairly competitive market has developed around this form of technology. A simple Google search of AR platforms can render a lengthy and somewhat overwhelming list of products that offer a vast range of capabilities for a variety of uses. While a number of AR products are available to consumers, only a handful provide an end-to-end experience in which the customer can create and distribute their content through a single, branded platform. Narrowing down the potential candidates for this thesis, end-to-end programs such as Aurasma, Layar, Zappar, Blippar, Wikitude, Nokia City Lens, and XARMEX were explored and tested. After researching these products, Blippar, Wikitude, Nokia City Lens, and XARMEX were ruled out due to a combination of reasons including cost, capability, and the level of technical knowledge and skill required to use the product. Among the remaining platforms, Zappar was determined to be best suited for this thesis; however, Aurasma and Layer were both tested and explored.

Although Aurasma and Layar offer comprehensive end-to-end branded apps for mobile devices similar to Zappar, Zapper was chosen for this thesis project for three main reasons: ease-of-use, capability, and price. These comparison points have been selected because, according to a 2012 *Mobile in Museums* study conducted by Fusion Research and Analytics, they are significant factors that are challenging to both mobile and non-mobile using museums. Although Aurasma and Layar were not chosen for this

thesis, they will be discussed at length in this section and compared on these same points of ease-of-use, capability, and price because they have the potential to excel in museums of various size and financial capability. Table 3 provides a visual summarization of the comparisons being made between platforms.

Table 3. Augmented reality product comparison.

AR Platforms	Mobile App	User Accounts	Ease-of-Use	Capabilities	Price
AURASMA	Free iOS Android App	Commercial Non-Commercial	Community network, topic forums, FAQs, and links to tutorials.	Photos/Video Audio Animation 3D Models Image Tracking Web Links	Free non-commercial accounts.
ar	Free iOS Android App	Basic Pro	Nine extensive user tutorials.	Photos/Video Audio Animation 3D Models Image Tracking Customized Buttons Geo Layers Social Media Link Analytics	$3.50 per page with a Basic account.
zappar	Free iOS Android App	Personal Business Education	"How To" articles, documents, videos, and a guide for educators.	Photos/Video Audio Animation 3D Models Virtual Reality Image Tracking Customized Buttons Social Media Link Analytics	$247.00 per year for an Educator's account and $2.00 a year for a Student account.

Overall, the purpose of this assessment is to address the third question regarding the feasibility of AR within museum of all sizes and financial capabilities, and to suggest the most practical AR platform for each kind of museum.

Aurasma. Originally selected for use in this thesis, Aurasma rivals Layar and Zappar in capability, user-friendliness, and price, but was ultimately replaced by Zappar due to its poor performance in low-lighting conditions. Aurasma was first created in 2011 by Autonomy, a software company out of Cambridge, United Kingdom, and has since grown into an AR platform that supports both iPhone and Android mobile devices (Aurasma 2016). Aurasma uses image recognition technology and triggers mobile devices' cameras to recognize "real world images and then overlay media on top of them in the form of animations, videos, 3D models and web pages" (Aurasma 2016). Additionally, Aurasma is available free to the public in both a web format and a mobile app, making the technology highly accessible.

Users can make an account using their email address and access the technology via the online studio or download a free app for their mobile device. After a brief tutorial, users can begin augmenting their reality (commonly referred to as creating an "aura") or explore auras created by other Aurasma users. For instance, an Aurasma user can use their mobile devices' camera to mark a photograph of a bird as a trigger and then overlay an audio recording of the bird's song. Once the layer has been saved as a trigger, any Aurasma users can hold up their device to the photograph, which now acts as a recognizable aura supported by image recognition technology, and the bird's song will play.

Aurasma has primarily been used commercially for marketing purposes, partnering with companies such as Conde Nast, Universal Pictures, Maybelline, and News International" (Aurasma 2016). However, due to its simplicity and free terms of use for non-commercial entities, Aurasma has been positively received within the educational community, and in return, Aurasma has committed itself to remaining an accessible and free technological platform for schools and nonprofits (Aurasma 2016). Furthermore, Aurasma's webpage provides external links for educators that suggest how Aurasma can be used within a classroom and contribute to enhanced learning. Delving into the external links found on Aurasma's homepage reveals an extensive online community of educators who share their experiences with the product as well as their own creative innovations using the platform within the classroom.

Furthermore, Aurasma simplifies the augmentation process significantly by providing users with an easy-to-use interface. In short, users do not have to be tech savvy to be able to use the platforms' full capabilities. Ease-of-use was a significant factor when selecting a platform for this thesis because it firstly had to be personally manageable for myself, and secondly, it had to be straightforward and non-intimidating to participants of my thesis who would be using the app directly to complete the interactive survey during the second phase of this thesis research.

Considering capability, Aurasma was selected for its simple yet affective abilities; a non-commercial account with Aurasma gives users free access to the online studio, the mobile app, and the capability to embed graphics, web links, audio, and video over physical objects. Taking into account the augmentation of a habitat diorama,

Aurasma's technological offerings meet the targeted goal of transforming a static diorama into an interactive and multimedia display without any physical alterations. Although the capabilities of a non-commercial account are admittedly less powerful than that of a commercial account, the free offerings are still more than sufficient.

Finally, Aurasma's free terms-of-use are an attractive component to individuals and institutions alike with a tight budget. The online Aurasma studio is free to users with a non-commercial account and the mobile app, available to iPhone and Android users, is also free. Because the app needs to be downloaded onto a mobile device to be utilized within a museum, a free program is infinitely more attractive to museum goers than one that comes with a price tag. In Rodley's 2011 article *Looking Around vs. Looking Down: Incorporating Mobility into your Experience Design*, cost effectiveness is cited as being a hallmark of a successful app; Rodley (2011:40) notes that the app should be free, if possible, because "getting people to take the time to download and launch your app is the biggest hurdle you're likely to face."

Ultimately, Aurasma's easy-to-use interface affords museum staff the ability to create professional mobile interactives without dedicating a significant amount of time to learning the software. Likewise, the free price tag of both the Aurasma online studio and mobile app means institutions with limited fiscal resources can offer their visitors a mobile experience free of charge. As a result, Aurasma is an excellent choice for small and large institutions alike; the ease-of-use, capabilities, and price of the platform should be appealing to larger museums with fewer time and resource restraints and an inspiration

to smaller museums that have shied away from mobile technology due to time, budget, and staff resource constraints.

Layar. As one of the first Augmented Reality browsers, Layar is the most widely used AR platform on the market. Founded in 2009, the Amsterdam-based company has since joined the Blippar group and expanded to include free apps for iOS, Android and an online "Layar Creator" studio in hopes of "bridg[ing] the gap between print and digital worlds" (Layar 2016). Layar is primarily used for commercial purposes and as such has partnered with major brands such as Pepsi, General Mills, and Honda (Layar 2016); however, Layar offers a non-commercial, "Basic" account, making it an applicable AR platform for use in museums, thus it has been reviewed for this thesis.

Considering Layar's ease-of-use, this AR platform is perhaps the most technically robust out of all three platforms being analyzed. Due to the platforms' capabilities, which will be discussed in the following paragraphs, Layar is geared towards commercial use, making it less user-friendly for non-commercial users than Aurasma and Zappar. Although the Layar Creator online studio is sleek, professional, and informative, the features offered appear to be restrained within a commercial context. For instance, when creating a "new campaign," users must select between categories such as "billboard," "magazine," "newspapers," or "packaging," making the user feel locked in to valuing branding and marketing components over educational components. Furthermore, the commercial feel of the platform is mostly inviting to tech-savvy individuals as opposed to those with limited technological backgrounds. Though the Layar Creator is easy to navigate and provides users with instructional tutorials, it seems unlikely that

non-commercial users would find this platform to be relevant to their non-commercial oriented goals. Considering the free Layar mobile app and its ease-of-use, the interface is straightforward and easy to navigate; however it should be noted that it is primarily aimed at passive, commercial consumers rather than engaged and active audiences.

Delving into the capabilities of Layar, this AR platform goes beyond the basic features of Aurasma; in addition to embedding images, audio, video, animation, web links, and 3D models, Layar affords users the opportunity to customize their own buttons, link their campaign to social media, and employ Geo Layers, a GPS-based, real world map that provides pop-up information about the individual's specific location. Highlighted Layar features include a powerful media player that supports high quality photos, video, and music, a 3D model converter that "creates quick-loading models that are great for mobile," animation controls for 2D and 3D objects, and embedded HTMLs and social media links to encourage conversation, interactive poll taking, and surveys (Layar 2016). Additionally, Layar allows creators to track and analyze their content, giving them access to the number of page views, interactions, unique users, and users per community (Layar 2016).

Keeping in mind Layar's commercial objectives, accounts and pricing are unsurprisingly aimed towards companies rather than individuals or non-profit institutions. Two account types are offered: Basic and Pro. Both kinds of account give users access to the same features, however a Basic account only allows content to be published for 30 days while a Pro account allows content to be published for a full year. Additionally, pricing for accounts is determined by the number of "pages" created. A page is a "single

item (e.g., a flyer, greeting card, poster, business card, etc.) that you can upload and add content to in the Layar Creator" (Layar 2016). A single page is priced at $3.50 for a Basic account and $34.00 for a Pro account. Because of the drastic price differences in accounts and the length of time content remains published, Layar usage in the museum is perhaps best suited for short-term marketing campaigns rather than long-term educational usage. As a result, Layar remains a commercially-driven AR platform that would excel in bigger institutions with the fiscal and time resources dedicated to launching trendy advertising and marketing campaigns.

Zappar. Founded in 2011 out of Cambridge University in England, Zappar was the third AR platform considered within this thesis, and was ultimately chosen to augment the GRPM marsh diorama. Similar to Aurasma and Layar, Zappar offers a free app for iOS and Android and has an extensive online studio, Zapworks, for creating AR content. Although Zappar is perhaps first for commercial use, educational and personal usage remains at the forefront of the companies' mission (Zapworks 2016). For instance, Zappar offers a specific account for educators, provides a downloadable toolkit outlining the ways in which Zappar can be used within classrooms, and boasts a product interface that has been tested on "primary school children as young as eight and nine…[who] found their appetite for learning, ease of use, and output from Zapworks nothing short of inspirational" (Zapworks 2016). For these reasons, Zappar is a highly feasible option for use within museums.

Zappar's ease-of-use is perhaps the most appealing attribute of this AR platform. In terms of marketing, Zappar has done an excellent job in simplifying the

advanced technology and making it unintimidating for users of all technological backgrounds. Phrases such as “super simple,” “hassle free,” and “effortlessly quick” appear frequently throughout the website and are paired with cartoon-like, instructional graphics. Like the Aurasma Studio and Layar Creator, the Zapworks Studio allows creators to build completely customized AR experiences online, apply a “zapcode” (similar to an Aurasma aura or a Layar page) to an object, and then use the Zappar app to view the content (Zapworks 2016). In addition to tutorials and guides that provide further instruction for Zapworks users, Zappar has issued an eighteen page document for educators dedicated to inspiring Zappar use within schools. As such, the document offers a step-by-step guide to creating zapcodes and suggests four lesson plans using Zappar for a variety of ages and subjects. Likewise, the Zappar app is as equally intuitive and user-friendly as the Zapworks studio and instructional guides; upon opening the app users are given basic prompts that act as a guide to the Zappar experience.

Considering the capabilities of Zappar, the available features are comparable, if not more impressive, than those of Aurasma and Layar. Like Aurasma and Layar, Zappar allows users to embed photos, video, audio, animation, and 3D objects. Moving beyond Aurasma’s capabilities, Zappar, like Layar, provides users with the ability to create customizable buttons that can perform a range of actions, links to social media, image tracking for convenience, and full analytics to monitor activity and performance. Moving beyond Layar, Zapworks studio contains a powerful toolkit capable of creating virtual reality that can be used with Google Glass. Furthermore, Zappar claims to possess the best image tracking technology in the industry, a solution aptly called “zapcodes.”

Zapcodes, which are circular, scannable codes that unlock content, can be scanned from far away or at an angle and can "roam free," meaning that the same code can be cloned and applied to multiple items or locations. Additional Zappar features include unlimited zapcode creation, unlimited zapcode views, content hosting and serving, file storage, and full analytics, known as "Zapalytics." Zapalytics were highly useful to this thesis because they provided use-related statistics for each individual zapcode, including the number of times a zapcode was activated and the length of activation.

Continuing the user-friendly theme, Zappar offers Personal, Business, Education, and Student accounts at reasonable and transparent prices, free of hosting, serving, and scanning costs, to encourage both commercial and non-commercial use. An Education account is priced at $247.00 per year while a Student account runs at just $2.00 per year, both accounts giving users access to Zappar's full ream of features. Additionally, a Zappar Personal account is free of charge so long as the number of zapcodes created remains under 12. Given Zappar's ease-of-use, capabilities, and affordable cost, this AR platform can definitely be recommended for museums with small, medium, or large fiscal and time resources. In particular, small and medium sized museums might significantly benefit from using Zappar; the Zapworks studio is a source of inspiration for the creation of educational content within exhibits and its simplicity will undoubtedly save time during the actual augmentation process.

Taking into account the attributes of Aurasma, Layar, and Zappar, it is easy to see how each of the AR platforms are highly relevant and usable within contemporary museums. However, because of the slight variation between these platforms in terms of

ease-of-use, capability, and price, the circumstances in which each program will thrive differs. For instance, Aurasma and Zappar's powerful and cost-effective capabilities are suited for both formal and informal learning, so it can be suggested that these programs are best equipped for small, medium, and/or large institutions. Likewise, because Layar's capabilities and price are geared towards advertisement campaigns, this program is perhaps best suited for larger institutions looking to expand their marketing presence within the community. These recommendations are primarily based on Rodley's (2011) analysis of a successful mobile app and the 2012 Fusion Analytics and Research survey on mobile usage in museums and will be discussed at length in Chapter IV.

Data Analysis Procedures

At the core of data analysis for this study is the qualitative data from visitor observations during the February, March, and June visits. Observations from the three visits to the GRPM yielded several pages of hand-written notes describing the various types of visitors, their interaction with the diorama, and their conversations with others. To parse out meaningful observations from the data set, an ethogram was created. The ethogram, which outlines and specifies the *social* and *solitary* interactions that took place at the marsh diorama, helped to organize the data and clarify the direction of the augmented storyline.

In placing the data into social and solitary categories, the data could then be broken down into more specific behavioral groupings such as *observing*, *interacting*, *reading*, *discussion*, and *experience preservation*. Furthermore, each of these behaviors was assigned a frequency rating that ranged from very common, common, somewhat

common, uncommon, and very uncommon. With the data clearly outlined by the ethogram, conclusions could be reached regarding the type of visitor and visitor behavior that most frequently occurred at the marsh diorama. For instance, although reading over the observational notes presented a general idea of visitor type and behavior, the ethogram clearly presented the difference between common or uncommon social or solitary behaviors. In viewing the data within an ethogram, decisions were made regarding the direction of the augmented storyline and type of content to be included. For example, because the ethogram expressed a significant social visitor disinterest in reading label content, augmented content leaned towards audio labels rather than written labels. Furthermore, the observational notes were used to reinforce the ethogram findings, and subsequently the augmented storyline. For instance, although label content was rarely read by social visitors, two labels were picked to augment, one popular and one unpopular, in attempt to improve social visitor's engagement with label content.

Considering quantitative data collection and analysis, Zappar provides zapalytics data measurements and analysis as part of personal, educational, and business accounts. As previously described, zapalytics allows users to measure the success of their zapcodes by looking at several factors such as the total number of zaps a zapcode has, the average zap time of a zapcode, the total zap time of a zapcode, countries engaging with the zapcodes, device platforms used, and the time of day zaps occurred. In short, each time a zapcode is activated, the interaction is recorded by the zapalytics tool and the data is automatically placed into easy-to-digest graphics. These graphics take the form of charts, graphs, and maps, making data interpretation and analysis very simple.

Additionally, zapalytics is provided for both individual zapcodes and collections of zapcodes, as a whole so users can compare and contrast the success of specific zapcodes or whole groups. One setback of zapalytics is that it does not record data regarding individual media usage of each zapcode. So for instance, if the video content of a particular zapcode made up the majority of interactions with that particular zapcode, the favorability is not expressed.

The zapalytics data has been used two-fold within this study. First, the analyzed data has been thoroughly examined for each individual zapcode in order to measure what kind of media content is the most successful at engaging visitors. By looking at the number of zaps and total and average zap times for each zapcode, comparisons have been made that suggest which combination of media keeps visitors active and interested. Second, the zapalytics data was then compared against visitor observations from the February visitor studies and the June visitor observations to make the data set more robust. By combining the quantitative and qualitative data, the numbers are supplemented by more anecdotal data that was observed while visitors engaged with the augmented diorama. This includes reception to the augmentation, conversations shared between participants, and tracking of what media was most frequently utilized. So for instance, a zapcode that had the highest number of total zaps according to the zapalytics can be further explored by considering the kind of interactions that took place between participants while that particular zapcode was in use as well as what media was most frequently engaged.

A final addition to the data collection was the summative survey, created to gauge visitor's experiences with the augmented display. However, the survey was eventually deemed irrelevant for several reasons and was instead supplemented by visitor observations during the June visits and zapalytics data.

Perhaps the biggest reason the survey was excluded from the study was due to the age of the primary participants. Initially, the augmented diorama was meant to draw in both younger and older visitors; however this was not the case. Participants were almost exclusively children, most of whom were on class trips and were therefore not fully accompanied by an adult. It was common for groups of five to ten children to be accompanied by a single adult, and for this reason, adults were not available to fill out a survey for the children. In fact, the outnumbered adults seemed to be relieved by the presence of the iPad and frequently stepped away to let the group of children engage with the diorama. Additionally, the survey was meant to be accessed using the iPad, and because children dominated iPad use during the observation, it was unlikely an adult would be able to interact with the display or commandeer the iPad long enough to fill out the survey. For these reasons, the majority of adults did not interact with the diorama and therefore could not fill out the survey, which decidedly, was thereupon thrown out because of its irrelevancy under these circumstances

The survey was not intended to be removed from the study, and in fact, it wasn't until the June observations that it was pulled. In an attempt to supplement the unplanned absence of the survey data, informal interviews with adults were conducted as the children interacted with the display. These informal conversations typically involved

giving a brief explanation of the study and then asking the individuals if they felt this was a good way to engage children. Although this form of interview yielded overwhelmingly positive comments, it was necessary for the information to be backed by more concrete forms of data such as visitor observations and zapalytics. Although these informal conversations helped to highlight the positive qualities of the augmented diorama, the areas requiring improvement were not mentioned, perhaps because the adults themselves had not interacted with the diorama and also because participants seemed more likely to give honest opinions under the guise of confidentiality, which was not a possibility.

Although it is undeniable that data from the summative survey would have added to the findings, its absence is not damaging to the data set. Working in tandem, the qualitative data from the June visitor observations are backed by the quantitative zapalytics data and vice versa. For instance, the observations provided anecdotal data in which participants' conversations and inquiries were recorded to gauge the effectiveness of the AR content while the zapalytics data supports the observations by quantifying the length of visitor engagement. Therefore, although the summative survey data would have provided concrete statements regarding visitors' opinions on the AR content, the combined data from the observations and zapalytics allows the same conclusions to be made, just in a more roundabout way.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

At the completion of the study, the collected data was analyzed and interpreted, resulting in several conclusions regarding the use of AR in revitalizing habitat dioramas and the integration of AR into museums. In this chapter, each phase of research, along with the findings, are discussed in relation to New Museum Theory, Visitor Identity Motivation Theory, the Post-Museum, and Mobile Learning Theory. Likewise, the results of each phase are discussed in consideration of the three key questions guiding the structure of the thesis, which seek to determine whether habitat dioramas should be preserved or replaced, if AR can update and preserve habitat dioramas, and if the integration of AR within a variety of museums is feasible. The core of this chapter is dedicated to the presentation of findings and the proposition that AR is capable of preserving and rejuvenating both habitat dioramas and the relationship between museum and community.

Presentation of the Findings from the February Visitor Studies

Following the observation of roughly 200 visitors over the period of two days, a number of general observations were made that aided in the implementation of a compelling augmented storyline. To reiterate, these findings were reached pre-augmentation; visitor studies data collected post-augmentation will be discussed at a later point in this chapter.

Perhaps the first and most obvious statement to be made about the marsh diorama is the popularity of the underwater viewing panel showcasing the snapping turtle. The majority of visitors stopped to peer into the underwater panel regardless of interest in the full display. For instance, some visitors *only* engaged with the display via this element. While it is unclear whether the snapping turtle or simply the uniqueness of the see-through panel is most attractive to visitors, it was not uncommon for visitors to comment on the snapping turtle, perhaps because of its familiarity or because of its ideal location near the center of the viewing pane. Regardless, the augmentation includes this element of the display due to its popularity.

Beyond the underwater viewing panel, reptiles and amphibians such as snake, turtle, and frog species in the display were a particularly popular draw for visitors. Due to familiarity, these animals were most likely to be pointed out by adults and children. Additionally, it was not uncommon for children to be familiar with these species on a more in-depth basis. For instance, many children would point to the animals and refer to them with specific names such as “snapping turtle,” “bullfrog,” and “water snake.” Likewise, the frog species sound buttons were more likely to be pressed by visitors in scenarios in which only one or two buttons were pushed.

In retrospect, the bird species in the display were almost never referred to on a specific name basis. In rare instances, a child or adult might point to the mallard dabbling for food and refer to it as a “duck.” Similarly, the osprey was occasionally pointed to and referred to as a “hawk.” This lack of familiarity with bird species carried over into the interactives in which the bird species sound buttons were less likely to be pushed in a

scenario where visitors chose to push only one or two buttons. Likewise, there was almost no reference to the plant species in the display beyond visitors remarking about how the grasses "blew in the wind." While augmentation features the popular reptiles and amphibians, special attention was given to the bird and plant species that are otherwise overlooked.

In considering unpopular elements of the marsh diorama, the left side of the display was the least attractive side. Primarily text-heavy, the left side was often passed by with little more than a glance; visitors wanted to see the underwater viewing panel at the center of the display and engage with the interactives to the right. As a result, significant information regarding the function of marshes, the water cycle, and an array of plants and taxidermy animals were ignored. The augmentation of the diorama attempted to draw visitors to the right side of the display by making the information on the labels more engaging and pointing attention to plants and animals that reside in this region of the diorama.

A final factor to consider is the location of the display within the diorama hall. Being near the end of the diorama hall and located next to an attractive play area featuring a treehouse and puppet theater, the display has significant competition for visitors' dwindling attention. The goal of the augmentation was not to take attention away from the surrounding displays, but rather to slow the progression of the visitor through the diorama hall and deepen the level of engagement with the marsh display. As such, the augmented storyline drew on the most attractive elements of the diorama while subtly

introducing elements that were typically overlooked by visitors such as information about bird and plant species and the function of a marsh.

Categorization of Observed Behaviors

Following the February 10-11, 2017 post-augmentation visitor study at the GRPM marsh diorama, several inductive themes emerged from the empirical data, resulting in the creation of an ethogram, as seen in Table 4. To start, the types of interactions observed at the marsh diorama can be generalized into two main behavioral categories: *solitary* and *social*. These two behavioral categories can then be broken down into more specific behavioral groups, which include observing, interacting, reading, discussion, and experience preservation. The ethogram provides a visual depiction of the specific types of solitary and social behaviors observed at the marsh diorama during the two-day visitor study with a description of the behavior and the frequency of occurrence.

Focusing on the solitary interactions with the diorama, the actions of observing, interacting, and reading occurred with relative frequency. Although solitary behavior did occur within a group, the individuals observed during the visitor study had mostly broken away from their group to take in the display by themselves. It was the solitary readers and observers who tended to spend the most time reading each label and noticing the more intricate details of the display. For instance, one visitor read each label panel while another slowly walked around the diorama noticing frequently overlooked elements, at one point setting off an alarm as he leaned over the diorama in attempt to get a better look at the wood ducks located in the upper left corner of the display.

In terms of engaging with the interactives, solitary individuals seemed more likely to try out the interactives but devote less time to engagement. For example, several solitary visitors were observed pushing a single button on the push button interactive whereas social visitors frequently pushed several. Interestingly, literature on engagement with habitat dioramas seems to favor social or "familial" visitors, making an in-depth

Table 4. Post-augmentation behavioral ethogram.

Behavior Type	Behavior	Behavior Description	Frequency
Solitary			
	Observing	Silent observation.	Common
	Interacting	Engaging with interactives.	Common
	Reading	Quietly reading texts.	Very common
	Discussion	Questioning, identifying, hypothesizing, affirming, and storytelling.	Non-existent
	Experience Preservation	Taking a photo or video of or with the diorama.	Non-existent
Social			
	Observing	Pointing to or identifying elements of the diorama.	Very common
	Interacting	Engaging with interactives with one or more people.	Common
	Reading	Reading aloud to one or more people.	Uncommon
	Discussion	Questioning, identifying, hypothesizing, affirming, and storytelling.	Very common
	Experience Preservation	Taking a photo or video of or with the diorama.	Uncommon

analysis of solitary visitors difficult. For instance, prominent literature from Ash (2004), Dana Nietzel (2005), Garibay Group (2008), Reiss and Tunnicliffe (2009), and Scheersoi

and Tunnicliffe (2009) focuses on the discussions and inquiries shared between social visitors, and are therefore less apt to focus on solitary visitors, who are unlikely to vocalize or showcase their thoughts on the diorama. As a result, solitary visitors are somewhat absent from these studies because they are an improbable source for studies hoping to parse out visitors' attitude towards these displays. However, although it is difficult to decipher the benefits solitary visitors receive from interacting with a habitat diorama, it is clear that an augmented storyline must cater to this form of visitor, perhaps by offering a narrative that allows the visitor to move at a slower pace and delve into the finer details of the storyline.

Due to the high amount of social engagement taking place at the marsh diorama, several behaviors were noted including observation, interacting, reading, discussing, and experience preservation. Social interactions at the marsh display typically manifested between two adults or an adult with one or more children. These forms of social behavior offered a variety of data.

Observational behaviors tended to take the form of pointing or active looking. For instance, children frequently pointed to the snapping turtle as a way to signal to peers that there was something interesting to be seen. Likewise, it was not uncommon to witness an adult pushing a sound button for the child, and the child to react by actively searching the display for the animal who may have been responsible for the sound.

Interaction behavior was noted by any engagement with the interactives at the marsh display. This included looking through the flip books, pushing the sound board buttons, and touching the beaver pelt and muskrat skull. The flip books were by far the

least popular interactive, typically garnering only a second or two of attention from both adults and children.

The push buttons were the most popular interactive, being pushed frequently by both children and adults. Children seemed to prefer pushing all of the buttons but on occasion, when only a few buttons were pushed, children appeared to prefer the bull, leopard, green, and pickerel frog buttons over the marsh hawk, long-billed marsh wren, and red-winged blackbird buttons. The beaver pelt and muskrat skull interactive, which was located at the far end of the diorama, tended to be a popular area to congregate and, thus, this interactive was frequently engaged with by adults and children. When engaging with this interactive, adults seemed less interested than children, who often called their peers over to touch the beaver pelt or remark about its softness.

Reading behavior was less common between social interactions and was typically performed by way of a parent reading off the name of an animal via the simple identification labels. This reading aloud behavior was done mostly with the intention of encouraging children to locate the animal within the diorama. Through visitor observations, it was determined that adults seemed more likely to choose animals they were certain their child could identify, resulting in a heavy preference towards reptiles such as turtles, snakes, and frogs.

Discussion was the most common form of social behavior represented at the marsh diorama, taking the form of questioning, identifying, hypothesizing, affirming, and storytelling. Questioning behavior was typically shared between adults and children, and children and children. Adults frequently asked children questions about the animals in the

diorama such as “Can you find the snake?” and “Where do birds live?,” while children asked the adults questions about animals they saw in order to clarify or affirm their Knowledge. The action of questioning was typically linked to identifying, hypothesizing, and affirming, and it was common for all of these actions to take place within a discussion. Because these behaviors appeared so frequently, an augmented experience should take advantage of these findings and offer a variety of questions and discussion topics to further facilitate discussion at the habitat diorama.

For instance, a group of school children observed the diorama and asked each other if there were “amphibians” in the display; one said “yes” and identified the bullfrog as an amphibian and was affirmed by another child who also believed the bullfrog to be an amphibian. However, two of the school children in the group disagreed and hypothesized that an amphibian was a type of plant and was probably somewhere in the marsh diorama. This type of discussion occurred most frequently between adults and children and children with other children. Storytelling was also a frequent form of discussion at the display; familiar animals within the display sparked memories and prompted brief conversations. For example, one child pushed the bullfrog sound button and said “This is what it sounds like at my grandma’s house at night.” In another instance, a women spied the snapping turtle and recounted a tale of an encounter with two of the animals while rafting down a river. Again, an augmented experience should cater to this type of discussion behavior by prompting visitors to reflect on and discuss a memory they have of an animal they see in the diorama.

Experience preservation was a less common form of social behavior observed at the marsh diorama but was nonetheless an important marker of engagement. Two types of experience preservation were demonstrated: photographic and video recording. Photographic experience preservation took the form of individuals taking photos of either the display or of others interacting with the display. For example, children asked their parents if they could take photos of the snapping turtle while parents took photos of their children looking through the underwater viewing window. Similarly, video recording took the form of parents recording their children pointing to animals, looking through the underwater viewing window, and playing with the interactives.

Considering these behavioral observations in concert with Falk's (2006) identity-related museum motivations, there is potential to improve visitor's experience with the Michigan marsh display. Falk's categorization of visitor types (explorers, facilitators, professionals/hobbyists, experience seekers, and rechargers) allows for more specific accommodation of visitor needs, resulting in a more fulfilling experience (Falk 2006:124). By first identifying these needs in relation to the types of visitors and the social and solitary behaviors observed at the display, the augmented storyline was created.

Explorers, who visit for curiosity-driven reasons, can be solitary or social and express a wide range of behaviors such as observing, interacting, reading, discussion, and experience preservation. As a result of their inquisitive nature, the augmented storyline attempted to cater to explorers through exhibiting a variety of information at varying

depths, presented in several different mediums. Audio, imagery, text, video, and games were implemented to appeal to this type of visitor.

Facilitators, who visit with the intention of enabling others who want to visit the museum, are social and exhibit the behaviors of observing, interacting, reading, discussion, and experience preservation. Perhaps the most obvious form of facilitator might be a parent, relative, or school trip volunteer who is at the museum on a secondary basis to oversee younger visitors. During the visitor observation, several parents could be classified as facilitators and were frequently observed responding to their children's inquiries. Because this individual is primarily visiting for the sake of others, the augmented storyline panders to facilitators by providing simple cues that prompt exploration and inquiry with the primary visitors.

Professionals and hobbyists who visit for specific "content-related" reasons, can be solitary or social and are likely to engage in observing, interacting, reading, discussion, or experience preservation. While this form of visitor could be classified as being curiosity-driven, they differ from the explorer in the way they seek specific information. Because of this, a professional or hobbyist might be less likely to interact with the marsh diorama unless it contains the desired content or objective. Taking the motivations of the professional/hobbyist into consideration, the augmented storyline attempted to provide a more in-depth look at specific topics, such as the repercussions of purple loosestrife on native species and a historical look at the recovery of the previously endangered wood duck.

Experience seekers, those who visit to experience an important or well-known destination, can be solitary or social, and although they might engage in observing, interacting, reading, and discussion, a key behavior that might be relevant to their needs is experience preservation. Photographs or videos can be shared on social media, a common practice that, in a sense, validates an experience (Kelly 2016:1). With this in mind, experience seekers are likely to preserve their experience through photos or video in attempt to curate and present their travels. Although the GRPM is Michigan's oldest and second largest museum, the diorama hall is unlikely to be considered an important or well-known destination. However, the experience seeking type has not been excluded from the augmented storyline; several elements of the marsh diorama are picturesque and provide ample opportunity for the experience-seeker type to take photo or video as a way to both remember and share their experiences. The augmented narrative is geared towards the experience seeker in the way it attempts to draw attention to areas of interest that are typically photographed, such as the underwater viewing window featuring the snapping turtle. Additionally, Zappar allows users to take photos and videos while the augmented content is in use; while this feature might be attractive to experience seekers using Zappar on their personal devices, this study relied on the use of shared iPads, making the photo and video function of Zappar less likely to be used.

Rechargers, who visit for contemplative or restorative reasons, are likely to be solitary and less active in interacting, discussion, and experience preservation behaviors. Observation and reading might be a common behavior of rechargers, but in general, rechargers observed during the visitor study seemed to be prone to either slowly

wandering around the diorama hall without giving attention to any specific display or sitting quietly on the chairs across from the marsh display. Depending on the busyness of the diorama hall, the calming lights and ample seating could be a draw to rechargers, or a loud and full treehouse and puppet theater could create a buzzing atmosphere that rechargers might find distracting. Given the marsh diorama's close proximity to the treehouse and puppet theater, it seems likely that the areas surrounding the display will be somewhat active and noisy. For this reason, the augmented storyline will not be overly geared towards rechargers. However, this is not to say that they have been entirely excluded; one embedded feature of Zappar is ambient music that plays in between activating zapcode content. Although a very minor element, the music could offer rechargers respite from the otherwise bustling atmosphere surrounding the display.

Falk's categorization of visitor types was immensely helpful in determining the motivations and desires of visitors to the GRPM marsh diorama, however, some limitations occurred in using this framework. Because of the proposed visitor types, during the visitor studies, I was intensely focused on identifying all five types. However, post data collection, it was apparent that only two types were present at the marsh diorama: explorers and facilitators. Had this realization occurred earlier, I might have been able to focus solely on explorer and facilitator types and create more descriptive sub-categories for these two visitor types. Therefore, it should be noted that while Falk's visitor categories are a helpful in deciphering visitor motivations, the categories are fluid, complex, and multidimensional. Therefore, these classifications should be viewed as a jumping off point rather than concrete and definitive categories.

Presentation of the Findings

March Visitor Findings

Findings from the GRPM March visit, which largely served as a trial period for the augmented program, helped to highlight common setbacks that institutions might face while implementing AR into their displays. During the March visit, issues concerning internet access, device availability, zapcode placement, and advertisement were highlighted. These findings have been outlined and explored with the ultimate goal of paving a smoother way for museums interested in introducing AR to their exhibits.

Perhaps the biggest issue from the March visit was the lack of access to the internet. Institutions looking to add AR to their displays should count on needing high speed internet with a strong signal throughout the building. For example, the GRPM has high speed internet, however the location of the diorama hall in particular had a very poor signal, making online access almost impossible. For this reason, museum staff should test internet strength in the particular location in which AR is going to be added and not simply assume that internet strength is constant throughout the building.

Beyond access to high speed internet, it is important to consider device availability. The original methodology for this study called for visitors to download the app on their personal devices, however this assumption raised several issues. As experienced during the March trials, visitors who attempted to download Zappar to their smart phones could not do so using the GRPM internet as it was extremely slow. Additionally, visitors seemed inconvenienced by the idea of having to download an app to their phone, a concept that is addressed by Rodley (2011), who suggests that "getting

people to take the time to download and launch your app is the biggest hurdle you're likely to face" (Rodley 2011:1). For this reason, it is suggested that devices such as iPads or tablets with the pre-loaded AR application should be available for visitor use, either via a free rental option upon entering the museum or by mounting the device to the particular display that has been augmented. Furthermore, devices should be double checked for compatibility with the chosen AR platform. For instance, while Zappar boasts an impressive list of compatible devices, the app seems to run better on newer editions of products. So, while a museum may have an applicable device, it should be checked ahead of time to determine whether a different device might be better suited to handle the particular AR program.

Zapcode placement is another important finding that was illuminated during the March trial visit. Depending on the size and location of the zapcodes, the amount of time it takes to "unlock" zapcode content varies. For instance, the relatively small size of the zapcodes (roughly two inches) used in this study meant that it had to be in a well-lit area in order for the app to be able to read the code. The low-lighting of the GRPM diorama hall posed a challenge to the placement of certain zapcodes. The zapcodes were originally intended to be placed on the small identification labels that bordered the diorama; however due to poor lighting, some zapcodes had to be moved to the Plexiglas shield that bordered the diorama just above the identification labels. Although this was an easily fixable problem, zapcode location should still be considered in advance.

One additional concern about zapcode placement involves the decision to make the zapcodes temporary, semi-permanent, or permanent. As a temporary study, the

zapcodes were affixed to the marsh diorama using blue painter's tape during the March and June visits; however, this solution is not advisable for short-term or long-term use. While the painter's tape is easily removed and residue-free, zapcodes were frequently taken off and misplaced by small children during the March and June visits. Museums considering semi-permanent or permanent augmentation should use a stronger adhesive or reprint the labels to feature the zapcode.

Finally, findings from the March visit suggest that advertisement is a potentially valuable tool for long-term AR exhibits. Considering the temporary nature of this study, advertisement was virtually non-existent and took the form of a simple 8"x 10" sign that was placed in front of the marsh diorama. The sign went unnoticed for the entirety of the March trial period and was therefore excluded from the June visit for this reason. However, museums interested in pursuing long-term AR exhibits might consider advertisement in attempt to first alert visitors to their options during their museum visit, and to potentially attract a new visitor base that it comfortable with and/or interested in technology, such as children and young adults.

Post-Augmentation Observation Findings

Following the March and June 2017 observations in which visitors were asked to interact with the augmented Michigan Marsh diorama using Zappar, several conclusions were reached regarding the effectiveness of AR use on habitat dioramas. To reiterate, this section will focus specifically on post-augmentation data and the observed connection between visitors, the marsh diorama, and technology's role in improving this relationship.

Using Zappar's data collection capabilities, known as "zapalytics," information was collected concerning the total number of zaps, average zap times, total zap times, individual zaps per zapcode, countries engaging with the zapcodes, device platforms used, and the time of day zaps occurred. Considering the zapalytics data as a whole, trends regarding the most popular (or unpopular) zapcodes were illuminated; these trends hint at what kind of content is most likely to engage a visitor and ultimately suggest ways to improve less popular zapcode content. These analytics were used in tandem with visitor observations during the March and June visits to assess the overall effectiveness of AR use with habitat dioramas. In general, the findings from both the zapalytics and visitor observations suggest that AR increases visitor engagement with habitat dioramas.

It should be noted that while the zapalytics concerning the "countries engaged," "device platforms used," and the "time of day zaps most frequently occur" are interesting, they are not relevant to this particular study. Due to the singular location and limited parameters of the study, "countries engaged" is already known, "device platforms used" is strictly iOS because only apple products were available to participants, and "time of day" was predetermined as the study was conducted during specific days and hours and was neither ongoing nor long-term. Had the study been conducted on a larger scale, these Zapalytics categories would have ultimately contributed to a richer data set.

Looking at the data set as a whole, 47 visitors over the course of two days netted a total of 14 zaps with an average zap time of 47 seconds per zapcode, resulting in a combined total zap time of 2 hours and 48 minutes. It should be noted that although

there were two observation periods, the March observations were primarily intended to be a trial period and therefore did not result in any visitor engagement with the diorama via Zappar. With this in mind, the zapalytics data set reflects the observations that occurred in June. Figure 18 expresses the total number of zaps on an individual zapcode basis, represented in blue, in comparison to the total length of time each code was used, represented in orange. Likewise, Table 5 depicts each elements' pre- and post-augmentation results, ultimately showing a significant increase in engagement, particularly among unpopular pre-augmentation elements. In Table 5, elements that have either increased or decreased in popularity post augmentation have been highlighted in grey.

Breaking the data down further, it is apparent that some zapcodes were more attractive to visitors than others, and in general, the level of attractiveness was dependent on active, video, photograph, and game elements. The most popular zapcode was the osprey, getting 31 zaps, an average zap time of 46 seconds, and a total interaction time of 23 minutes and 48 seconds. This data is perhaps unsurprising due to the fact that the osprey was a popular element within the display pre-augmentation. However, during the February visitor studies, the osprey was almost unanimously misidentified as a "hawk," whereas the during the June observations, visitors using Zappar to interact with the marsh display correctly identified the bird as an "osprey." This was most likely due to the fact that participants had to focus on the osprey identification label as this was the location of the zapcode. As a result, participants appeared more likely to connect the identification label with the animal in the exhibit.

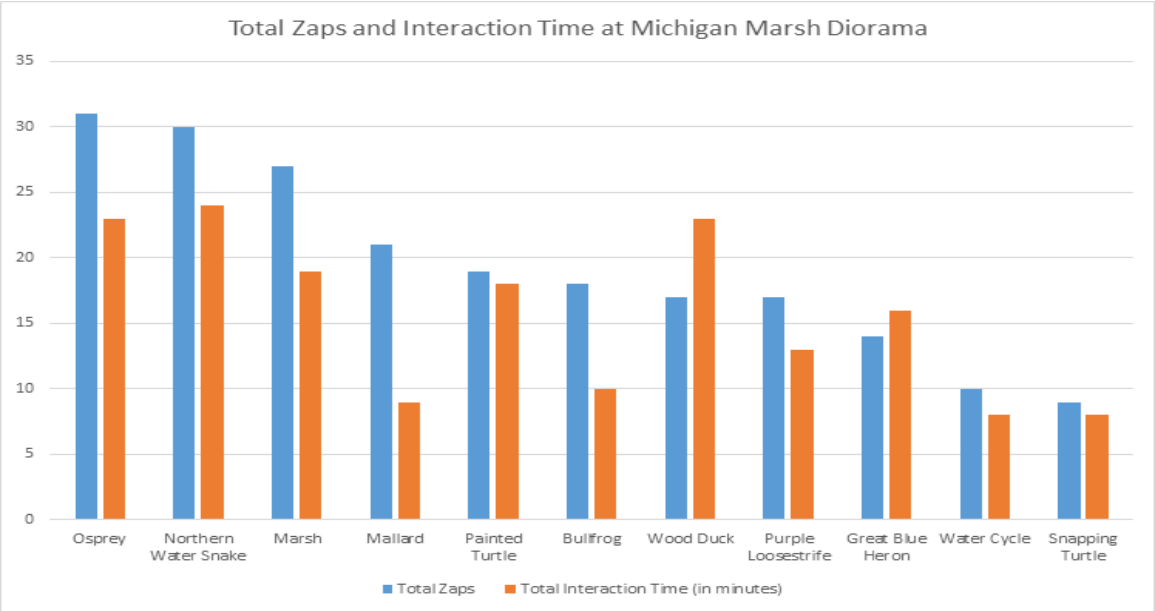

Figure 18. Total zaps and interaction time at the Michigan marsh diorama.

Table 5. Pre- and post-augmentation changes in element popularity.

Elements	Pre-augmentation	Post-augmentation
Snapping turtle	Popular	Unpopular
Western painted turtle	Popular	Popular
Bullfrog	Popular	Popular
Northern water snake	Popular	Popular
Osprey	Popular	Popular
Water cycle label	Popular	Unpopular
Purple loosestrife	Unpopular	Unpopular
Wood duck	Unpopular	Unpopular
Great blue heron	Unpopular	Popular
Mallard duck	Unpopular	Popular
Watermilfoil	Unpopular	Popular
Marsh function label	Unpopular	Popular

Considering the total interaction time of 23 minutes and 48 seconds, a time that significantly overshadows the majority of other interaction times, it is important to consider both the typical participant and the available content. The overwhelming majority of users were children accompanied by adults, and as a result, the children seemed more likely to focus on video content. While several zapcodes had video content, the osprey video, which showed an osprey diving into a lake to catch a fish, was perhaps the most entertaining video, and in fact, children sometimes watched the video several times. Reflecting on the observations from the June visit, the popularity of the osprey zapcode is most likely the result of an already likeable element being given additional favorable content.

As the second most popular zapcode, the northern water snake received 30 zaps, had an average use time of 49 seconds, and a total interaction time of 24 minutes and 17 seconds. Similar to the osprey, the northern water snake was a popular element pre-augmentation. Although the reptile did not see the same identification success post-augmentation as the osprey did, it improved from being referred to as simply "a snake" during the February observations to the more specific title of "water snake" during the June visit. Again, this is likely the result of participants having to focus on the identification label in order to access the zapcode content.

Focusing on the lengthy total interaction time of 24 minutes and 17 seconds, the longest interaction time of any of the zapcodes, the northern water snake content was largely popular due to its video and game content. Although the video was largely non-active, showing the reptile sun bathing on a stone, participants still eagerly watched the

entire video, often commenting on the snake's large size. Likewise, the northern water snake was the only element to have a game component, a quiz that tested participant's knowledge of venomous and non-venomous snakes. Considering the quiz results, in which half of the participants scored a 60 – 69 percent or lower, it is likely that the audio content, which described the difference between venomous and non-venomous snakes, was not engaging to participants.

The marsh label zapcode, which netted 27 zaps, an average of 43 seconds, and a total interaction time of 19 minutes and 17 seconds, was the third most popular zapcode in the bunch. These findings are exciting because the marsh label was formerly an unpopular element pre-augmentation, receiving little to no attention. The marsh zapcode content was one of the simplest of the group, having only a brief audio explanation of what a marsh is and a video of a busy marsh during a bird migration. However, the simplicity of the content appeared to be the labels' greatest draw. Pre-augmentation, visitors were unlikely to read the small-print label or examine the faded photographs, resulting in no take-away from the content of the label. Post-augmentation, participants listened to the short audio blurb and then watched the full video. One additional draw to the zapcode was likely the noise from the video, which was unintentionally very loud; even at a low volume the audio quality was clear, robust, and very busy, accurately capturing the sounds of several thousand birds gathering at a marsh. As a result, participants waiting to use the iPads became curious about content and seemed more likely to engage with this particular label. Although the added audio and video content

was meant to increase visitor engagement, the drastic change in popularity with this particular label was somewhat unexpected.

The fourth most popular zapcode, the mallard duck, garnered 21 zaps, had an average interaction time of 28 seconds, and a total interaction time of 9 minutes and 48 seconds. Similar to the marsh label, the mallard duck experienced a significant increase in popularity post-augmentation. However, the increased popularity of this diorama element should be taken with a grain of salt. Taking a closer look at the zapalytics, the number of zaps is quickly outweighed by the low interaction time of 28 seconds. Having the lowest interaction time of any of the zapcodes, it is important to assess why this might have occurred.

Considering the June observations, it is apparent that the low interaction times are a result of both the position of the taxidermy mallard and the zapcode content. Although the mallard retains a favorable front-and-center location within the diorama, it is positioned in a dabbling pose in which its back end is bobbing out of the water, leaving its head completely obscured. While this position attracted several visitors' attention and commentary during the February observations, it hides the male bird's tell-tale identification features: the vibrant green head. For this reason, several visitors identified the mallard as simply "a duck" and may have struggled to connect the mallard featured in the zapcode content with the mallard in the diorama. Additionally, the zapcode content focuses more so on the mallard's relationship with watermilfoil, an invasive plant species, rather than the bird itself. While the video featuring a dabbling duck appeared to

be the biggest draw to participants, the explanatory audio and photos were largely unengaging.

Following the augmentation, the painted turtle continued to sustain visitor interest. With 19 zaps, an average zap time of 58 seconds, and a total interaction time of 18 minutes and 17 seconds, the painted turtle appeared to show no significant change in popularity. During the visitor observations in February, visitors tended to gravitate towards the reptile because of its familiarity. A typical interaction with the painted turtle involved a brief conversation discussing a personal interaction with the animal ("I've seen one of those at the pond"), or basic identification. This continued post-augmentation, however, as visitors were more likely to engage on a deeper level. For instance, participants were more willing to listen to the short introduction about the painted turtle and watch the short video featuring a painted turtle sitting on a log. Although the video was largely inactive, some participants, mostly young children, liked to re-watch the video. In general, the painted turtle's relatively low average zap times are likely a result of the light content, which was composed of only a short audio blurb, video, photos, and a brief, one-sentence label prompting visitor's to try and locate the turtle in the display.

Like the painted turtle, the bull frog remained a popular element post-augmentation. Having 18 zaps total, an average zap time of 35 seconds, and a total interaction time of 10 minutes and 36 seconds, the amphibian's popularity appeared to be largely unaffected by the introduction of AR to the diorama. However, this claim can be refuted by the qualitative data collected during the June observations. Although the

average zap time appears to be low, the June observations revealed that participant engagement was deepened post-augmentation. During pre-augmentation, several visitors properly identified the bull frog and shared a conversation, personal story, or inquired about the frog. This trend continued during post-augmentation, but was then increased by the zapcode content. For instance, the short audio blurb detailing the makeup of a bull frog's diet garnered surprised reactions and inspired conversation while the brief label explaining where a bull frog gets its name received similar reactions.

The wood duck, having 17 zaps, an average zap time of 49 seconds, and a total zap time of 14 minutes, is another element that received significantly more attention post-augmentation than it did pre-augmentation. During the February visits, the birds, which were located in the upper left-hand corner of the display, hardly received any attention. The introduction of a zapcode to the wood duck's identification label worked to draw in several visitors that would have otherwise not noticed the birds.

The wood duck content was one of the most heavily loaded zapcodes for several reasons; first, this bird is a conservation success-story, allowing for the augmented storyline to expand on human-environment relationships, second, its hidden location in the diorama resulted in low visitor engagement pre-augmentation, and third, it is an aesthetically attractive bird that I determined would interest visitors (similar to the draw that vibrant tropical birds or Peacocks have on individuals who might otherwise not be interested in birds). Additionally, the wood duck narrative featured informative audio labels in both English and Spanish, audio of the bird's call, a video of a male wood duck swimming and preening, several up close photos, and do-it-yourself wood duck house

instructions. Interestingly, although the wood duck's popularity was significantly increased, its average and total zap time remained relatively low. Observations revealed that users were mostly interested in quickly flipping through the photos and then watching only a few seconds of the video. In general, although attention was increased to this particular element, visitors seemed generally disinterested in the wood ducks. One possible explanation for this lack of interest might be the location of the ducks. Tucked away at the top of the display, participants seemed less likely to locate the ducks and then connect them to the zapcode content.

With 17 zaps, an average zap time of 46 seconds, and a total interaction time of 13 minutes, purple loosestrife's attraction qualities were significantly improved post-augmentation. Like the wood duck, the plant tended to hide within the exhibit and also offered the opportunity to bring human-environment relationships into the augmented content (due to its status as an invasive species); for this reason, it was given some of the heaviest zapcode content. Included in the content was an explanation of purple loosestrife's negative impacts on native species, specifically Manoomin, offered in both English and Spanish, supplemental images, a folk tale about Manoomin, and a video showing traditional Manoomin harvest methods. However, similar to the wood duck, the purple loosestrife zapcode struggled to maintain participants' attention given its relatively low average and total zap times.

The low interaction times were likely a result of the audio-heavy content; participants tended to look through the photos and then quickly switch to the more desirable video content, skipping the spoken content entirely. The main issue with the

progression of this interaction is that the participant receives no explanation of the relationship between purple loosestrife and Manoomin and instead becomes confused as to how photos of purple loosestrife are relevant to a video and folktale about Manoomin. This indicates that future augmented storylines need to contain content that doesn't depend on a specific viewing sequence, as that sequence will most likely not be followed by visitors.

The great blue heron zapcode received 14 zaps, had an average zap time of one minute and nine seconds, and a total zap time of 16 minutes and 12 seconds. Though on the lower end of total zaps, the average zap time of one minute and nine seconds suggests that the great blue heron's popularity significantly increased post-augmentation. For instance, pre-augmentation the birds, although positioned near the front of the exhibit and being the largest animals in the display, tended to receive little attention while post-augmentation the birds netted the longest average interaction times. This data implies that although the birds may have initially been unengaging to visitors, once the zapcode was activated, visitors became drawn in by the content.

The content, which featured several close-up photos of the bird, audio of its unusual call, short audio quips regarding it's hunting and preening actives, and two videos featuring a Great Blue Heron hunting and a visual explanation of preening, gave visitor's an attractive variety of options. The video content was the most popular, and viewed in tandem with the photos, several visitor's inquired about the bird's long beak, its diet, and if the beak was used for hunting. This inquiry could of course be answered by listening to the audio content, however it was frequently ignored. As a result,

participants who viewed the preening bird video, which featured a Hoopoe rather than a Great Blue Heron, had trouble connecting the preening action of the Hoopoe to the taxidermy heron in the display that was posed in a preening position. Regardless of the dissonance, visitor's seemed to enjoy the video content, perhaps because of its short nature and high quality.

As one of the more popular diorama elements pre-augmentation, the Water Cycle label turned out to be one of the least engaging elements post-augmentation with 10 zaps, an average zap time of 48 seconds, and a total interaction time of roughly eight minutes; this is almost certainly due to the zapcode content. Pre-augmentation, visitors, especially children, were eager to follow the progression of water through the cycle regardless of the label's faded quality. This was still the case post-augmentation, resulting in a disinterest in activating the zapcode; it appeared that the simplicity of the label was enough for visitors. Additionally, when the zapcode *was* activated, several visitors were unengaged by the simple animation showing the water cycle, perhaps due to its slow progression and lack of audio. The video, which was slightly dated in appearance, was a result of having limited public domain options, an issue that museums may struggle with depending on their augmented storyline topic.

Perhaps the most surprising finding of the study was the unpopularity of the snapping turtle zapcode. With only nine zaps, an average of 59 seconds, and a total interaction time of 8 minutes and 49 seconds, the most popular element of the marsh display pre-augmentation became the least popular element post augmentation according to Zappar. However, when this data is considered in tandem with participant

observations, it becomes apparent that the snapping turtle is a significant draw to the display regardless of AR. For example, February visitor observations concluded that the Plexiglas viewing window that allowed individuals to look under the marsh waters and see the snapping turtle was easily the most popular element in the exhibit. This was still the case during the June observations - but why didn't this trend appear in the zapalytics? The simple answer is that participants were so eager to look through the underwater window and point out the snapping turtle that they seemed to forget they were holding an iPad! To the participants, simply examining the reptile through the Plexiglas was more interesting than using the iPad to further engage. This is positive news for museums fearing that the use of technology within an exhibit will take away from the experience or distract from the objects.

AR Product Comparison Findings

Following the completion of the product comparison between Aurasma, Layar, and Zappar, conclusions regarding the feasibility of AR use within museums of varying size and financial capability can be asserted. Likewise, these assertions are supported by Rodley (2011). In *Looking Around vs. Looking Down: Incorporating Mobility into your Experience Design*, Rodley (2011) discusses the use of mobile apps within museums and describes six key components of a successful mobile app. As outlined by Rodley, successful apps hit these six points: appropriate for the medium, relevant to visitors, encourages authentic feedback, possesses a narrative, doesn't skimp on quality, and is free (Rodley 2011:37-40). Addressing the common fear that mobile devices will detract from the museum experience, Rodley posits that apps should be both

immersive and contextualizing in order to add to the museum experience rather than take away from it (Rodley 2011:35). While an immersive app, such as a game, might provoke visitors to "look down," a contextualizing app, one that encourages "looking around," will enable the mobile phone to become a transparent medium (35). A combination app that employs immersive and contextualizing qualities motivates visitors to engage with new or unfamiliar concepts through a familiar and comfortable medium.

Reflecting on the six highlighted qualities of a successful mobile app, "appropriate for the medium" tops the list. Rodley suggests that the app should incorporate the functions of a mobile phone that are most commonly used; this includes watching video, listening to audio, taking photos, playing games, and sharing media (Rodley 2011:37). Selecting an app that takes advantage of these commonly used functions increases the chance that it will be utilized by museum goers. In this same vein, a successful app should first be "relevant to visitors, not the institution" (37). In short, institutional priorities should reflect the visitors' needs, not the other way around. Ensuring that the mobile app is relevant to visitors means that the institution should "encourage authentic feedback" (38). With this in mind, a successful app should not only provide a context for visitors to comment on app content but also allow visitors to take an active role in contributing to the type of information diffused within museums. Rodley suggests that this kind of meaningful interaction can take a form as simple as allowing visitors to tag labels with inaccurate or out-of-date information (39), a component that could do wonders for an aged habitat diorama.

Additional attributes of a successful app include narrative-driven content, high quality media, and a free or low cost price tag. Rodley suggests that a strong narrative can breathe life into an exhibit that might not have “blockbuster” artifacts, and additionally, multiple narratives can be offered on a single app, increasing the opportunity to connect visitors to objects that might otherwise be passed by (39). Likewise, investing in high quality photos, sounds, and overall content increases the chance that visitors will invest their time in using the app (40). Finally, Rodley suggests offering the app for free to appeal to a wider audience base (40).

Reflecting on the capabilities of Aurasma, Layar, and Zappar, each of these platforms have the ability produce successful apps for museums in some form or another. Regarding Rodley’s six identified hallmarks of a successful app, all three of these platforms are an appropriate medium for the museum due to their capacity to capitalize on commonly used mobile phone functions such as video, audio, and image viewing. However, Layar and Zappar go beyond Aurasma because they facilitate media sharing and gaming via their social media and customizable button functions. As a result, Layar and Zappar can connect users both inside and outside the museum walls by encouraging content sharing. In this way, Layar and Zappar utilize more of a mobile devices’ popularly used functions, making them slightly more advantageous than Aurasma for use within museums. In particular, museums seeking out a younger visitor base might be more inclined to choose Layar or Zappar over Aurasma because of the platform's’ ability to share content on social media websites such as Facebook, Twitter, or Instagram.

Apropos of Rodley's second recommendation that a successful app should first prioritize the desires of the visitor, all three platforms are exceedingly capable of producing visitor-oriented experiences pending the institutions' knowledge of its visitor base. Ultimately, the likelihood that an app will create relevant experiences for visitor populations is less dependent on the platform itself and more dependent on the institution's awareness of the community it serves. All three platforms wield powerful technology that can be creatively employed to enhance visitor experiences but only if the institution is willing to ask and listen to its visitor base. Through prioritizing open-communication with diverse members of the community it is meant to serve, museums of various size and topic can utilize Aurasma, Layar, and Zappar as tools that facilitate and reflect the pulse of the community.

Working in this same vein, Aurasma, Layar, and Zappar can serve as a line of communication between the visitor and the institution; Rodley marks this as a characteristic of a successful app because it invites visitors to comment on and critique exhibition content via a comfortable and familiar device. While visitor comment boxes are common within museums, Aurasma, Layar, and Zappar are capable of creating experiences in which visitors can give feedback. Due to the ubiquity of mobile devices, visitors might feel more comfortable and therefore more likely to comment on museum content from their mobile device. Additionally, all three platforms have the technology capable of producing creative formats for visitors to give feedback. Rather than filling out a slip of paper at the front of the museum and attempting to remember their critiques or comments, visitors could potentially use their devices to create auras, pages, or zapcodes

on the spot that alert museum staff to broken exhibits, out-of-date information, or areas for content improvement. Similar to the second recommendation on Rodley's list, the successful fulfillment of this advice is primarily dependent on the museum's willingness to create an app that facilitates communication with visitors. Ultimately, all three platforms provide museums with the tools needed to enhance interactions with visitor populations. However, for larger institutions in particular, Layar and Zappar offer analytics that might provide useful insight into problematic areas of exhibitions. For instance, by looking at which pages or zapcodes are scanned and commented on the most, museum staff can more easily pinpoint troublesome areas and prioritize content alteration. As shown within this thesis, Zappar's zapalytics were particularly useful in highlighting which augmented features were the most and least popular among visitors.

Reflecting on Rodley's suggestion for narrative-driven and high quality apps, Aurasma, Layar, and Zappar offer the technology capable of producing multiple and layered storylines accompanied by sharp video, audio, images, and animation within a single exhibition space. Prioritizing the needs of a diverse visitor base, multiple narratives allow visitors to engage with ideas or objects from multiple perspectives and at varying depth. Aurasma, Layar, and Zappar are capable of producing contextualizing apps that lead visitors from location to location through an interactive storyline and encourage looking around rather than looking down. For instance, all three platforms have the ability to support scavenger-hunt style narratives in which visitors are challenged to read content, reflect on its meaning, and be led to the next interactive location or object. Likewise, high quality, aesthetically pleasing media that is supported on all three

platforms keeps visitors engaged and invested in the story. While Aurasma, Layar, and Zappar all support animation and 3D models, Zappar affords creators the ability to produce virtual reality experiences, a component that might be particularly intriguing to larger institutions or those with the resources to provide visitors with the technical equipment needed such as headsets or products like Google Glass or Google Cardboard.

Last on Rodley's list, but arguably one of the most important hallmarks of a successful app, is price. This is perhaps the area at which Aurasma, Layar, and Zappar differ the most. While all three platforms boast free mobile apps for iPhone and Android, access to the online studios can be costly depending on the selected platform. Rodley appears to be speaking mainly about visitor's access to free apps, but because all three platforms have free apps available to the public, the issue of price is being refocused onto the institutions for this discussion. Considering Aurasma, a non-commercial account is free and therefore appealing to both small, financially stressed institutions and large institutions looking to increase savings. Non-commercial accounts have the same capabilities as Commercial accounts, the only difference being that Aurasma does end-to-end app creation, branding, and support for a baseline cost of roughly $5,000. Considering Aurasma's easy-to-use interface, museum staff with limited or intermediate technological backgrounds should be able to create a meaningful and engaging app using the free Non-Commercial account.

Adversely, Layar's Basic and Pro accounts end up being significantly more expensive than Aurasma; at $3.50 a page, a museum building an interactive app using the Basic account would quickly rack up a bill considering the number of pages that would

need to be created for a contextualizing, narrative-driven app. Furthermore, using a Basic account, pages are only public for 30 days, making Layar a more financially demanding platform. Likewise, a Pro account makes content available for a full year but at $34.00 a page, most institutions, especially those that are smaller and/or more resource-strained, would benefit from selecting a less expensive platform or using Layar for short-term marketing or branding projects rather than educational content.

Finally, Zappar offers a range of accounts at affordable prices; depending on the style of institution (non-profit or for profit), Zappar provides a Business account for $135.00 a month and an Education account for $247.00 a year. Given the educational function of an app for museums, institutions could utilize the Zappar Education account and save a significant amount of money, ultimately making this platform most feasible for small to medium sized institutions looking to invest in a mobile component or a large institution with more financial, staff, and time resources to commit to a Business account.

Ultimately, a comparison between Aurasma, Layar, and Zappar that considers ease-of-use, technical capability, and cost supports the assertion that AR technology is an entirely feasible option for museums of varying size and financial capacity. While not all AR platforms are created equally, the market is vast enough to cater to the unique needs of an institution and the community it serves. With this in mind, Aurasma, Layar, and Zappar are just three widely used and accessible platforms that can enhance learning objectives, insert more diverse and multivocal narratives into the exhibition space, encourage dialogue between visitors both inside and outside of the museum, and open new lines of communication between the community and the institution.

Discussion of the Findings

Considering the findings from the February, March, and June observations, the zapalytics data, and the AR product comparisons in relation to the three key questions outlined, several conclusions can be reached regarding the effectiveness of AR in improving habitat dioramas. In reflecting on the findings from each stage of the study, all three of the questions can be answered with support from qualitative and quantitative data, relevant literature, and selected theoretical frameworks.

In posing the first research question of the study, which seeks to determine whether habitat dioramas should be kept for nostalgic purposes or be replaced by more up-to-date exhibits, the answer is both yes and no. Aged habitat dioramas should be not be physically replaced, but rather strategically updated using innovative and non-invasive technology such as AR. In the case of dated dioramas, the nostalgia experienced by a visitor can be used as an important educational tool that alerts individuals to the significant changes that have taken place between the past environments displayed in dioramas and the environments of today.

Aged habitat dioramas are, in themselves, a piece of history, carrying an important message about anthropomorphic habitat alteration, biodiversity loss, and conservation; to remove them from museums would be to eliminate a powerful visual comparison between past and contemporary environments. These displays have already proven their ability to increase scientific thought, inquiry, and conversation, and the findings from this study suggest that these educational outputs can be increased by simple and accessible technology such as AR. Furthermore, keeping these nostalgic displays

affords museums the opportunity to non-invasively update the dioramas with technology, an affordable and attractive option that can increase the museums relevancy to its visitor base. In general, the negative functions of habitat dioramas are significantly outweighed by their positive attributes, making them the perfect recipients of technological updates such as augmented narratives. In this way, these nostalgic displays are preserved and at the same time updated, resulting in a solution that benefits both museums and their visitors.

Considering the data collected from the February visitor studies at the GRPM, it can be asserted that while the Michigan marsh diorama suffers from several problems associated with age, it is still capable of attracting visitors of all ages, prompting scientific discussion and inquiry, and inspiring curiosity and excitement. Reflecting on the observations from the visitor study, it is evident that both the positive and negative functions of habitat dioramas, as posited by the literature review, were clearly expressed within the data. Assertions made by Reiss and Tunnicliffe (2009), Scheersoi and Tunnicliffe (2009), and Ash (2004) boast the positive attributes derived from visitor interactions with habitat dioramas such as an increased interest in biology in children, boosted scientific inquiry and interpretation, and improved observational and critical thinking skills. Again, data collected during the visitor study directly supports all of these claims and can be observed in multiple instances. For example, repeated occurrences of pointing, species identification, inquiry, discussion, and storytelling between children and children and adults confirms the positive derivatives of habitat dioramas.

Likewise, the negative functions of habitat dioramas were similarly expressed within the data. Visitors were observed rarely reading the labels, a common issue at habitat dioramas, especially those that look out-of-date (Scheersoi and Tunnicliffe 2009; Garibay Group 2008). The small print, lengthy paragraphs, and discolored photos all attributed to the lack of visitors who paused to read the labels during the visitor study. Passiveness and interactivity, an additional negative facet of habitat dioramas (Garibay Group 2008), was evident in the ways in which visitors appeared to ignore the left side of the marsh exhibit due to its lack of interactives. Finally, the marsh diorama fell prey to exhibiting seemingly pristine views of nature in which distributing realities were edited out (Reiss and Tunnicliffe 2011). For instance, the diorama displays an array of species clustered happily in front of a vibrant blue sky - death, sickness, and pollution all excluded from the scene.

However, the marsh diorama departs slightly from the expected absence of humans within habitat dioramas (Reiss and Tunnicliffe 2011:447-459) by showcasing the old wooden rowboat at the center of the display. Although a seemingly extraneous element, the rowboat calls attention to the presence of humans within nature and provides ample opportunity for the augmented storyline to address anthropomorphic biodiversity change and loss. Likewise, the diorama displays invasive plant species such as purple loosestrife and watermilfoil, presenting a subtle but real issue that plagues Michigan biomes; the choice to include invasive species within the display means that this aged diorama is still relevant to contemporary representations of ecology, unlike many other aged habitat dioramas (Marandino et al. 2015:256). Although the marsh diorama has

avoided some of the negative attributes frequently contributed to this form of display, the somewhat idealistic portrayal of the marsh and the relative lack of resonating visitor engagement suggests that, similar to other aged habitat dioramas, the display requires update if it is to be self-reflexive and pluralistic.

With these findings in mind, it can be asserted that by viewing the Michigan marsh diorama within a New Museum Theory framework, issues resulting from age can be transformed into assets. In New Museum Theory and Practice (2008), Janet Marstine explains that New Museum Theory posits that while museums are often perceived as being pure or authentic, these institutions are not neutral and wield the capability to shift meaning-making to the communities they serve through transparency, cross-cultural exchange, and the consideration of several viewpoints (Marstine 2008:2-5). Although the marsh diorama exhibits several issues, specific elements within the display can be highlighted and improved using AR, with the ultimate goal of increasingly its relevancy to a more pluralistic visitor base. Relying on the findings from the February visitor study, portions of the display were improved upon by making them more applicable to a diverse visitor population and by linking said elements to important contemporary environmental issues. As a result, the augmented content is useful on two levels; it works to increase relevancy among more diverse audiences and highlights nuanced perspectives within the marsh display, such as the detrimental impacts humans frequently have on the environment.

For instance, the augmented storyline provided portions in Spanish in attempt to invite non-English speakers to engage with the display. During the February visitor

study, a handful of Spanish speakers were observed engaging with the display, ultimately drawing attention to the blatant exclusion of non-English speakers from not only the marsh diorama, but also the museum as a whole. By providing portions of the augmented storyline in Spanish, the diorama automatically becomes more accessible to a larger and more diverse visitor base. As a result, the incorporation of a bi-lingual experience affords Spanish speakers the opportunity to switch between English or Spanish at their leisure, enables Spanish speakers to take on a more active role as an explorer or facilitator if they were not fluent in English, and signals to the Spanish speaking community that they are valued by the museum.

Likewise, the augmented storyline worked to illuminate portions of the display that are relevant to Anishinabek communities. In its baseline condition, the marsh diorama fails to allude to local native populations whose cultural practices can be traced to specific plants found in marshes; following augmentation, visitors could learn about purple loosestrife, an invasive plant that has significantly impacted the growth of Manoomin, a culturally important crop to the Anishinabek. Augmented content associated with the Manoomin storyline attempted to shift the meaning-making to the Anishinabek by providing a community-made video that explains the cultural importance of the Manoomin harvest. Likewise, the inclusion of the purple-loosestrife-as-an-invasive-species narrative allows visitors to engage with concepts of anthropomorphic environmental degradation, an imperative storyline that contemporary museums should be pushing.

AR, Environmentalism, and the New Museum

Additionally, augmented storylines that focus on conservation alert visitors to important contemporary environmental issues. According to New Museum theory, museums are capable of framing issues and concepts, and in the face of climate change and biodiversity loss, it is imperative that these institutions are not neutral on such pressing matters. With this in mind, Marstine suggests that framing is "a metaphorical process that creates a vision of the past and future based on contemporary needs" (Marstine 2008:4). Therefore, because the contemporary need should be to alert the public to matters of biodiversity loss and conservation, an aged but augmented habitat diorama presents the ideal opportunity to frame past, present, and future ways of thinking about the environment. In this way, aged but augmented habitat dioramas are the perfect tool to draw attention to conflicting and contrasting views of the past. While the marsh diorama, in its dated condition, might lack obvious references to humans, the newly added augmented content highlights the various ways in which humans have and continue to impact the environment. For instance, the wood ducks and osprey augmented storylines tell positive conservation stories about humans' capability to reverse the harm caused, while the purple loosestrife and watermilfoil content addresses current human-caused issues that need to be considered in both present and future conservation efforts. In using AR to highlight areas of improvement, the GRPM becomes more transparent to its community by expressing the need for updated content that more closely aligns with the conservational message that a hall of habitat diorama *should* be pushing.

Ultimately, through augmentation, the formerly static marsh diorama was transformed, if only for a few days, into an area of active visitor engagement in which multiple narratives and viewpoints were expressed and explored. While the February visitor study drew attention to the kinds of issues that might prompt a museum to remove its aged habitat dioramas, the positive attributes of this form of display should not be so easily dismissed. As contemporary museums strive to become as diverse as the communities they intend to serve, technology such as AR can be utilized to both update these old displays and express the institutions' commitment to remaining relevant to pluralistic and current needs. For this reason, aged habitat dioramas should not be removed from museums; they are valuable snapshots of the past that can be used to compare, contrast, and prompt concern about the present and future states of the environments on display.

Considering the second research question, which asks whether the use of AR can preserve and update habitat dioramas in order to meet the desires of contemporary museum goers, the findings from the augmentation process and the March and June visitor observations suggest that AR is capable of transforming these displays into relevant and current exhibits. To support these claims, the augmentation process and March and June visitor observations will be discussed in relation to Falk's Visitor Identity Motivation theory, Hooper-Greenhill's Post-Museum, and Sharples et al.'s (2007) Mobile Learning theory to exemplify the ways in which AR is capable of meeting the desires of contemporary museum goers.

Reflecting on the augmented storyline creation, careful attention was paid to literature that fleshed out the dos and don'ts of technological additives. Providing visitors with a technological interactive is one thing, but making said interactive meaningful is another. To avoid the production of either a meaningless augmented storyline or one that is overly saturated, dry, and/or unengaging, work by Rodley (2011), Tsai and Sung (2012), and Marques and Costello (2015) was closely examined. In general, all three pieces of literature press the importance of creating technological interactives that enhance or transform the visitors' mindset through the use of high quality, free media. Data collected from the February visitor study helped to identify what aspects of the marsh diorama were valued by visitors, what areas required re-address, and what type(s) of visitor the AR storyline would need to address. As a result, the storyline attempted to turn the static marsh diorama into an interactive display in which visitors could further engage with popular aspects such as the snapping turtle, be introduced to commonly overlooked elements such as the wood ducks, deepen their knowledge of familiar animals such as the northern water snake, and be alerted to a range of cultural and environmental topics.

With all of the information organized into a storyline, media was selected that could be enjoyed by a variety of ages and visitor identity types. Because Falk's Identity-Related Motivation theory posits that meaning-making within museums directly correlates to an individual's identity-related motivations, it is apparent that a single narrative or form of media is not sufficient enough to meet the needs of a contemporary and diverse visitor base (Falk 2006:121). Therefore, the augmented storyline was

composed of videos, photos, audio content, and miscellaneous media that presents easy-to-digest scientific facts, in-depth historical, environmental, and cultural narratives, and appealing visual prompts suited for a multitude of visitors. For instance, animal videos and photos were selected with younger visitors or facilitator types in mind, while lengthier audio content available in both English and Spanish was created for experience or professional type visitor identities who would be more likely to desire in-depth substance. By categorizing visitor types that frequented the marsh display, diorama augmentation attempted to improve visitor interaction; this was achieved by fabricating creative content catered to visitor's identity-related needs while simultaneously reaching audiences that may have been previously excluded from GRPM diorama hall.

Likewise, the concept of the Post-Museum was consulted in tandem with Mobile Learning theory during the augmented storyline creation. Opportunely, these theories work well together because Hooper-Greenhill's Post-Museum concept asserts that museums must have multiple platforms from which visitors can be engaged and scientific imagination can be nurtured and likewise acknowledges the role of mobile technology in achieving these goals. Similarly, Sharples et al.'s (2007) Mobile Learning theory posits that mobile technology itself not only caters to a variety of learning platforms, but also creates contexts for learning by providing the resources for conversation to continue across time and space. Reflecting on these frameworks, the creation of the augmented storyline attempted to strike a balance between focus on the augmented additives and the actual marsh diorama. As previously stated throughout this thesis, the augmented storyline and content is meant to add to the visitor experience

rather than distract from the physical display. With this in mind, augmented content attempted to constantly draw the visitor back to the actual display; in this way, the addition of a new technological learning platform did not decrease interaction with the primary learning platform - the diorama itself. For instance, augmented content built off of information already available within the display, therefore requiring the visitor to focus on and engage with selected elements within the diorama.

As a result, this balanced approach allowed two learning platforms, one based in reality and the other in digital, to be blended. In creating the opportunity for unification, visitors are given the chance to utilize one or both learning platforms, depending on individual motivation. Likewise, the addition of a digital learning platform not only creates an alternate way for visitors to learn and engage, but also leads to more personalized learning and conversation outside of the museum context. For instance, the augmented storyline provides users with a link to a simple wood duck house that can be built at home after learning about the bird's nesting needs. Furthermore, if used on a personal device, Zappar allows users to take photos and video with the augmented layer and has social media sharing capabilities, allowing the experience to be shared with others outside of the museum.

Following the creation of the storyline, the augmentation was implemented at the GRPM in March 2017. While this event eventually devolved into a test run due to technical difficulties, the March visit provided ample insight into the components necessary for a successful AR exhibit that is appealing to contemporary visitors. As previously mentioned, the March visit suffered from the absence of communal devices,

poor wireless connection, and a lack of advertisement. While these issues are important to confront, the most essential findings from the March visit relates to users' device preference.

In contrast to the notion that mobile devices, such as smartphones, personalize the museum learning experience, as suggested by Kahr-Højland (2007), Sanchez (2010), Economou and Meintani (2011), Rodley (2011), and Tomiuc (2014), the March visit highlighted visitor's reluctance to use their personal mobile devices. While it is true that mobile technology promotes continual learning, creates informal learning environments, and personalizes users' access to material and the pace at which the material is delivered (Sharples et al. 2007:2-13), user's still seemed reluctant to use their own devices. When participants were asked to interact with the marsh diorama, the majority seemed inconvenienced by the thought of downloading the Zappar app to their own phone; the download would take time, use their data, and take up space on their phones, three very unappealing elements to smartphone owners. Generally speaking, the visitors found a mobile app that can only be used for a single exhibit to be unworthy of the time or energy required to access the content.

Although smartphones are capable of fostering mobile learning and offering visitor's multiple learning platforms, it seems that access to the technology must, above all, be convenient. While it is ironic that personal mobile devices are toted as being the epitome of convenience, smartphones appeared to be the incorrect tool choice for this particular study, due to the level of inconvenience for downloading Zappar. Mobile devices are of course still relevant to the museum experience; however, a shareable

device provided by the museum is preferable for smaller, augmented exhibits such as the marsh diorama in this study. Hooper-Greenhill (2000) and Sharples et al. (2007) are not wrong to suggest the positive capabilities of mobile devices within museums. However, it should be noted that smartphones are not a one-size-fits-all solution to updating tired exhibits. Recognition of this fact from the March visit led to removing personal devices from the equation and replacing them with communal iPads.

Considering the data collected from visitor observations and zapalytics during the June visitor study and diorama augmentation, several conclusions regarding the apps capacity to meet the needs of contemporary visitors can be reached. Perhaps the most significant conclusion reached was the visitor identity type that was most drawn to the augmented diorama. Explorers were the most engaged visitor type. The explorer identity type, as posited by Falk (2006), is motivated by curiosity. Almost exclusively taking the form of a child, the explorer type was by far the most likely to experience increased engagement with the marsh diorama, a result most likely springing from the presence of an iPad. The iPad was extremely appealing to children, and often times the child would approach to inquire if they could use the device before being asked. Although the Zappar app was new to almost all of the participants, the majority mastered use of the app within seconds, and in some cases, the children had to show their parents how to work the app.

The simple addition of the iPad drastically increased the level of engagement between the explorer identity type and the marsh diorama in several ways. First, unpopular elements within the display increased in popularity following augmentation; two prime examples of this are the great blue heron and the marsh label. Almost

exclusively ignored pre-augmentation, qualitative and quantitative data from the visitor observations and zapalytics showed frequent and sustained engagement. For instance, the marsh label became the third most popular element within the diorama while the great blue heron sustained the longest engagement time according to the zapalytics data. While these findings are highly encouraging, the observations from the June visitor study suggest that the increased engagement was primarily a result of the media used rather than the content.

Because the AR was most attractive to children, the preference towards augmented elements was reliant on access to quick and easy-to-digest video and photo content. For instance, while the purple loosestrife and wood duck zapcodes experienced a significant increase in engagement, their interaction times remained low. Conversely, elements such as the osprey and northern water snake remained highly popular. While all four of these elements had video and photo content, the osprey and northern water snake content could be described as being geared towards the explorer type while the purple loosestrife and wood duck content was designed for the professional/hobbyist type. For example, the osprey content included a video of an osprey hunting, which was very popular among groups of children, while the northern water snake content had a video and a simple picture quiz. Likewise, the wood duck and purple loosestrife content had videos but were primarily composed of lengthier audio content that was geared towards individuals seeking out specific and in-depth information. However, because this visitor type, the professional/hobbyist, desires content-related objectives from their museum

visit (Falk 2006:120) and was largely absent from the data set, the purple loosestrife and wood duck narratives experienced a lack of engagement.

Additional data trends that resulted from the dominance of the explorer type visitor include the preference towards familiar animals and an increase of accurate species identification resulting from group conversation. Considering the preference towards familiar animals, children seemed to choose animals they have likely encountered in the wild, such as the painted turtle and bull frog. The recognition of these diorama elements resulted in children wanting to access the Zappar content first. For example, when given the iPad, children seemed more likely to choose animals that they recognized first. Only when all of the familiar animal zapcodes had been clicked on would children move to less familiar animals. This trend was even more apparent within groups of children, who wanted to learn about the familiar animal and then share an experience they had with the particular animal.

Likewise, group use of the iPad among children appeared to increase accurate identification of species. Because there were only two iPads available during the June visit, groups of three to four children would share the device, an act that ultimately increased scientific inquiry and dialogue. Children were vocal about the animals they wanted to see and the group discussion that followed resulted in improved identification of both familiar and unfamiliar species. For instance, after viewing Zappar content about the osprey, northern water snake, and painted turtle, children were more likely to start referring to the animals by their accurate name and also correcting peers who misidentified the animal. For example, after viewing Zappar content, the “hawk” became

the “osprey,” the snake became the “water snake,” and the “turtle” became the “painted turtle.” This simple improvement in species identification also carried over to child-adult interactions. Adults, who frequently took on the facilitator identity type, seemed to encourage the selection of animals that would be most familiar to children such as the bull frog or painted turtle, and in selecting these recognizable animals, dialogue often reinforced the correct identification of the species.

Regarding the facilitator visitor type, who frequently fulfilled the role of a parent or chaperone on a school trip, this individual was the second most prominent type observed during the visitor study but also the least involved. While the facilitator did engage with the augmented diorama when encouraged by the children, this visitor type appeared to prefer disengagement. This is unsurprising as the facilitator type is identified by Falk as being the enabler of others who want to attend the museum (Falk 2006:120). In short, facilitators are primarily motivated to visit for the sake of others rather than for personal content consumption. However, because the explorer and facilitator types were the two most prominent kind of visitor to the diorama, a serious look must be taken at the lack of engagement from facilitators. Though perhaps naturally less engaged than other visitor types, facilitators are still contemporary visitors and therefore AR and other technological additives should attempt to meet their museum-related desires.

During the creation of the augmented diorama, portions of the content were geared towards facilitators; for instance, short labels asking questions such as “can you find the northern water snake in the display?” were meant to act as queues for the facilitator to interact with the explorer. In this way, the content did not demand serious

engagement but rather encouraged dialogue between the facilitator and the individual(s) accompanying them, however, this was typically not the case. While there are several reasons the facilitator type could have chosen to disassociate with the augmented diorama, a 2004 study at the Uffizi Gallery in Florence highlights an inherent issue between facilitator types and mobile technology.

During the Uffizi study, researchers Brugnoli and Murelli monitored 28 visitors as they explored the gallery space. Because the gallery had very little information for visitors beyond the title of the artwork and the artist, participants were given mobile phones, Personal Digital Assistants (PDAs), pocket PCs and notebook computers equipped with an MOBIlearn system, a software containing extensive information about the artwork (Brugnoli and Murelli 2007:311-335). The findings from the study suggested that younger individuals, who knew less about the artwork, tended to be more interested in the MOBIlearn system (Brugnoli and Murelli 2007:311-335). Brugnoli and Murelli's separation of age indicates that younger users were perhaps more comfortable with the technology provided and were therefore more likely to benefit from the MOBIlearn system.

This assertion is supported by the data collected during the June GRPM studies which found younger participants to be significantly more interested in the technology and also quicker to adapt to the Zappar app than their older, facilitator counterparts. This observation is not meant to generalize that all explorer types are technologically-interested children and that all facilitator types are technologically-disinterested adults. However, in the case of the GRPM June visit, evidence is provided

for this argument. Considering the context of the study, this assertion is not surprising. While the GRPM diorama hall is attractive to all ages, it is primarily geared towards younger audiences, as indicated by the play area and puppet theater that dominates the space. AR content is absolutely capable of meeting the desires of contemporary museum goers. Yet, select visitor types will without a doubt be more engaged than others, depending on the exhibit context. In the case of the marsh diorama augmentation, the explorer type visitors were engaged while the facilitator type visitors were not. This is not to say that a solution cannot be reached through additional studies. Developing a new technology such as AR within a museum is certainly possible, and will take trial and error to produce a product that meets the desires of all visitor types and subsequently, a diverse visitor base. Likewise, although the augmented diorama was only highly successful among a specific type of visitor, several positive outcomes can still be noted.

First, developing an AR program forces museums to consider what type of visitor they are attracting and affords these institutions the chance to create an updated and more diverse exhibit that caters to previously excluded visitor types. In the case of the GRPM study, explorers and facilitators were identified as being the most common type of visitor, however the lack of facilitator engagement with Zappar signals that additional, facilitator-geared content must be added to the AR storyline.

Second, creation of an AR program gives museums the opportunity to connect with the community, allowing for collaboration, dialogue, and a shift in authority and meaning-making. While this particular study did not include community collaboration, the addition of the Manoomin storyline attempted to include Anishinabek narratives

while the addition of Spanish content attempted to invite non-English speakers into the space. Finally, the addition of AR within a museum creates a personalized learning context for a variety of learners. For instance, the layered format of Zappar allowed users to look at photos of a wood duck or learn about their successful conservation story while using a familiar and enjoyable device. Furthermore, while children were excited to use a familiar form of technology, the introduction of a new app in itself creates an informal learning context in which multimedia skills are cultivated and improved (Sharples at al. 2007:21). Likewise, the addition of technology provides users the opportunity to learn alone, in a group setting, or switch between the two, a format that challenges traditional learning within a classroom. Overall, while the June visit unveiled a favoritism towards explorer type visitors, the success within this particular group suggests that AR technology supports mobile learning, and creates new learning platforms that fit into the Post-Museum, an institution which aims to serve the entire community.

The third and final phase of thesis research, which seeks to determine whether AR is a feasible option for museums of varying size and financial capabilities, is perhaps less dependent on a theoretical framework due to its comparative approach. Underlying concepts from New Museology theory will be applied when determining the overall efficiency and feasibility of supporting AR technology within museums of all sizes and capabilities.

A major factor used in determining the usefulness of AR software within a contemporary museum is its ability to tell several narratives and provide visitors with the agency to explore an object or idea at their chosen depth. Before AR, museums were

forced to choose narratives based on available exhibit space, and prior to New Museology practices, museums were likely to choose authoritative or dominant narratives that excluded marginalized members of the community. Moving towards a more inclusive space, AR transforms static exhibits into areas where learning can be highly personalized, allowing individuals to seek out points of personal interest and learn through various mediums without requiring additional, physical exhibition space (Zimmerman 2010). With AR, an endless amount of information can be layered into a single object or display, ultimately increasing interpretation and contextualization (Schavemaker 2011).

With this in mind, AR not only allows all members of the community to have a narrative on display, but it allows others to interact with and explore narratives outside of their own, a component that can expand beyond museum walls via AR's social media functions. Although AR is a relatively new technology within museums, if prioritized, it has the capability to shift outdated displays into self-reflexive and inclusive exhibits.

At the same time as acknowledging the several positive attributes stemming from the introduction of AR into the museum space, there exists some special considerations on feasibility of implementation. For instance, museums must have high speed internet within augmented exhibits so that users do not experience slow content loading, an issue that takes away from the augmented experience and decreases user participation. Additionally, museums must possess current technology that is compatible with the selected AR platform and any updates to the program. This was found to be a minor issue during the study, when a "compatible" device struggled to run Zappar smoothly due to its age. Considering the age of the devices, battery life could also lead to

complications, as an older device is unlikely to remain charged during a full day of use. During the June visit, the newer iPad lost battery at roughly 10 percent per hour while the older device lost battery at 15 percent – 20 percent per hour. If used consistently, museums might expect to replace device batteries more frequently than usual, creating additional costs.

Finally, feasibility issues pop up concerning minor physical alterations to the displays that enable smooth visitor interaction with the augmented storyline. These issues mainly concern zapcode placement and iPad security. Because Zappar depends on zapcodes, museums would need to invest in semi-permanent or permanent zapcodes, so that visitors cannot remove the codes, as experienced during the March observations. Smaller, more financially limited institutions might opt for a heavy-duty adhesive to attach their zapcodes to the display while a larger, more capable museum might reprint labels to have the zapcodes imbedded. Regardless, Zappar, along with most AR platforms, requires minor physical changes to be made to the display so the technology runs smoothly. Likewise, an iPad mount with an extension cord is ideal so that the iPad can remain securely fixed to the display but available to visitors at any time. Similarly, while an iPad mount is a smart investment, financially strained museums might opt to have the AR experience be a special event maintained by volunteers every few days or during high volume hours. Although these issues are minor setbacks to the implementation of AR within museums, the technology is feasible if appropriately prioritized and utilized.

AR: Feasible, but Necessary?

Considering the feasibility of AR platforms within museums in regards to ease-of-use, technical capability, and cost, it can be posited that institutions of various sizes and access to resources can support this form of mobile platform. However, one essential question remains: is this form of technology worth prioritizing? While platforms such as Aurasma, Layar, and Zappar provide institutions with the tools necessary to introduce new forms of education and communication, is AR actually a desired technology among museum goers? A 2012 study by Fusion Research and Analytics titled *Mobile in Museums* addresses this question and ultimately supports the use of AR technology within museums.

The survey, which circulated via email to American Alliance of Museums (AAM) and Museum Association (UK) members garnered responses from 740 museums in attempt to understand how institutions use "mobile technology to engage, educate and entertain their visitors" (Fusion Research and Analytics 2012:4). During the survey period, 44 percent of US adults and 58 percent of young adults (18-29) owned a smartphone, making it a fairly ubiquitous form of technology that was expected to increase in popularity (Fusion Research and Analytics 2012:11). Considering the pervasiveness of mobile devices, survey respondents were highly receptive to using mobile technology within museums and in fact "more than half of US museums offer[ed] mobile platforms" during the survey period (Fusion Research and Analytics 2012:12). However, although the survey mostly produced a positive outlook for mobile use within museums, it posited that roughly "four in ten museums [did] not offer any mobile

features, citing the lack of dedicated budgets, limited resources and limited knowledge as key reasons" (Fusion Research and Analytics 2012:13).

Taking a closer look at these findings, issues concerning budget, limited resources, and limited knowledge about the mobile technology in question are prevalent problems that will likely continue to plague museums regardless of time, making the slightly dated data from the 2012 Fusion survey still highly relevant to this thesis. Considering the reasons why museums did not employ mobile technology within their institutions at the time of the survey, 25 percent cited a lack of staff knowledge regarding the technology, 55 percent cited that there was no dedicated budget to mobile technology, 33 percent claimed the technology was too expensive, 51 percent cited that there was insufficient staff time, 52 percent said there were too many other demands on internal resources, and 33 percent claimed there was not enough of a visitor demand to justify introducing the technology into the museum (Fusion Research and Analytics 2012:42).

Interestingly, these challenges carried over into museums using mobile technology at the time of the survey. For instance, 70 percent expressed challenges with funding, 62 percent claimed it was demanding on internal resources, 50 percent said the technology was time consuming to maintain, and 30 percent cited challenges concerning the technical expertise needed to maintain the platform (Fusion Research and Analytics 2012:47). Reflecting on the statistical data outlined by the Fusion survey, it can be asserted that both mobile and non-mobile museums share similar challenges in terms of budgeting time, money, and resources to support mobile platforms. However, since the circulation of the Fusion survey, mobile technology has continued to become more

streamlined and accessible, making it easier to use, more powerful, and less expensive, ultimately increasing its relevancy within museums.

With this in mind, end-to-end AR platforms such as Aurasma, Layar, and Zappar have been specifically selected for this thesis because they offer solutions to the common challenges faced by museums during the mobile technology implementation process. While each has its own strengths and weaknesses, these platforms both directly and indirectly resolve challenges related to time, resources, and finances.

Aurasma, Layar, and Zappar's easy-to-use qualities mean that staff do not need to be specifically trained in computer sciences or even possess a fine-tuned understanding of AR technology to be able to use these platforms. Thus, the ease-of-use factor means that it is not necessary to have staff specifically dedicated to creating and maintaining the platform, though it would certainly be ideal. As a result, the implementation of AR technology via Aurasma, Layar, and Zappar platforms relieves the demand on staff time and intellectual resources. In this same vein, the Aurasma, Layar, and Zappar online studios offer affordable prices to museums, ultimately reducing the strain on already limited financial resources. Arguably, even free technology comes with a price in one form or another, whether it manifests in the hiring of a staff member to maintain the platform or paying for high speed wireless internet access throughout the building. However, as discussed above, the benefits of AR within museums, outweigh the drawbacks, ultimately making the choice to implement this form of technology a sound financial decision.

Finally, the 33 percent of non-mobile institutions that cited a lack of visitor interest as being a primary reason for not introducing the technology into their institution should consider reassessing this stance if they have not already. According to a 2015 survey conducted by the Pew Research Center on smartphone usage in the United States, nearly two thirds of Americans own a smartphone (Pew Research Center 2015). While smartphone use is high among younger populations, introducing mobile technology into museums is no longer a matter of attracting a younger crowd but rather a matter of being relevant to 64 percent of the US population.

Likewise, a 2013 survey by the Museums Association (UK) on mobile use in museums echoed the findings of the 2012 Fusion survey, signaling that while mobile technology continues to strain museums of various sizes and financial capabilities, it is becoming commonplace for museum goers to expect a mobile experience in one form or another (Museums Association 2013). Ultimately, despite the tribulations associated with mobile technology adoption within museums, the future is undeniably positive and continues to brighten as end-to-end platforms like Aurasma, Layar, and Zappar make access to educational technology, such as AR, a realistic and financially feasible option.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

When Carl Akeley in 1889 revealed his muskrat marsh diorama, considered to be the first habitat diorama of its kind, it is unlikely that he imagined the wild success, gradual demise, and eventual nostalgic embrace of this innovative form of display. For over one hundred years, the habitat dioramas of museums have inspired imagination, awe, curiosity, advocacy, education, and conversation - a large feat for such a simplistic form of display. While habitat dioramas have come to be synonymous with natural history museums, their presence within these institutions has become contentious. Museums now face the relevant question: should these aged but charming displays be left for nostalgic purposes or replaced by contemporary exhibits? Confronting the diorama dilemma is no simple task. The historical and artistic quality of these displays transform them into artifacts in need of preservation while at the same time, their age makes them often inaccurate and out of touch with contemporary museums and their visitors.

The dilemma thickens as the positive and negative functions of habitat dioramas are debated. Literature supporting the educational attributes of habitat dioramas is meaningful and paramount, touting increased scientific inquiry, dialogue, and critical thinking, particularly for children, as well as sharpened observational and interpretation skills (Ash 2004; Nietzel 2005; Scheersoi and Tunnicliffe 2009; Reiss and Tunnicliffe

2011). Yet, highlighted shortcomings of this form of display are just as prominent in the literature. Beyond being costly and time consuming to maintain, habitat dioramas are frequently criticized for their passivity, lack of interactives, and out-of-date environmental representations which clash with current scientific discourse (Garibay Group 2008; Marandino et al. 2015; Morris 2015). Both sides of the argument are highly valid, resulting in a difficult decision for contemporary museums of all sizes and forms.

Research Questions and Solutions

In between the two extremes of the diorama dilemma, preservation for the sake of preservation and destruction for the sake of progress lies the middle ground: a solution of technological infusion. By keeping aged habitat dioramas in their original state, the addition of augmented reality technology capitalizes on the out-of-date elements within the display. In doing so, attention is drawn to the stark differences between past and present environments, ultimately creating a fertile space for contemporary conversations about culture, nature, conservation, advocacy, and science. In support of these claims, this thesis has provided evidence drawn from empirical data on research conducted with the Michigan marsh diorama located at the Grand Rapids Public Museum in Grand Rapids, Michigan. Data analysis answers three important questions regarding whether these displays should be kept or replaced, if AR technology is capable of both preserving and updating dioramas for contemporary museum goers, and whether this AR solution is a feasible option for museums of varying size and financial capabilities.

Each of these questions is associated with a phase of research that occurred over a period of five months. Starting in February 2017, the first phase was completed

after a two-day visitor study at the Grand Rapids Public Museum in which both quantitative and qualitative data was collected through direct visitor observations. These observations monitored visitor's interactions and behavioral patterns with the marsh diorama and facilitated the creation of an ethogram; the ethogram identified the most common type of visitor to the diorama, their motivations, and their interest in certain aspects of the display. Ultimately, the data comprising the ethogram aided the completion of the second phase of research: the augmentation of the marsh diorama.

The second phase of research took place during March and June 2017 and involved augmenting the marsh diorama using Zappar, an AR software, to improve visitor interaction with the display. Using the data collected from the February 2017 visitor studies, 12 elements from the display were selected based on visitor interest. Each element was carefully researched and assigned relevant, multi-media content to be input into the AR software. After the augmented storyline had been created, the augmentation was implemented at the GRPM in March and again in June, during which visitors were observed as they interacted with the display. Data collected from these two visitor studies exhibited a significant increase in visitor engagement with the marsh diorama.

Following the second phase, the final stage of research was completed in June 2017, and involved the investigation and comparison of AR software to test for the feasibility of use within museums of varying sizes and financial capabilities. The comparison considered three AR platforms, Aurasma, Layar, and Zappar, and evaluated them on points of capability, ease-of-use, and price. At the completion of the third phase,

recommendations were made regarding which AR platforms were best suited for small and large institutions.

Conclusion

Following the completion of the study, quantitative and qualitative data collected from visitor observations in tandem with supportive literature suggests a positive outcome for habitat dioramas threatened by removal or destruction. By using augmented technology, inaccurate, unengaging, or dated dioramas can maintain their nostalgic qualities and be updated to meet the desires of contemporary museum goers without physically altering the display. Furthermore, augmented reality additives can cover several topics at varying depth through a number of media, ultimately personalizing the experience by offering more content to a wider range of visitors. Likewise, augmented dioramas can introduce visitors to pressing issues such as climate change, biodiversity loss, and conservation by capitalizing on the inherent vice of aged habitat dioramas - outdated ecosystems. Finally, the growing capability, ease-of-use, and affordable price of AR software allows museums of all sizes and financial capabilities to put their diorama dilemma to rest using a form of technology that is attractive to their constituents.

Limitations and Future Research

Beyond the positive outcome of this study and advocacy for habitat diorama alteration over elimination, some limitations and weaknesses require further attention in future research. To start, the body of literature related to diorama augmentation is very limited and requires significant growth. This study contributes to such literature.

However, the case evidence its limited in sample size, singular research location, and thorough testing of only one augmented reality platform. Likewise, findings from the June visitor observations suggest that augmentation is significantly more attractive to children. Therefore, future studies should aim to increase adult participation while maintaining popularity with younger visitors. Reflecting on single case challenges, for future research I would prioritize front-end advertisement, work with a larger sample, and increase the number of dioramas augmented. I feel that even minor advertisements would significantly increase the number of participants and perhaps draw a more varied selection of visitor types. A larger number of augmented dioramas would increase the depth of visitor engagement and attract a larger and more diverse crowd of participants.

Importantly, the limitations of this small study do not overshadow the wider, positive implications that are revealed. Beyond the preservation of habitat dioramas, AR technology has the capability to rejuvenate tired exhibits, invite multiple narratives into a single display, and cater to a diverse audience. In order to serve the community they intend to represent, contemporary museums must be relevant to both current and future visitors; a task that can be aided by the simplicity, ingenuity, and versatility of AR technology.

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APPENDIX A

CALIFORNIA STATE UNIVERSITY, CHICO
Chico, California 95929-0875
Office of Graduate Studies
Ph: 530-898-6880
Fax: 530-898-3342

December 02, 2016

Jacquelynn Coon
229 W Lindo Ave
Chico, CA 95926-2172

Dear Jacquelynn Coon:

Protocol # 741

As the Chair of the Campus Institutional Review Board, I have determined that your research proposal entitled "Augmented Realities: Reimagining Habitat Dioramas through Augmented Reality Technology" is exempt from full committee review. This clearance allows you to proceed with your research.

I do ask that you notify our office should there be any further modifications to, or complications arising from or within, the study. In addition, should this project continue longer than the authorized date, you will need to apply for an extension from our office. When your data collection is complete, you will need to turn in the attached Post Data Collection Report for final approval. Students should be aware that failure to comply with any HSRS requirements will delay graduation. If you should have any questions regarding this clearance, please do not hesitate to contact me.
Sincerely,

John Mahoney, PhD., MA (Music)
Professor, Department of Biological Sciences
Director, University Honors Program
Chair, HSRC & IACUC & IBC
MLIB 171D
CSU, Chico 95929-0115
530.898.3276

HUMAN SUBJECTS IN REVIEW COMMITTEE

Post Data Collection Questionnaire

Under Federal law relating to the protection of Human Subjects, this report is to be completed by each Principal Investigator at the end of data collection.

Please return to: Rosemary White, HSRC Assistant
Office of Graduate Studies
Student Services Center (SSC), Room 460
CSU, Chico
Chico, CA 95929-0875

Or Fax to: Rosemary White, 530-898-3342

Name: Jacquelynn Coon Chico State ID#006688228

Phone(s) 810.962.2326 Email: Coon.jacquelynn@gmail.com

Faculty Advisor name (if student): Dr. Colleen Milligan Phone 530.898.6220

College/Department: College of Behavioral and Social Sciences

Title of Project: Augmenting Realities: Improving Habitat Dioramas through the Use of Augmented Reality Technology at the Grand Rapids Public Museum in Grand Rapids, Michigan.

Date application was approved (mo/yr.): 2 /17 Date collection complete (mo/yr.): 6/17

How many subjects were recruited? 200 How many subjects actually completed the project? 200

***HARM**--Did subjects have severe reactions or extreme emotional response? No

If yes, please attach a detailed explanation: _____

Your signature: _____ Date: 10/31/17

***Final clearance will not be granted without a complete answer to this question.**

Approved By: _____ Date: _____
John Mahoney, Chair

****

VERY IMPORTANT: If you will or have used this research in your project or thesis you are required to provide a copy of this form (with John Mahoney's signature in place) to your graduate committee.

Do you want a photo copy of this form emailed to you? Yes
If yes, provide email address: Coon.jacquelynn@gmail.com

HUMAN SUBJECTS IN REVIEW COMMITTEE

Amendment

Under Federal law relating to the protection of Human Subjects, this amendment is to be completed by the Principal Investigator if there are any changes to the original, approved application. Please return to HSRC Chair, c/o Rosemary White, HSRC Assistant (898-5413), Office of Graduate Studies, Student Services Center, Room 460, Zip 875.

Name: Jacquelynn Coon CSU Chico ID #: 00668822 8

Phone(s) and Email: (810) 962 2326 Coon.jacquelynn@gmail.com

Faculty Advisor (If student): Dr. Georgia Fox

Phone and Email Address: 530-898-5583 gfox@csuchico.edu

College/Department: Behavioral and Social Sciences, Anthropology

Title of Project: Augmented Realities: Reimagining Habitat Dioramas through Augmented Reality Technology

Changes to Original Approved Application: Research location has changed from the California Academy of Sciences in San Francisco, California to the Grand Rapids Public Museum in Grand Rapids, Michigan.

Your Signature: Jacquelynn Coon Current Date: 1/23/17

Approved By: **Date:** 1/20/17

John Maloney, Chair

APPENDIX B

Informed Consent

Introductory Protocol

Please sign the consent form if you agree to this observation and survey. For your information, only I will have access to the information that will eventually be destroyed following the completion of the project. Essentially, this document states that: (1) all information will be held confidential, (2) your participation is voluntary and you may stop at any time if you feel uncomfortable, and (3) I do not intend to inflict any harm. Thank you for your agreeing to participate.
I have planned this observation and survey to take no longer than 15 minutes. During this time, I will observe your interactions with the habitat diorama and ask you to complete a brief 5 question survey which will ask questions about your experience with the habitat diorama.

Introduction

You have been selected to be observed and take a survey today because of your interest in visiting the diorama hall of the California Academy of Sciences. As a graduate student of Museum Studies and Anthropology, my thesis research focuses on addresses the current diorama dilemma in museums. It argues that Augmented Reality technology can significantly improve the level of interaction between the visitor and habitat diorama, resulting in increased educational benefits that will work to reshape the visitors' understanding, relationship, and perception of both man-made and naturally occurring environments. The aim of this study is to understand how visitors interact with habitat diorama and gauge how much their experience is altered when Augmented Reality technology is employed within the habitat diorama. The five survey questions below attempt to quantify the visitor's experience with an augmented habitat diorama.

CONTACTS FOR QUESTIONS OR PROBLEMS?

Call Jacquelynn Coon at (810) 962-2326 or email Coon.jacquelynn@gmail.com if you have questions about the study or any problems.

Contact Rosemary White, Administrative Support Assistant and Human and Animal Care Assistant at (530) 898-5413 or rwhite@csuchico.edu if you have any questions or concerns about your rights as a research participant.

Consent of Subject (or Legally Authorized Representative)
Signature of Subject or Representative Date

_____

APPENDIX C

Survey Instrument

Introductory Protocol

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1.) On a scale of 1 to 10 (1 being poor and 10 being excellent) how would you rate your experience with the augmented diorama? Please explain your rating.

2.) Do you feel that habitat dioramas (non-augmented) are beneficial to your museum experience?

3.) Did your opinion of habitat dioramas change after experiencing the augmentation? Please explain your answer.

4.) Did you find the Aurasma app easy to use? Why or why not.

5.) Did you find the augmented content to be compelling? Please explain and give critiques and/or feedback.

Thank you for your time and participation in this thesis project, I greatly appreciate it.

APPENDIX D

Augmented Storyline

Michigan Marsh Diorama

Augmented Storyline Overview:

Following the observation of roughly 200 visitors over the course of two days, some general statements can be made regarding the strengths and weaknesses of the Michigan marsh diorama at the Grand Rapids Public Museum. The display, which attracted a diverse range of visitor types (explorers, facilitators, professional / hobbyists, experience-seekers, and rechargers), demonstrated the ability to draw visitors, provoke inquiry, discussion, and excitement, but frequently struggled to maintain visitor's attention for extended periods of time. These observations will be used in tandem with the solitary and social behaviors exhibited by visitors at the marsh diorama to facilitate the creation of a compelling augmented storyline. Popular elements such as the underwater viewing window, snapping turtle, and frogs will be incorporated into the augmented storyline along with less popular elements such as plant and bird species and information contained in the labels. The ultimate goal of the diorama augmentation is to increase the levels of visitor engagement, slow the progression of the visitor through the display, and present information through diverse media that will appeal to a variety of visitor types.

Storyline 1: Purple Loosestrife

Do you see pops of purple in this display? The vibrant flowers of Purple Loosestrife may be attractive, but this plant can do serious damage to a healthy marsh. Brought to the United States in the 1800s for medicinal and decorative reasons, this invasive species has spread far and wide, choking out native plants and disrupting ecosystems.

One plant that has been severely impacted by the spread of Purple Loosestrife is Manoomin (pronounced Ma-nō-min), or wild rice. According to origin stories,

Manoomin was given to the Anishinaabe people of the Great Lakes region by the Creator, and as such, it is a culturally significant crop. Used in ceremonies, for curing, and eaten at feasts, Manoomin is threatened by the invasive presence of Purple Loosestrife.

Despite the threat of invasive species such as Purple Loosestrife, Manoomin continues to grow and in turn, is harvested. The act of harvesting is communal and cultural, allowing people to come together, share stories, and learn how to collect the rice. Traditional harvest methods are still practiced and involve a boat or canoe, a pole to push the boat, and two sticks to loosen the rice from the stalks.

The Gift of Manoomin

The story of how the Anishinaabe peoples found Manomin is as follows:
Over one thousand years ago, the Anishinaabe people lived along the Atlantic coastline of Turtle Island in North America. They were visited by eight Prophets and given seven Prophecies to follow, the third of which directed them to travel westward until they found the place where "food grows on water". When they arrived in the Great Lakes region they discovered vast beds of wild rice, or Manoomin (pronounced Ma-nō-min). As the story is told, Nanaboozhoo, the cultural hero of the Anishinaabek was introduced to rice by fortune, and by a duck. One evening Nanaboozhoo returned from hunting, but he had no game. As he came towards his fire, there was a duck sitting on the edge of his kettle of boiling water. After the duck flew away, Nanaboozhoo, looked into the kettle and found wild rice floating upon the water, but he did not know what it was. He ate his supper from the kettle, and it was the best soup he had ever tasted. Later, he followed in the direction that the duck had taken, and came to a lake full of Manoomin. He saw all kinds of duck and geese and mudhens, and all the other water birds eating the grain. After that, when Nanaboozhoo did not kill a deer, he knew where to find food to eat.

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Traditional harvest methods are still practiced and involve a boat or canoe, a pole to push the boat, and two sticks to loosen the rice from the stalks.

Storyline 2: Wood Duck

Can you find the Wood Ducks in the Marsh?

HINTS:

Wood Ducks do not nest on the ground.

If Wood Ducks can't find a tree cavity, they nest in man-made wooden boxes.

For a Limited Time Only

The plumage of a male Wood Duck during breeding season is a sight to behold. In stripes and speckles, metallic greens and purples, and rich shades of burgundy and blue, opulent males court mates from fall to late summer before their feathers fade to a dull greyish-blue.

Suffer for Fashion

The striking plumage of a male Wood Duck is bound to attract more than just mates. Desired for their meat and feathers, Wood Ducks became both a food and fashion staple with their exquisite feathers adorning women's hats in the 19th century. As a result, Wood Duck populations severely declined.

On the Rebound

The rapid decline of Wood Duck populations, along with several other bird species, prompted the creation of the Migratory Bird Treaty Act of 1918. This protective act allowed Wood Duck populations to recover significantly. Listen to this Wood Duck call, perhaps it is a familiar sound.

Wood Ducks

Today, Wood Ducks once again grace marshes, swamps, and ponds. Naturally preferring to nest in tree cavities, the creation of man-made nesting boxes has been an additional help to Wood Duck repopulation. Building a nesting box of your own gives Wood Ducks

a safe place to nest and the opportunity for you to see these birds in your own backyard. You can learn how to make a nesting box of your own.

Storyline 3: Species Specific Augmentation

Snapping Turtle

Weighing up to 70 pounds or more in the wild, this solitary reptile has gained a fearsome reputation for itself. If you've ever encountered this creature near water or slowly crossing a road, you've probably been told to steer clear of its powerful snapping jaws.

How Hard Does a Snapping Turtle Bite?

While the Snapping Turtle's sharp, beak-like mouth might seem intimidating, it is more bark than bite. To put its bite into perspective, humans have a higher biting power than Snapping Turtles. Regardless, these animals should be treated with caution and their space should always be respected.

Did you know?

Snapping Turtles can live to be 30 years old in the wild

Western Painted Turtle

Help our State Reptile!

Michigan's colorful and docile reptile is not endangered but could always use your help – Wild Painted turtles are often hit by cars while crossing the street, can be outcompeted for food by pet turtles that have been released into the wild, and are sometimes captured to be kept as pets. You can help by always watching for turtles that are crossing the road, never releasing a pet turtle into the wild, and never capturing a wild turtle to keep as a pet.

Did you know?

The Painted Turtle is Michigan's state reptile

Bullfrog

As the largest frog in North America, this big amphibian has an appetite to match its size. Bullfrogs have been known to eat rats, snakes, birds, and even other frogs.

Did you know?

Bullfrogs get their name from their deep croak that
resembles a cow's "moo"

Northern Water Snake

Can you find the Northern Water Snake in the display?

HINT:

These brown, tan, and grey snakes may blend in with the marsh grasses

It is near the Great Blue Heron

Help the Northern Water Snake!

These non-venomous snakes are often mistaken for being venomous, and are killed by humans. Water Moccasins, also known as Cottonmouths, are one such venomous snake species that looks similar to Northern Water Snakes. There are a few ways to tell the difference between a Northern Water Snake and a poisonous Water Moccasin – the latter has a thick body, blocky head, slender neck, and vertical pupils, while Northern Water Snakes have long, skinny bodies, a narrow head, and rounded pupils.

What is a Great Blue Heron?

- Found in much of the United States year round, Great Blue Herons can be spotted in marshes, swamps, and ponds waiting patiently to strike at fish, amphibians, reptiles, small mammals, insects, and even other birds. Its spear-like bill makes a great hunting tool.

- What is this Great Blue Heron Doing?
  With so many feathers to take care of, a bird must groom, or *preen* itself daily. Preening is done by spreading oils with their beak from a preen gland to keep feathers waterproof, aligned, and free of dirt and parasites. You've probably seen birds preen themselves before - they preen for several hours a day!

Osprey

Like several bird species, Osprey's once suffered the impacts of pesticide use. Following the ban of the pesticide DDT in 1972, these powerful raptors have enjoyed a successful recovery. Commonly seen hunting near marshes and bodies of water, Osprey dive into the water to catch their meal.

Rowboat

What is this rowboat doing in a marsh diorama? People often view themselves as being separate from nature, but we humans leave traces behind, sometimes more than we realize. This rowboat gives the Osprey a place to rest, but often the things we leave behind are not so nice. Pollutants such as trash and chemicals damage environments like marshes and threaten the plants and animals that live there.

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What is this Mallard Duck Doing?

This Mallard sticks its head underwater to "dabble" for food. Depending on the season, it could be dabbling for snails, aquatic insect larvae, or vegetation such as Watermilfoil seeds. Can you spot its head underwater through the Watermilfoil?

- Watermilfoil is an invasive species that grows quickly and prevents native plant growth. Although Mallards eat the seeds, many water fowl's diets depend on the native plants that are disrupted by Watermilfoil.

Storyline 4: Label Interactives

Right As Rain (animation)

Follow the cycle of a water molecule

Marsha, Marsha, Marsha

Near and far, marshes can be found around the world. From the famous Florida Everglades to local marshes such as the Ross Coastal Plain Marsh Preserve near South Haven, marshes clean our water, help to prevent flooding, and provide a habitat for several plants and animals. Take a look around this marsh display to see what kind of plants and animals you can find.