Augmented Reality: The Next Generation of Landscapes

by

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Abstract

Augmented reality (AR) technology remains an area of research given limited focus to, in relation to landscape design, and the discipline of landscape architecture. Recent advancements in mobile technology has strengthened the potential for augmented reality to move from a primarily indoor setting, to a more complex outdoor environment. Case study research is conducted to further understand AR's communicative potential in regards to the practice of landscape architecture. An existing site is reprogrammed using the AR case study research, to explore the opportunities and constraints of landscape architects designing interactive AR landscapes, and how their designs would be modified to enhance the user experience. The results generate a framework of design guidelines and considerations, for landscape architecture professionals, and researchers, to build upon, as AR continues to become an integral part of modern culture.

Biographical Sketch

Years of schooling at the University of Florida, and finding my place within the broad scope of landscape architecture, I have slowly started to create an identity for my work that fits my innovative design perspective. My forward thinking, advanced spatial analysis understanding, and skill at creating social interactive spaces, has come naturally to me throughout my studies. My desires and interests to do more within the scope of landscape architecture, has shaped my area of focus for my thesis project.

Society is steadily moving into a new digital age where nearly every environment the public experiences is interconnected or overlayed with some form of technology. This cultural shift is creating new areas of studies, like digital humanities and mobile application programming. My passion and interests have guided me to attempt understanding how to form purposeful, interactive connections between humans, technology, and nature. As a designer of the public realm, my job as a landscape architect is to not only transform and design the landscape, but to program and organize the site with the public interest in mind. Augmented reality is a technology receiving a large amount of public and developer interest, projected to become a billion-dollar industry by 2020. (Augment, n.d.) The technology has been around for decades, but with the emergence of extremely popular mobile application, like “Pokémon Go,” there has been a shift in research studies to explore how this application’s use of augmented reality has changed the way society navigates and interacts within a landscape. The area of focus for my thesis will research and be among the first in the field of landscape architecture to demonstrate the possibilities of utilizing this popular augmented reality technology to create urban spaces that allow for new ways for the community to connect with one another.

Chapter One: Introduction

The design approaches and methodologies landscape architects use to transform the landscape, have changed dramatically with the advancement of new technology. As modern technology becomes more sophisticated, widely applicable, and globally accepted, there is an emerging paradigm shift for designers to begin adapting to these rising cultural trends (Cantrell and Holzman, 2016). The proposed alternative design approach for landscape architects does not entail deviating from the professions foundation in art, literature, and representational design methods, but rather attempts to build upon these conventional landscape practices, through the integration of modern technology to enhance the publics experience within a space. If the proposed alternative application were applied, this would result in the creation of a new set of design guidelines for the profession to build upon. Traditionally, landscape architects have updated their design approaches and methods to cater to the changes in social and technological trends. As the worlds technology evolves and becomes an essential tool in societies everyday life, landscape designers are faced with new challenges. Landscape architects must attempt to program new landscape spaces within the community that incorporates and balances popular interactive technology and landscape aesthetics.

More than 4000 years ago, the first known examples of terrain representation involved using specialized tools to scratch landscape designs onto clay tablets (Lange and Bishop, 2005, 5). The technology methods used to create and manipulate the landscape, may not be portrayed as the sophisticated technology designers use today, but these tools aided landscape designers in many of the same ways. Perspective technology, along with advanced hand rendering techniques, quickly outdated these original design methods, formulating new design guidelines which were used by many landscape architects during the 15th century. Landscape architect Humphry Repton refined this perspective design technique during the 1800s in his famous “Red Books,” which incorporated 3-dimensional (3D) before-and-after paintings (Lange and Bishop, 2005, 5). His book consisted of moveable flaps which allowed clients to transition back and forth between the panorama paintings depicting the existing landscape, and the paintings representing the proposed landscape (Lange and Bishop, 2005, 5). This method of reveal and conceal is a design approach that is still widely used today. Perspective technology was soon enhanced with the invention of photograph technology, which quickly became a widely used design method by many landscape architects.

The large-scale panorama paintings became outdated with the rise of photography in the 1800s, which provided designers with a technology that was capable of a faster design output than using hand rendering production forms. Photography design methods continued to progress into the 19th century as the technology became more sophisticated, and eventually digital. The new advancements in photography technology gave designers the ability to easily manipulate viewing sizes, and visualize the graphics through multiple forms of media (Lange and Bishop, 2005, 7). The 1970s began a strong shift toward digital landscape representation, which was made possible using newly developed computer aided design (CAD) programs. The heightened ability to digitally photomontage graphics together through computer programs, allowed designers to create more complex landscape representations through cut and paste techniques (Lange and Bishop, 2005, 9). Digital design methods continued to be enhanced into the 1980s with the advancement of computer graphic cards, software, and geographic census data.

Geographic information system (GIS) programs provided landscape architects with a tool that would soon become essential for designing geometrically accurate environments to code, using continually updated geolocated data sets. The ability to design 3D graphical visualization models utilizing real-world data sets, allowed landscape architects to broaden their design skills, methods, and approaches, with regard to their landscapes. These technological progressions have aided in the creation of more ecofriendly, and aesthetically pleasing social spaces for the community and the surrounding ecosystem to enjoy. Everchanging technological advancements and cultural trends have resulted in an ongoing responsibility for the profession of landscape architecture to continually adapt their landscape design practices to these changes in society. Today in the 21st century, the profession is faced with a new technological and social trend that is growing rapidly in popularity called, Augmented Reality (AR).

“Augmented reality (AR) is defined as, “a direct or indirect view of real world scenes in which physical objects are annotated with, or overlaid by computer generated digital information (Alem, and Weidong, 2011, v).” Since AR is dependent on the real-world environment to successfully form this interactive experience, there is a unique opportunity for landscape architects to begin redefining their design approaches to incorporate AR experiences. Landscapes have traditionally been viewed as consisting of multiple designed layers, as well as, “an ongoing medium of exchange, a medium that is embedded and evolved with the imaginative and material practices of different societies (Corner, 1999, 5).” AR technology is a new program element used in landscapes, that has the potential to enhance the professions “imaginative practices” within the landscape. Adapting the landscape to cater and integrate this hidden digital layer, would provide the public with a whole new interactive AR experience that has been proven to increase social, educational, and spatial interactions within a space. The ability to create digital media using AR experience, has been made easier with the recent advancement in new AR design software.

Modern landscape architecture already utilizes a large array of computer aided design programs to help communicate, analyze, and design public spaces. Modeling programs like SketchUp and Rhino, have the ability for designers to outfit and personalize their design software, using program extensions. Every year AR software and application development continue to be updated, and recently have begun creating plug-ins and extensions to be easily incorporated into designers' programs. These new AR extension features gives designers the opportunity to begin creating AR digital media, using their common modeling and drafting programs. This AR technology advancement reduces the necessity for landscape architects to learn a new program to begin designing with this popular new technology. (Cantrell and Holzman, 2016, 26) These technological advancements have released the designing of AR media from a strictly code based background, and shifted the technology resources to a more visual scripting paradigm (Cantrell and Holzman, 2016, 26). Therefore, just as landscape architecture have adapted and benefitted from new design program enhancements in the past to increase the effectiveness of their designs (AutoCAD, Photoshop, GIS, etc.). AR technologies present landscape architects with new tools to utilize when thinking about AR experiences within the landscape. The means in which the public access or interacts with AR media has also become increasingly simplified as smartphone capabilities and other handheld devices become more sophisticated.

The explosion of mobile phone popularity in America has been associated with the release of the first iPhone (smartphone) only 10 years ago in 2007 (Vico, 2011, 85). "Handheld devices are nowadays able to support intensive resource demanding applications, what makes possible for developers to create applications that change the way end users experience the world and communicate with each other." (Vico, 2011, 83) Today, nearly two thirds of Americans own a smartphone device, equipped with the technological accessories needed to perform a successful AR experience (Smith, 2015). The recent enhancements of mobile smartphone technology, partnered with a strong cultural shift in acceptance, and necessity for mobile device, has transport AR opportunities from a strictly lab setting, to seamlessly projecting digital media into the outdoor landscape.

Landscape architects have traditionally approached designing and programing landscapes around one central idea, representational method, or cultural context. AR technology, however, creates new opportunities for designers to begin programming their landscapes to cater to a wide variety of uses and experiences. Landscape architects should not fear this new interventionist way of thinking about public space, but utilize this new technology trend to design more complex, immersive landscapes, never before experienced by society (Amidon, 2003, 7). “It is human nature to search out the new, the exciting, the source of energy that will release us from bonds of the ordinary, the expected, the known. At the same time, we seek beauty and balance within ourselves and in relation to the world around us (Amidon, 2003, 7).” Humans use landscape aesthetics to form relationships and connections with the world around them; therefore, just as people have connected to the visible, physical elements traditionally designed by landscape architects, society can begin interacting with the hidden, invisible landscape aesthetics through the integrating of AR experiences within the landscape.

The integration of programmed AR landscape experiences, is an area of study that has so much to offer yet, has been underutilized within the profession of landscape architecture. There are however professions that have seen the success of incorporating this popular technology into their designs, programs, and business plans. Landscape architects have the tools necessary to begin formulating their own set of design guidelines to adapt landscapes to this rising cultural trend. Landscape architects have the design software needed to design AR digital media, and with the growing acceptance of smartphones combined, makes the public space the perfect setting to incorporate the AR interaction. The combination of digital and public views allows landscape architects to successfully and confidently design using this new approach. The project uses AR research, case studies, and interactive technologies to generate a framework for a new set of guidelines. To better understand the design considerations that landscape architects must make when attempting to integrate these AR technologies, as well as what sort of questions must be addressed to design a successful AR experience for the public.

Chapter Two: Literature Review

History Augmented Reality (AR)

Augmented reality (AR) has been around since the 1960s when Ivan Sutherland developed the first head mounted display (HMD) system, which projected simple wireframe graphics into the real-world environment. The HMD technology was the first example of successfully merging real world scenes with virtual media. The technology was so massive it had to be suspended from the laboratory ceiling, and was given the name, *Sword of Damocles*. The project sparked a new area of research for many different disciplines, beginning with the understanding of potential of integrating virtual media elements, and real world elements, together. The creation of *Videoplace* in 1975, by researcher Myron Krueger, allowed users to not only project virtual objects, but kinesthetically interact with the digital media for the first time. The term, *Augmented Reality*, was finally coined by Boeing researcher, Tom Caudell in 1990, to describe this interaction with virtual objects. Research into this new established concept quickly progressed into the 1990s through the development and advancement of AR technologies.

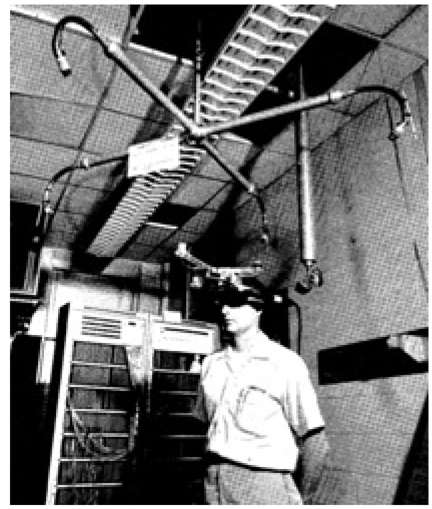

Figure 1. First augmented reality project by Ivan Sutherland called, *Sword of Damocles*. Reprinted from Manifest Technology, in Augmented Reality Goes Mobile, by Dixon, Douglas, 2010, Retrieved April 4, 2017, from http://www.manifest-tech.com/society/augmented_reality.htm

The U.S. Air Force Research Lab was one of the first to develop a functioning AR system called, *Virtual Fixtures*. The advanced technology, developed by Louis Rosenberg, help new Air Force pilots practice flying a plane, through an AR interactive experience. The concept of AR was further defined in Milgram's creation of the *Reality-Virtuality Continuum Model*, which helped the population better understand the distinction between the real world, AR, augmented virtuality (AV), and virtual reality (VR). The distinction helped researchers understand where their research fell on the continuum or which area of focus would be the most applicable to use in the field of study they were researching. The *Touring Machine* research project, conducted by Columbia University Researchers, marked a huge milestone in the history of AR technology, through the development of the first ever interactive mobile augmented reality (MAR) experience. The project demonstrated a new potential for AR through the development of a collaborative, educational, and spatially interactive MAR experience. Regardless of the technological hurtles, and the expensive and bulky technology used for the experiment presented were all the necessary tools needed to perform a successful MAR experience, shown in Figure 3. The last large influence

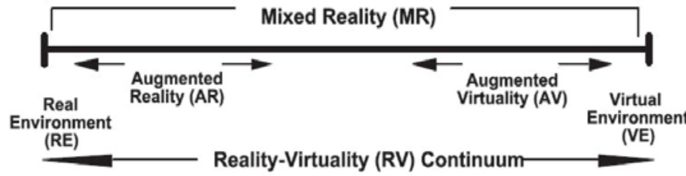

Figure 2. Milgram Reality-Virtuality Continuum. Reprinted from *From Virtual to Reality and Back,* p. 7, by Schnabel, M., Wang, X., Seichter, H., and Kvan, T., Retrieved February 2, 2017, from http://drhu.eu/wp-content/uploads/2012/05/FromVirtualityToRealityAndBack.pdf

Mobile Processor: Central Processing Unit (CPU) for processing user input, video images, and running any application simulations.
Graphics Hardware: Graphical Processing Unit (GPU) system for generating virtual images.
Camera: Camera hardware for capturing live video images, to be used for AR tracking and/or for overlaying virtual imagery onto the video images.
Display Hardware: Either a handheld, head mounted, or projected display used to combine virtual images with images of the real world, creating the AR view.
Networking: Wireless or cellular networking support that will allow the mobile device to connect to remote data sources.
Sensor Hardware (optional): Additional GPS, compass or gyroscopic sensors that can be used to specify the user's position or orientation in the real world.

Figure 3. Core pieces of technology needed to produce a mobile augmented reality experience. Reprinted from *Recent Trends of Mobile Collaborative Augmented Reality* (pgs. 3-4) by Leila A. and Weidong H. (Eds.), 2011, London: Springer New York. Copyright Springer Science+Business Media, LLC 2011.

toward AR's popular public appeal in the 21st century, was *SportsVision's* broadcast. The 1st and ten-yard line was augmented onto the field during a national football league (NFL) game in 1998. Public awareness of AR was not only knowledge for research, but a new public demand. AR technologies quickly progressed into the 21st century development of the personal digital assistant (PDA) and smartphone devices.

The technological enhancements in mobile devices processing power, camera display, and sensor technology, presented researchers, with an increased opportunity to explore the possibilities of AR technology without the need of oversized, wearable equipment, as shown in Figure 4 (Vico, 2011, 83). The first ever mobile collaborative augmented reality (MCAR) experience, called the *Invisible Train*, utilized newly advanced PDA devices. The MAR technology allowed multiple researchers to collaboratively view a train moving on the tracks in real-time. Advancements in processing power have allowed developers to create and run these experiences in real-time, which means the mobile devices are projecting the digital media at the same time it is being processed by the user. The researchers successfully projected the train onto the tracks using *trackers*, which is a projection technique utilizing specific visual cues, such as a logo, QR code, or other unique combination of symbols. Once the tracker has been scanned by the mobile device,

Figure 4. Wearable computer and head mounted display software to run first MAR experience. Reprinted from Manifest Technology, in *Augmented Reality Goes Mobile*, by Dixon, Douglas, 2010, Retrieved April 4, 2017, from http://www.manifest-tech.com/society/augmented reality.htm

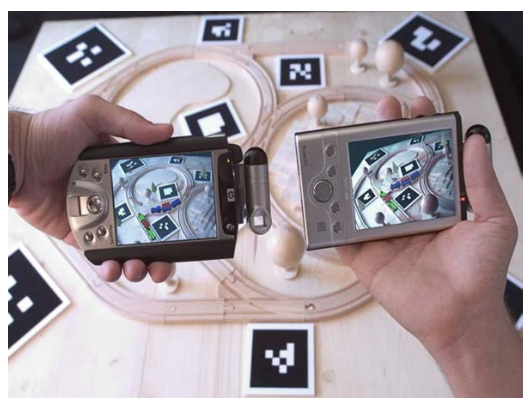

Figure 5. First collaborative mobile augmented reality using personal digital assistants (PDAs) to augment an invisible train onto the track. Reprinted from *Recent Trends of Mobile Collaborative Augmented Reality* (p. 7) by Leila A. and Weidong H. (Eds.), 2011, London: Springer New York. Copyright Springer Science+Business Media, LLC 2011.

the digital information associated to that unique symbol will then be projected in the designed location. Esquire Magazine was the first printed media company to attempt using this AR projection method by printing a QR code on the front of their magazine. If scanned by the a MAR application, the digital media of Robert Downy Jr. would project onto the cover of the magazine. Today's popular mobile device, called the smartphone, is equipped with the processing power, network and memory bandwidth support, and camera features that are almost parallel to that of a computer (Perey, Engelke, and Reed, 2011, 30). The progression in mobile device technology has led to the creation of new mobile AR applications, AR projection methods, and AR research projects.

Research has proven that the most accepted AR applications are the ones running on mobile devices (Vico, 2011, 84); therefore, MAR applications have quickly advanced with new capabilities, which have allowed AR media to be projected using geolocation. This AR application is primarily used by *browser AR applications*, which consist of the largest type of AR applications available to the public. The application uses a projection method which involves geotagging and/or geolocating digital media. The virtual objects are programmed with real world coordinates, and oriented using smartphone geographic positioning systems (GPS), compass sensors, and a live camera view. Researchers have studied this form of MAR and found that interactions with browser capable MAR applications have positively influence peoples' knowledge about their surroundings, as well as increase social interaction, and used as an educational tool. AR browser applications present exciting new possibilities for the discipline of landscape architecture when designing and programing public spaces. The incorporation of AR digital media to spaces within the landscape, using MAR applications, has the potential for society to positively benefit from this proven successful AR experience. The mobile applications success has resulted in a push for developers to begin creating a more universal coding language between varying AR platforms.

The rise in the development of AR technology has resulted in a large mix of coding languages and AR platforms styles. Experts say, “To meet the needs of developers, content publishers, platform and tool providers and users of AR ecosystem, the experts in hardware accelerated graphics, imaging and compute, cloud computing and Web services, digital data formats, navigation, sensors and geospatial content and services management and hardware and software devices must collaborate (Perey, C., et al., 2011, 27).” On February 2014, one of the largest congregation of mobile developers, location data providers, network operators, and location based service (LBS) users, came together for a first ever seminar on AR Browser Interoperability, to address this need for collaboration (Layar, 2014). Martin Lechner of Wikitude (one of the largest AR browser application), proposed developing a common AR interchange format, which would increase interoperability between multiple AR applications platforms (Layar, 2014). The proposal would allow the public to be able to download one AR application, and have access to all the AR content provided by other AR applications, as shown in Figure 6. Layar CTO, Dirk Groten stated, “In order for this medium to become ubiquitous and easy to use, it is necessary to create standards so that content publishers can rely on their creations being viewed by the largest possible group of end users, regardless of the application they use; like the web that can be browsed with multiple browsers thanks to the W3C standards (Layar, 2014).” The standardization coding and design platforms has made possible the development of AR design software plug-ins and extensions. This new feature provided by AR

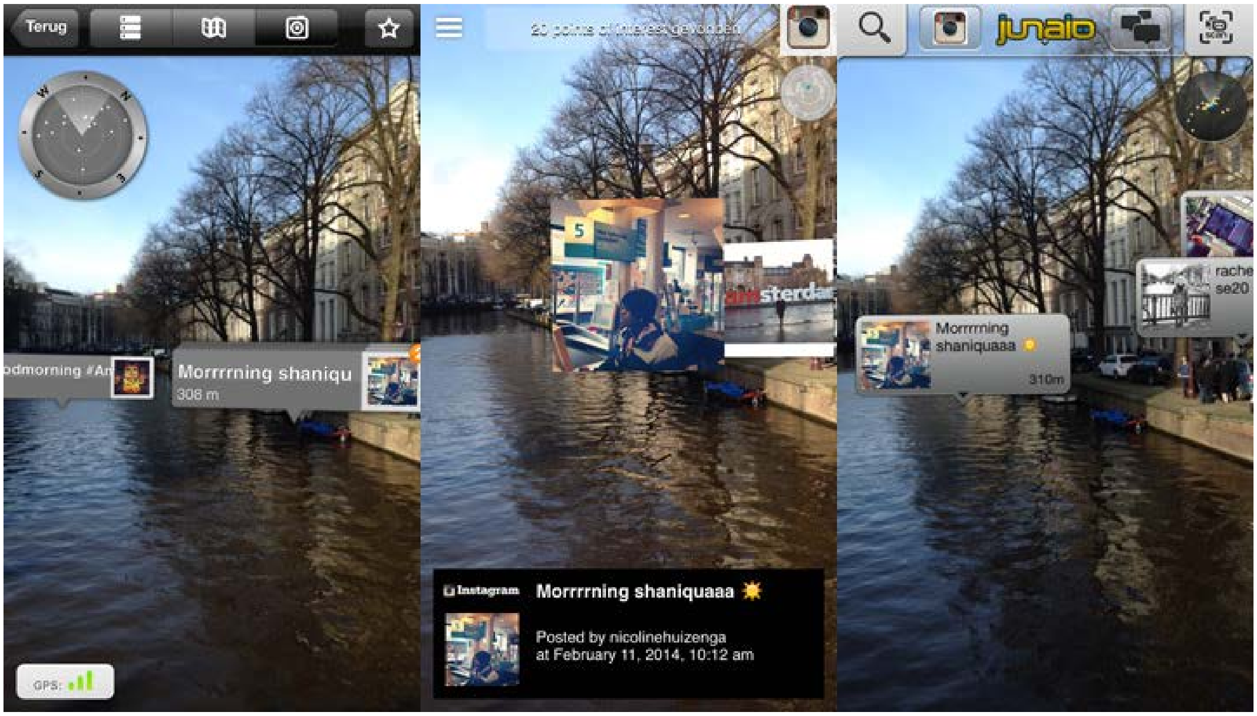

Figure 6. Same content being accessed from different augmented reality applications like *Layar* (left), *Wikitude* (middle), and *Junaio* (right), through this process of interoperability. Reprinted from Layar Press Release, in *Layar*, 2014, Retrieved January 22, 2017, from https://www.layar.com/news/press-releases/ogc-interoperability/

developers, allows landscape designers to input AR design capabilities directly into their common design programs like Rhino or SketchUp. As computer and mobile design platforms continue to become more interconnected and widely accessible through various applications, landscape architects have an opportunity to begin designing AR interactive experiences, which is currently captivating the public around the world.

The success of AR technologies has rapidly progressed the need for researchers and developers to continue studying these AR experiences. AR technologies market value has increased to 1.1 billion in 2016 and is projected to reach 90 billion in 2020 (Augment, 2016). The global interest in AR technology has resulted in recent advancements and developments in AR technologies. Most of the research to date has been directed toward the fields of retail, real estate, architecture, and computer engineering but, remains an area of limited focus within the discipline of landscape architecture. Landscape architects can begin to study these emerging AR research projects better to understand AR's communicative potential with regard to the profession of landscape architecture. Landscape architectures unique opportunity to begin to focus attention, shift perception, and direct consciousness, allows the AR objects to, "become a type of locative ink mark that combines with the environment to lead to a type of virtual painting or aesthetic overlay integrated into the real world (Dolinsky, 2014, 297)" The advancements of AR technologies, and progression in AR research, have allowed designers to begin integrating this aesthetically attractive, and beneficially interactive AR experience, through the artful composition of landscape elements.

<u>Socially Interactive AR research</u>

The 21st century has been filled with emerging interactive AR technology that is rapidly changing the way the community socially interacts with one another within a public space. Social networking platforms like, Facebook, Snapchat, and Instagram, have revolutionized the way humans connect and share digital information with one another. Social media has been strengthened in the past decade through recent advancements in smartphone application development, internet connectivity, and interactive phone features like touchscreens, and dual cameras. Not only has the functionality and accessibility of mobile devices improved the way one connects with others, but the various methods available for users to collaborate has also risen. Mobile applications have developed multiple options for communicating with others outside the realm of traditional phone calls and text messages such as, facetime, multimedia messaging, and short video stories. The technological advancements in smartphones and application features, have contributed to helping keep the public informed about local news, other community members, and events (Smith, 2015, 23). The problems begin to arise when observing how individuals socially interact with one another in a non-virtual, physical environment.

A study at the Pew Research Center surveyed smartphone owners for a week, and found that one-in-three people said they used their smartphone, “to avoid having to deal with people around them (Smith, 2015, 38).” In addition, 77% of the smartphone owners in the survey reported they looked to their phone to avoid being bored. Smartphones now consist of millions of interactive mobile applications able to be downloaded to instantly entertain, and satisfy the needs of an individual. This instant satisfaction has been perceived by other smartphone users as, “distracting,” representing 28% of the survey population (Smith, 2015, 7). On the other side of that spectrum, 77% of the surveyors viewed smartphones as, “connecting (Smith, 2015, 7).” Finally, the survey asked smartphone owners where they use their mobile devices. The survey showed that while a large percentage use their devices at home, another large percentage of people use their devices in public spaces, or while traveling from place to place. Concluding that 51% of smartphone owners used their device in a community place, 82% in a transportation vehicle, and 50% walking from place to place (Smith, 2015, 37). There is an opportunity for designers to begin approaching the public landscape, utilizing smartphone availability and their AR capabilities to better create an interactive landscape that can increase social interaction within a space.

Landscape architects can begin to synthesize the study’s findings, and begin formulating new design approaches that increase social engagement, without the abandonment of popular smartphone technology. The study clearly shows that people have their mobile devices on them when traveling from place to place, or while occupying a public space. The study presents a large opportunity to begin purposefully designing landscapes that integrate this smartphone cultural trend, in a way that creates positive social interactions and experiences within a space. Society already looks to their phones to avoid boredom; therefore, landscape architects can design landscapes that enhances the comfort, entertainment experience, and/or collaboration with others in the community. One application launched last year in 2016, presented an example of a successful mobile application which addressed many of the potential opportunities found in the smartphone study, through the creation of a MAR entertainment application, called *Pokémon GO*.

The social potential these interactive AR technologies can provoke within the public realm was first largely demonstrated by a mobile application called, *Pokémon GO*. There is no denying that at the height of the *Pokémon GO* craze, the mobile application had a higher daily usage time than popular social media applications like Snapchat, Instagram, and WhatsApp. (Lynch, 2016) The concept of the game was simple, but the results sparked new social interaction within communities around the world, resulting in discussion among urban planners, application developers, and landscape designers.

The first key component to the application's worldwide success was the integration of a real-world location map, running in real time, which allowed the entire worlds landscapes to become a part of this MAR experience (Cantrell and Holzman, 2016, 22). The map consisted of "Pokestops," which were real world landmarks where players could obtain in-game items, or verse other players within the community in gym-like settings, using their Pokémon (Lynch, 2016). The Pokestops were generated through a unique, human-powered mapping system, which allowed the in-game landmark locations to deviate from typical building, or monument locations.

Pokestops ended up becoming widely dispersed, and located in areas around the world that may be less familiar, or traveled by many of the application users. The seemingly random locations cause players to explore the environment around them, venturing into areas one would not normally go (Lynch, 2016). Research into successful Pokestop locations revealed, “it must be a nice open environment, have comfortable places to sit, and be easily accessible – nearly all of the same qualities of what makes any public space successful (Lynch, 2016).” In addition to successful Pokestops bringing the public together, business/customer interactions were also influenced by the large scale public appeal in *Pokémon GO*. The increase in pedestrian foot traffic provided many businesses near Pokestop locations, with free advertising. Therefore, many businesses began offering free products in return for users playing the popular mobile application, shown in Figure 7. *Pokémon GO* generated a whole new business/customer relationship around this popular mobile phone game application. This research should appeal to landscape architects and urban planners, because it demonstrates an opportunity for public environments to be reprogrammed to allow for this increase in positive social interaction through mobile gamification technology. The second feature that made the application so appealing was the simple, but effective, interactive AR interaction.

Figure 7. Business signage giving away free products and welcoming *Pokémon GO* gamers. From *Mobile Marketing*, by Spencer, A., 2016, Retrieved January 25, 2017, from http://mobilemarketingmagazine.com/pokemon-go-business-offers-lure-module-marketing/

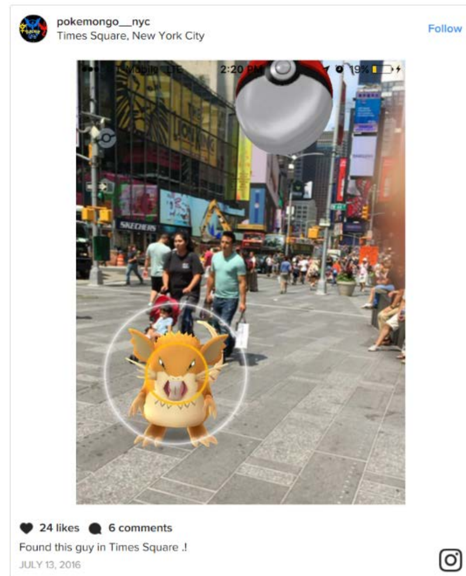

Figure 8. User catching Pokemon in *Pokemon GO* application and sharing the experience and location using *Instragram*. From *Instagram*, by user pokemongo_nyc, 2016, Retrieved on February 5, 2017, from https://www.instagram.com/p/BHz_D8RDum0/

Players were able to use their smartphone cameras, and interactive touchscreens, to catch the Pokémon, which were geolocated in the existing environment through AR. The interactive experience, was only seen through the users' phone screen; therefore, the mobile application did not take away from the user or other people experiencing the landscape, but resulted in the complete opposite. A landscape, landmark, or local place a person may have visited a hundred times, becomes instantly transformed through their smartphone into an innovative interactive landscape experience. In addition, the application does not burden the site in any way, except for large congregations of people using a space, or an increase in local business sales. The application's success derived from the fact that all one needs to play the game is a wireless data connection and a smartphone (Lynch, 2016). Further research into the results of this globally popular mobile application, and the influence it has on large scale social interaction, presents new possibilities for landscape architects to begin using interactive AR experience in landscape designs with only minimal adjustments. Other research is being done to utilize physical movement to socially interact with others using specialized lighting.

Xin Liu, a researcher at MIT, created a product called *Fluxa*, that augmented digital information through body movement. The wearable device used visual effects called persistence of vision (POV), to create lit up displays (Lui, 2016). POV has to do with an optical illusion created due to retina afterimage. When the LED strip quickly flickers, part of the image at certain spatial positions, an illusion connects and displays the graphic as a unified image, as shown in figure 9 (Lui, 2016). The technology utilizes a small, portable linear strip of LED lights, that can be worn anywhere on the body. Then, with a little movement, the hidden digital information becomes visible. The research demonstrates the AR technology through a practical use by applying the LED *Fluxa* technology to a runners' shirt sleeve. The rapid back and forth movement of the man's arms, allows the augmented digital information to be seen as he passes by other individuals. The strip displays his distance traveled, heart rate, and other unique images. The experiment presented one way through AR lighting and wearable AR technology, for designers to begin thinking about public spaces and how AR technology could be useful to increase social engagement. Like *Pokémon GO*, the success of this technology is in its interactive ability. When attempting to design a socially active public space forcing people to move meaningfully, or in a silly way, can reveal the augmented information and communicate with others, creating a whole new design consideration for landscape architects. Because lighting is a very integral part of landscape design, *Fluxa* presents new possibilities to increase movement, exploration, or social engagement within a designed space.

Figure 9. Wearable technology that displays an augmented image when in motion. From *MIT media lab*, by Liu, X. 2016, Retrieved February 10, 2017, from https://www.media.mit.edu/projects/fluxa-body-movements-as-a-social-display/overview/

The design possibilities and uses for *Fluxa* technology, creates new design alternatives when landscape architects are thinking about lighting within the public landscape. For example, linear light poles have potential to be outfitted, or programed with *Fluxa* technology. Individuals could run past, or move around the light fixture quickly, to reveal the hidden augmented information. A seemingly ordinary landscape element, now has the unique ability to spark peoples' curiosity, promote physical fitness, and increase social interaction. Students at MIT were continuing to research alternative ways to create socially interactive AR experiences, using personalized wearable AR clothing.

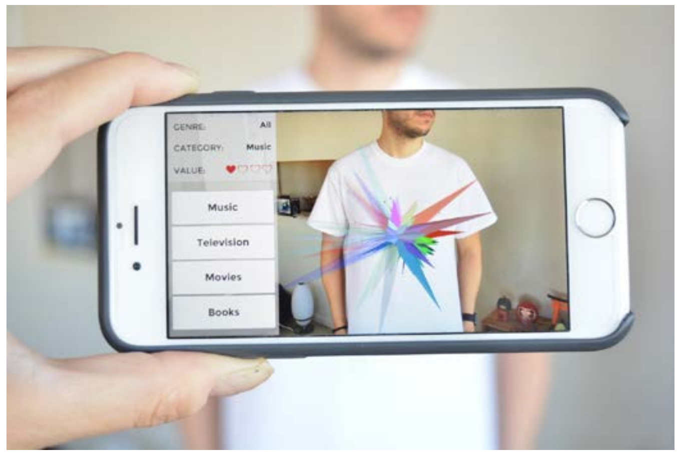

Figure 10. Wearable Augmented reality shirt to promote social interaction. From *MIT media lab*, by Polyhedra AR, 2017, Retrieved February 10, 2017, from https://www.media.mit.edu/projects/polyhedra/overview/

The researchers began a project called *Polyhedra,* which involved creating AR designs, and could be accessed through interactive wearable clothing. The clothing consisted of a unique tracker printed on the clothing, which is typically in the form of an asymmetrical design. The tracker could then be scanned using a MAR application and the digital information assigned to that specific tracker would then be project onto the clothing, instantly becoming an interactive 3-demensional experience. A design on a shirt could instantly be augmented into a completely different design, or an enhancement of that design. Project *Polyhedra* was created to provoke social interactions and collaborations among the public (Schmandt and Fuste, 2016). Tracker based AR research like this demonstrates a simple, innovative design approach for landscape architects to begin overlaying interactive digital media directly onto the landscape. Physical landscape elements, such as hardscape patterns, could act as a tracker, and be assigned digital AR information for the public to scan, and interact with. The ability to overlay additional hidden information over new or existing environments has resulted in a large amount of research studying the educational benefits of AR experiences or interactions.

Educationally Interactive AR Research

A large portion of AR research has been directed toward understanding the technologies that contribute to education. The ability to engage individuals in a more interactive, hands on learning environment, has proven to be largely beneficial in heightening people's knowledge toward a subject of interest. AR technologies have been used to support multiple types of learning like skill training, assembly tasks, discovery-based learning, and collaborative learning (Nilsson, Arvola, Szczepanski, and Bang, 2012, 2). The unique characteristics of MAR technology make it the perfect medium for many professions to utilize, and educate the public. The smartphones ability to be mobile, connected, and widely accessible, creates the perfect platform to actively engage the public through interactive learning on a large scale. Research has shown that individuals form a stronger connection with the 3-demensional AR, than trying to learn the same information in a traditional 2-dimensional way (Rosello, 2016). One group of researchers explored this theory, by creating a mobile application that resulted in a more hands-on learning experience.

Salvatore Iaconesi, Luca Simeone, and Cary Hendrickson, created an MAR application that attempted to engage human interaction, through informing one about the natural ecosystem surrounding the individual (Iaconesi, Simeone, and Hendrickson, 2011, 254). The researchers created a phone application called, *Leaf++*, which had the ability for one to go out into their environment, scan plant foliage, and augment virtual information onto the leave to educate other community members about the environment around them. The information, and location would then be posted in real-time on the location map within the application, allowing other users to locate and access the material (Iaconesi, et al., 2011, 254). There are many other mobile applications that allow people to post information in specific locations throughout the environment but, the contribution of this project comes from its educational benefits. The natural world around the user instantly has more meaning, and becomes an interactive AR experience to enhance ones' sense of place. The application demonstrates to landscape designers an applicable example of how digital information can be easily overlaid over an existing environment, giving the public the proper tools to access the material. In addition, *Leaf++* suggests a potential design consideration allowing the public to help define and design the space. Another similar conceptual MAR application developed by researchers, is in the form of a scavenger hunt. The educational mobile game would begin to influence people to explore the landscape around themselves, and uncover the educational knowledge about the sites rich historical significance.

Figure 11. The application scanning plant foliage and assigning augmented information. Reprinted from *MindTrek'll*, by Iaconesi, S., Simeone, L., and Hendrickson, C., (p. 254-257), Doi: 10.1145/2181037.2181080. Tampere, Finland. Copyright 2011.

The researchers created an application called, *Minnesmark*, which involves augmenting a culturally significant landscape through the form of an interactive treasure hunt (Nilsson, et al., 2012, 411). The site chosen revolved around a famous children's book by, Astrid Lindgren, who based most of her books on her childhood memories and natural surroundings of Smaland, Sweden (Nilsson, et al., 2012, 411). The mobile application provides opportunities for participants to work together to explore the famous site by uncovering hidden digital augmented reality digital information about Astrid Lindgrens' life. The scavenger hunt involved trackers dispersed around the site, which were used to project the AR information in the form of images, audio clips, videos and 3D models (Nilsson, et al., 2012, 416). Families had to collaborate with each other to correctly find and reveal the linear educational story. Researcher found that the small phone screen resulted in participants having to huddle together to understand the provided map and reveal the information together (Nilsson, et al., 2012, 417). Both adults and children had a chance to use, interact, and learn through the mobile treasure hunt application, so everyone was able to engage with the interactive story. “The results showed that AR treasure hunts can be a way of telling stories about culturally significant places (Nilsson, et al., 2012, 417).” The research provides insight on how landscape architects could approach existing historical sites, in a purely digital way, to enhance peoples’ knowledge about the space. The research presents an opportunity for landscape architects to begin implementing undisruptive AR experiences into culturally significant places, without having to be concerned with designing around strict codes, and taking away from the sites historical aesthetics. One group of researchers demonstrated this idea of overlaying digitally interactive information directly on top of an existing site through the collaboration with a public zoo, to help educate the world about a significant issue concerning animals.

The project, *Mission Wildlife*, involved a collaboration between the MIT Center for Civic Media, and San Diego Zoo Global. The goal was to raise awareness within the zoo about animal extinction, through the use of MAR gamification (Ho, P., 2016). The digital information was made accessible to the public on the 100th year anniversary of the San Diego Zoo, just a week after the popular MAR game application, *Pokémon GO,* was released (Ho, P., 2016); therefore, the public appeal in AR technology was already underway. The research projects success came from the games unique interactive methods by engaging a large majority of the public about a specific issue, which ultimately resulted in an increase in annual zoo visitors.

The MAR game experience, involved visitors having to compete with other zoo visitors by, “triggering 3D animations from animal signs, taking selfies, and sharing photos on their social media with specific hashtags with the goal of spreading awareness about certain issues (Ho, P., 2016).” The research project demonstrated how MAR experiences, has the ability to reach a large-scale audience quickly, through the use of mobile devices advanced connective qualities. The researchers at MIT for Civic media stated that the project, “exhibited a real-life example of how small actions can collectively make a large difference (Ho, P., 2016).” Again, this exemplifies another AR experience that builds upon the technologies influence on social interactions within a community, as well as, provides educational insight about a current global issue. The *Mission Wildlife* project presents a perfect example of how mobile devices, like smartphones or iPad’s, can be used as the perfect tool to create AR experience that heighten public knowledge, as well as, provide individuals with the ability to connect, and share their experiences instantly with others in the community. More technically advanced projects have been created that provide a less mobile experience, but still allows the user to navigate a large amount of educational AR information, from a single location.

Figure 12. Poster cube with assigned augmented reality information being viewed through an iPad. From *YouTube*, by Ho, P., 2016, Retrieved February 4, 2017, from https://www.youtube.com/watch?v=6GB782m9DnQ

The Theater of Lost Species was an interactive installation for the YBCA “Dissident Futures” show in 2014, that fabricated a unique theater experience to help different generations learn about past landscapes and species (Cantrell and Holzman, 2016, 97). Shown in Figure 13, the viewer peers into the “Mars Rover” style sphere, revealing the digital information housed within the “theater” prototype. “As we collectively speed up geologic change, our current methods for recording, visualizing, or memorializing past landscapes will become increasingly valued as both historical record and as tools to inform landscape management practices within new ecological conditions (Cantrell and Holzman, 2016, 100).” The stationary installation successfully provides viewers, and landscape architects, educational information about the evolution of the environment around them through environmental augmentation (Cantrell and Holzman, 2016, 100). The exhibition exemplified how a designer could “compress” and project large amounts of time and data into a single interactive, navigable experience, from a one location (Cantrell and Holzman, 2016, 101). The benefits of a single location of digital information provides less mobile citizens, the ability to still participate in the educational experience. A similar research project continues to explore AR technologies potential to increase the publics knowledge about a space, and increase peoples long term memory when moving through a familiar environment.

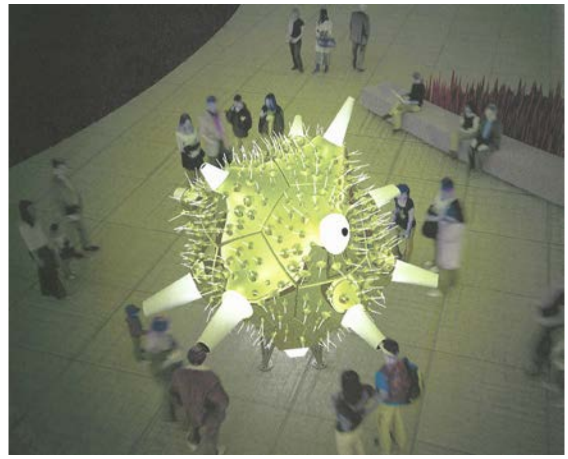

Figure 13. Conceptual rendering of the *Theater of Lost Species*. Reprinted from *Responsive Landscapes* (p. 100), by Future Cities Lab, 2014, New York, NY: Routledge. Copyright 2016 by Cantrell and Justine Holzman.

Researchers at MIT have created an application called, *NeverMind*, which aims to utilize AR to form ones’ memory palace, to help memorization of past experiences. Studies show that, “the long-term memory recall accuracy of a sequence of items is nearly tripled compared to paper-based memorization tasks (Rosello, 2016).” The designed application uses a similar sequencing method to achieve, and increase a person’s memory as one walks through a given space or place.

The study incorporated the use of wearable AR glasses, shown in Figure 14, to display the digital information provided in the MAR application. The application process involved individuals navigating through a space they are familiar with. When a person stops, they drop a digital image (personal or application generated), to help with memorization of the spaces visited, and the experiences they had. Visual and experiential learning facilitates memorization; therefore, by creating a network of augmented images in the spaces one experiences, it assists in both wayfinding and memory, through association with the images dropped throughout the site by the application user (Rosello, 2016).

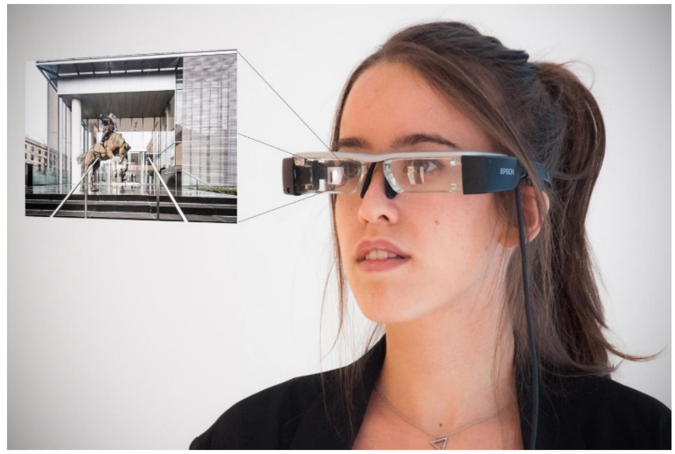

Figure 14. Wearable augmented reality glasses projecting images at certain locations to help memorization on how to navigate through a space. From *MIT media lab,* by Rosello, O., 2016, Retrieved February 21, 2017, from https://www.media.mit.edu/projects/nevermind/overview/

The project *NeverMind* was successful in producing a workable application that assisted individuals in generating their own unique memory palace when walking through a known space. The applications digital media also helped the user learn, understand, and form spatial relationships with the site they were experiencing. By walking around, viewing, and interacting with the augmented images, the individual engaged in a spatial interaction with the AR media. This ability to move around 3-demensional objects within a space has shown endless spatial and educational benefits. Architectural students have begun experimenting with AR applications to better communicate their designs to people less trained at viewing 2-dimensional architecture drawings and being able to see the model in 3-demensional form.

Javier Valdivieso, an architecture student at the University of Cuenca in Ecuador, paid tribute to a famous architectural firm named CONAR, using AR. (Augment, n.d.) Javier, and other architecture students in the group, used the application *Augment*, because of its free AR resources to educational students and faculty. The project, shown in Figure 15, was the first in architectural history to present student work in such a way. (Augment, n.d.) The public was able to better learn about the architectural designs by walking around the 3-dimensional (3D) models that were projected using the MAR application, *Augment.* The 2-dimensional (2D) architectural drawing were used as the assigned tracker for the model, which the public would scan to reveal the 3D model. Overall, the project shows how designers could create an alternative educational experience, through interactive AR design techniques, that helps community members learn about the given material in a more relatable format. Scale is an important design consideration when one is attempting to create an interactive experience for the public. Spatially interactive AR technologies are continuing to be researched and developed to create a more realistic experience for multiple people to utilize and engage in.

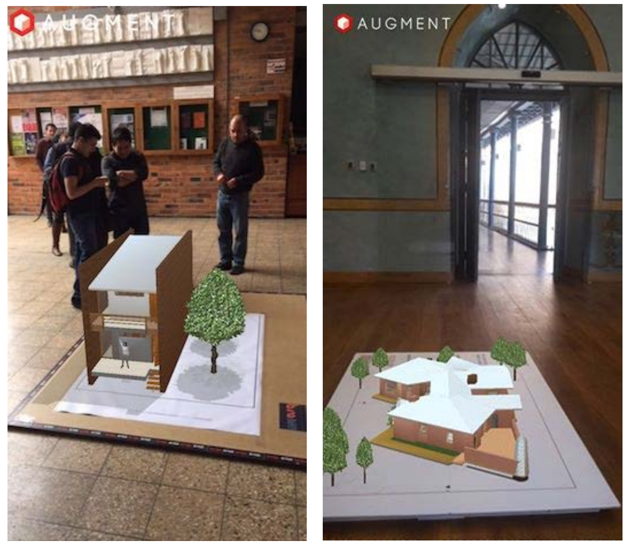

Figure 15. Architecture project utilizing mobile *Augment* application to display models. From *Augment*, by Valdivieso, J., 2016, Retrieved February 1, 2017, from http://www.augment.com/portfolio-items/universidad-de-cuenca/

Spatially Interactive AR Research

The power of AR resides in the technologies ability to orchestrate how an environment is to be used, interacted with, or perceived (Dolinsky, 2015, 296). Many research projects have been performed to understand just how powerful augmented reality is at increasing peoples understanding of space and scale. A research team in Barcelona created an assignment for architectural students to discover if AR could be a valuable tool for architecture and building engineering education. The assignment involved a geographical positioning system (GIS) to register the virtual architectural models into the real-world environment. The methodology for the assignment was described to the students. The project involved MAR applications such as *Layar*, and design programs like, *SketchUp* and *3dsMax* (Sánchez Riera, Redondo, and Fonseca, 2015, 366). All the programs and applications used in the assignment, were learned within the course of the semester, before the assignment was given. Following the students successful completion of the assignment, multiple questionnaires were conducted by the researchers to understand the efficiency, effectiveness, satisfaction, and usability of the MAR learning experience.

The results of the responses showed a high correlation in the “representativeness of the exercise” and the “material presentation,” which demonstrated a high appreciation for the effectiveness of the AR visualization outcome. In addition, the “purpose” and the “content and software used,” was responded to positively by the students, meaning the usefulness of the applications for the given assignment, was appropriate (Sánchez Riera, et al., 2015, 372). Overall, the project concluded that MAR applications are a powerful tool for helping individuals think spatially and visualizing their models, to scale, within the landscape. The opportunity for designers to visually see 2-dimensional computer graphics translate into the complex scale of the real world in 3-demensional form, proved largely beneficial to the group of students. Retail and manufacturing companies have begun to further explore the potential benefits of AR’s ability to assist with peoples spatial understanding of their products.

Augment, an AR company established in 2011, provides retailers and manufacturers with the tools necessary to bring their products and websites to life using their specialized AR products. *Augment* provides a mobile application to scan and project AR, a SDK (software development Kit) to incorporate AR into company websites and, a desktop application to assure the AR media is perceived in the way one designed it. Because of the ability for customers to visualize their products, scaled, in AR, companies had an increase in merchandise sales. “Low consumer confidence is a big contributor to high rates of abandoned purchases (Williams, 2016, 9);” Therefore, innovative companies have begun solving this issue among consumers by incorporating interactive AR experiences.

Figure 16. Mobile *Converse* application letting a buyer visualize the desired shoe on their foot. Reprinted from *Foundations and Future of Augmented Reality and Ecommerce: How augmented reality will impact online retail* (p. 10), by Williams, D., 2016, France: Augment. Copyright

Lego has created an in-store AR powered kiosk which allows potential buyers to scan and digitally visualize the assembled *Lego* product within the box, before the person buys the item (Williams, 2016, 9). Similarly, *Converse* created an AR application that allows the buyer to project the shoe they wish to purchase directly on his/her feet. One of the biggest users of AR’s ability to increase peoples spatial understanding is *IKEA.* In 2013 the company created an AR catalog which allows one to project the company’s products to scale, in the desired

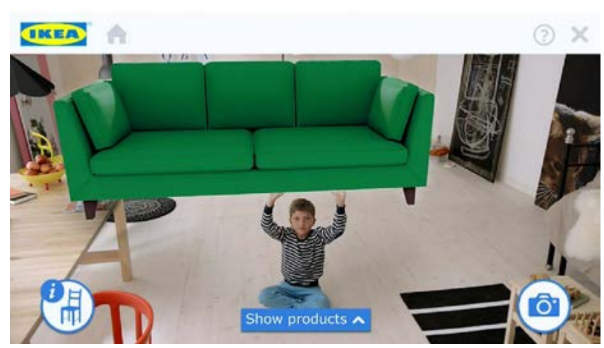

Figure 17. Mobile view of an *IKEA* couch being projected into the room from the augmented reality company catalog. Reprinted from *Foundations and Future of Augmented Reality and Ecommerce: How augmented reality will impact online retail* (p. 11), by Williams, D., 2016, France: Augment. Copyright 2016.

material directly into the location of the room one wishes to put the product (Williams, 2016, 11). MAR technology is continuing to progress as smartphones become more and more equipped to create a seamless connection between the virtual and the real-world environment.

Smartphones are beginning to implement depth-sensing capabilities which will increase AR's educational and spatial contributions to society. Beginning with the Lenovo Phab 2 Pro (paired with Google Tango right off the shelf), smartphones will have the ability to map out the space around them, and people will be able to project objects in the desired location, the same way one would a physical item (Williams, 2016, 26). With further advancements in mobile device features such as this, MAR is quickly progressing to be able to understand and handle the complex outdoor environments even more, which excites landscape architects everywhere.

Augment's uniqueness comes from the company's decision to gear their AR software and design programs toward companies, rather than many MAR applications, which gear their applications more toward the public. The companies advanced suite of interconnected products, allows for an easier design flow from the AR computer software, to the MAR applications. This versatility allows landscape design professionals to easily integrate AR creations for the public to access within the landscape. This increased opportunity to design AR digital media through more user-friendly design programs, would require landscape architects to once again adapt their design practices to utilize these new technological advancements to adapt to this rising public interest in AR. Researchers are beginning to test the future of AR interactive experiences within a designed space, by experimenting with AR sensory technology, which will allow one to feel texture augmented onto virtual or real objects.

Sensory Interaction Research

Researchers at Disney have created a new interactive AR experience through the application of tactile augmentation to real, and virtual environments. The product created is called REVEL, involving sensory technology that remains a largely unexplored area of research today (Bau and Poupyrev, 2012, 1). The design employs the principle of "reverse electrovibration," which involves sending a weak electrical signal into the users' body, creating an oscillating electrical field around one's fingers (Bau and Poupyrev, 2012, 1). *REVEL* stands apart from other tactile technology in the past which typically applied the electrovibration directly onto the object one is interacting with, or through wearable sensory technology. By inputting the electrovibration directly into the user, the entire world has the potential to become a programmable canvas to alter the user's tactile perception, despite the current inclusion of some other temporary electronic equipment (Bau and Poupyrev, 2012, 9).

Figure 18. The user feels virtual tactile textures, when one uses an augmented reality application, apply the tactile augmentation directly a physical or virtual object. Reprinted from *REVEL: Tactile Feedback Technology for Augmented Reality* (p. 1), by Bau, O., and Poupyrev, I., 2012, New York, NY: Publications Dept. ACM, Inc. Copyright 2012 by ACM.

The device outputting this unique sensory experience is a small, inexpensive, mobile device that can be applied almost anywhere on the users' body, or placed discretely on an object being touched by the user. Currently the sensory experience can only augment active human tactile interactions, such as moving one's finger across a surface. In addition, the surroundings currently require electronic activators to complete the augmented tactile feedback loop (Bau and Poupyrev, 2012, 10). The research resulted in the production of multiple design proposals utilizing the technology to help guide the visually impaired using invisible tactile paint along walls, interactive gaming experiences, picture paper with multiple textures, and the ability to feel AR models (Bau and Poupyrev, 2012, 10). The technology to create these augmented tactile interactive experiences may fall outside the typical landscape architects' knowledge, but the ability to soon incorporate this advanced tactile *REVEL* coating to typical landscape elements could be applicable in the near future.

Construction documents are a common practice in landscape architecture. Every landscape, hardscape, or technological application must have assigned design specifications, describing all the need to know information for an item to be installed correctly. *REVEL* presents new opportunities for landscape architects to turn seemingly basic landscape elements into an augmented sensory experience for users to interact with. Many researchers have attempted activating the sense of touch using more limiting AR technologies, like wearable electronic muscle stimulators, shown in Figure 19, or interactive user created AR sense technology, shown in figure 20. Both methods are influential to the users' experience, but the appeal in *REVEL*

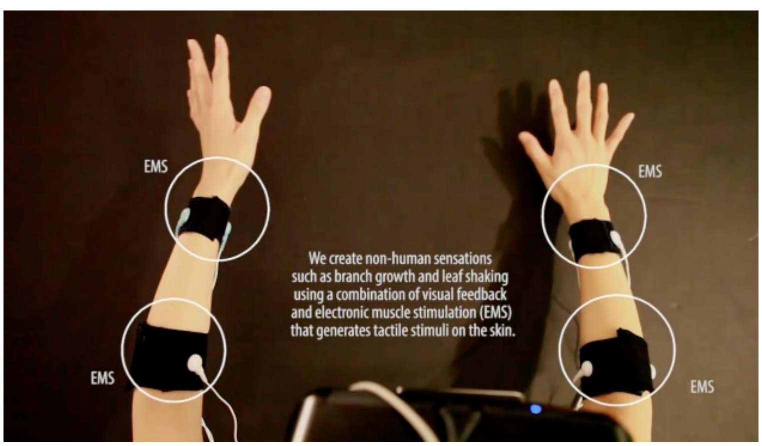

Figure 19. Wearable sensory system attached and correlated to an augmented reality experience. From *MIT media lab*, by Liu, X., 2016, Retrieved February 17, 2017, from https://www.media.mit.edu/projects/treesense/overview/

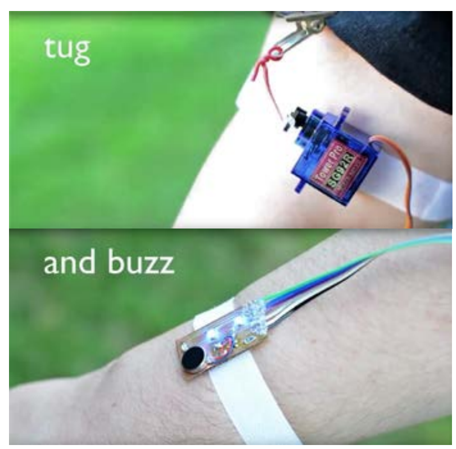

Figure 20. Sensory technology coordinated with augmented reality phone game application. From *Youtube*, by Pixelscanner, 2013, Retrieved January 20, 2016, from https://www.youtube.com/watch?v=vyPP7pejN-U

technology is in the technologies ability to allow the user to be free from extra equipment, which has the potential to hinder the user's mobility within a space (Bau and Poupyrev, 2012, 10). Research into this AR sensory experiences continue to be enhanced by new technologies that not only allow one to feel sensations through augmented reality, but taste them.

Keio University's Yasuaki Kakehi Laboratory recently showcased *TagCandy* at the SFC Open Research Forum 2010 in Tokyo, Japan. The prototype technology created an augmented reality interaction that stimulated a unique alternate tasting and auditory experience. The project used a lollipop to demonstrate the technology. Junichi Yamoaka, a member of the Yasuaki Kakehi Lab team said, "when your tongue touches the vibrating candy, you receive a sensation, and when your teeth touch the candy, you hear a sound through bone conduction (Smith, 2011)." The pictures projected on the screen ranged from fizzy soda to firework explosions, which allowed for multiple different tasting sensations (Smith, 2011). Research continues to progress studying how technology can enhance peoples sensory experience, through AR interactions. The technology being researched and developed today, continue to produce new methods for redesigning the public landscape to incorporate these exciting, multi-sensual, and engaging technologies.

Figure 21. Technology prototype creates an augmented reality experience to ordinary candy, allowing one to taste and hear the images on the computer. From *YouTube*, by ikinamo, 2010, Retrieved February 4, 2017, from https://www.youtube.com/watch?v=FgkvcGjFNuY

Section Three: Methods and Approach

The creation of landscapes where nature, advanced technology, and people are all interconnected, remains a largely unexplored area of research within the discipline of landscape architecture (Cantrell and Holzman, 2016, xvii) Augmented reality (AR) research projects have begun to demonstrate new opportunities for landscape architects to not only design landscapes that adapt to this rising technological trend, but through the use of advancements with new tools to design the AR experiences themselves. AR research has also shown a potential for the public to contribute to the design and programming of the landscape as well, through various user friendly mobile design applications. This unique opportunity allows for a space to become a pluralist environment, able to cater to a wide variety of users, cultures, and interactive experiences. The research project will utilize the AR research and technologies previously

Figure 22. The original base landscape design to be outfitted with AR technologies, spaces, and experiences. From *LPA Inc.*, by D'Amato, R., 2014, Retrieved April 1, 2017, from http://blog.lpainc.com/lpa-blog/bid/110330/A-New-Vision-for-West-Hollywood-Park

discussed, to formulate a new set of design considerations and guidelines for the landscape architects to follow, as the profession begins to utilize these popular AR technologies.

The project explores and examines an existing site, which is not specific to a geographic location, to allow for a more open ended discussion as to what the design possibilities are for integrating AR. The landscape chosen includes 9 common landscape elements to be redesigned, such as a rooftop plaza, traditional children's playground, open lawn, relaxation space, nature trail, outdoor amphitheater, walking/jogging path, basketball court, and community lawn and event space. The landscape areas will be either reprogrammed with AR technology, enhanced to adapt to AR technologies, or a mix of the two design approaches. The elements within the site, such as hardscape, landscape, and the community interactions, will be discussed after applying these new AR approaches. By experimenting with these spaces, the profession of landscape architecture can begin to understand how these elements fit together. Integrating new AR

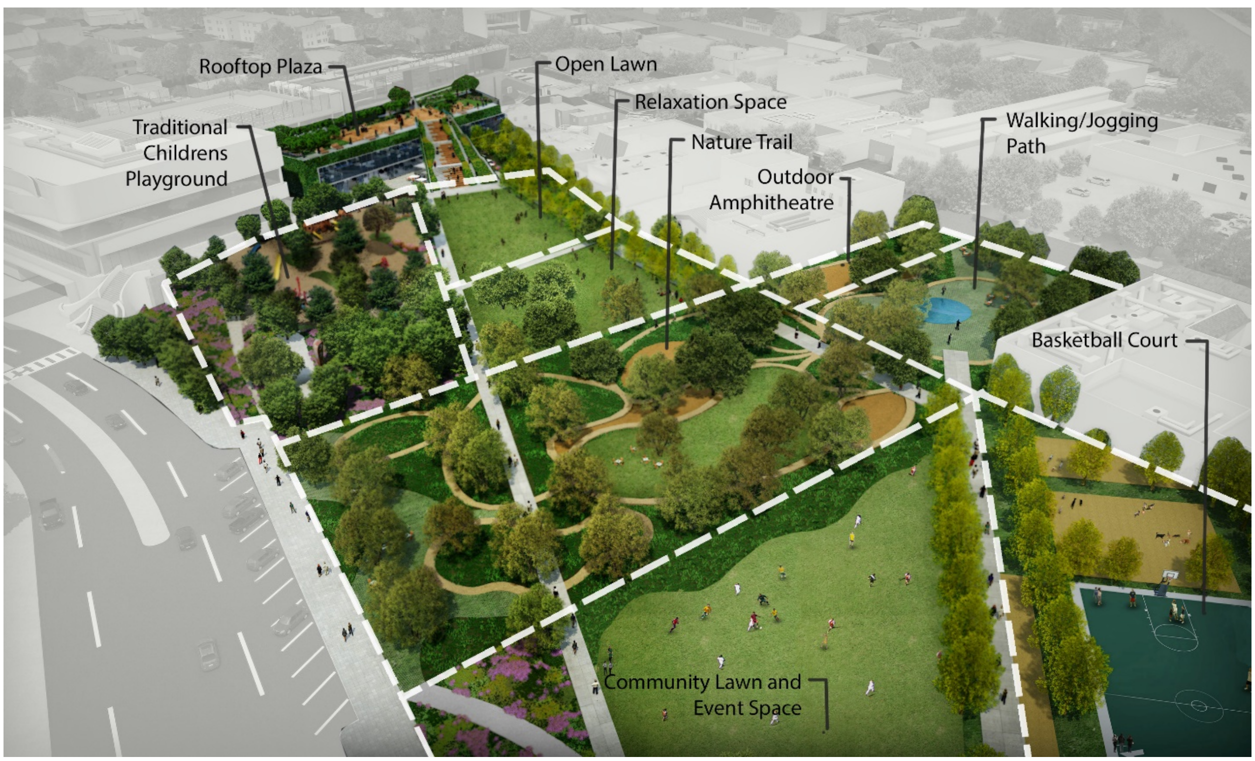

Figure 23. The original landscape's program elements to be redesigned using augmented reality design methods. From *Photoshop*, by Lopez, R., on February 10, 2017.

technologies and/or interactions a total of 5 perspective designs are created to help landscape designers visualize some of the more complex landscape spaces.

AR projects and research is applied in the construction of these new public spaces, enhanced by interactive AR technology. Each new landscape characteristic and design approach used to alter the given space, are then integrated into the formation of a new set of design guidelines for landscape architects to discuss, further research, and use as an aid. The considerations used are organized into a helpful design guideline chart. The chart will serve as the beginning framework for future designers and researchers to build upon as programmed AR landscapes become more prevalent, and AR technologies continue to progress.

The landscape design guidelines formulated by this study, are then assessed based on the design aids usefulness in the application of AR. The chart created (found in section 4) will show the value of this design aid as a potential tool for the profession to utilize and build upon in the future. The assumption is that AR technology is here to stay, so why not utilize it? Given the technological trend in AR and the increasing use of smartphone devices, pushes the profession of landscape architecture to begin experimenting, and researching with new design elements. The profession of landscape architecture needs to keep evolving with these cultural trends for the profession to continue designing interactive, and educational spaces, for the public to enjoy.

Chapter Four: Findings and Discussion

Original Landscape Design

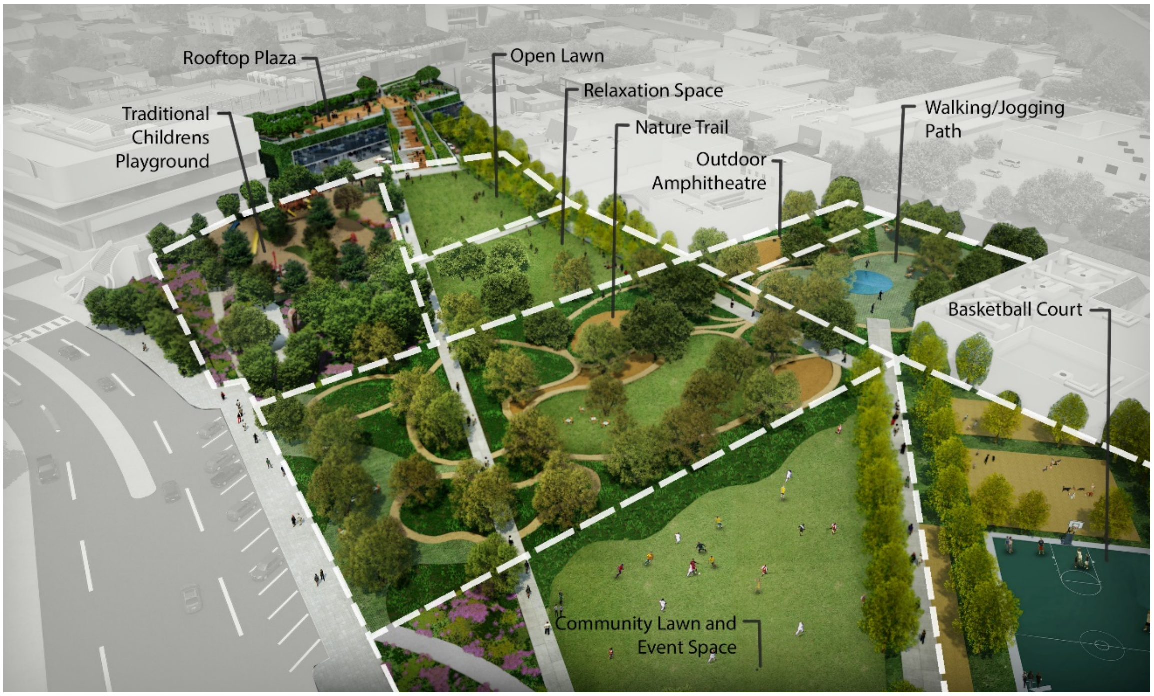

Figure 24. The original landscape's program elements. From *Photoshop*, by Lopez, R., on February 10, 2017.

Landscape Design Integrated with AR Technologies and Experiences

Figure 25. The new landscape program elements with AR experiences integrated and designed into the existing site. From *Photoshop*, by Lopez, R., on February 10, 2017.

The reconfiguration, adaptation, and renaming of the 9 program spaces shown in Figure 24. The transformed site, shown in Figure 25, demonstrates how each of these designed landscape areas could be approached to create a whole new, immersive environment for the community to interact with. This concept of reprogramming the programmable, provides landscape architects, as well as the public, with the potential to influence this ever-changing site. The research has demonstrated how AR digital media can be overlaid over real world scenes, without the necessity to make large manipulations to the space itself. One area of the project site that applied these landscape design considerations was the *Geolocation MAR Exhibition Space*, shown in Figure 26. The space still utilized the same landscape elements that were previously designed onto the site, such as a walking/jogging path, pond, and various tree coverage for shade, but incorporated the design approach integrating and designing an interactive AR digital landscape layer that could be continuously reprogrammed for a specific community purpose. The landscape addition utilized was through the installation of small labels along the existing walking path, which consisted of geographic coordinates. The geo-coordinates using mobile AR browsers, were to inform the visitors of where digital AR media was located, and provided them with the data needed to geolocate AR models into the landscape.

The AR research showed mobile AR browser applications to be the most abundant and widely used mobile application. The application uses mobile devices geographic positioning system (GPS) to project AR digital media into the environment, in their assigned, real-world locations. The research has been applied to the site, utilizing this AR design concept, which aims to use mobile AR applications to create an interactive AR exhibition space that can be programmed for the desired use. The AR digital media, located along the path, demonstrates one design approach as to how landscape architects could activate a traditional walking path, and

Figure 26. The graphics demonstrates one example of how the *MAR Exhibition Space* could be used to geolocate digital augmented reality media throughout the site to increase community awareness about autism. From *Photoshop,* by Lopez, R., on February 25, 2017.

transform it into a *MAR Exhibition Space.* In this example, a group of community members from the surrounding community came together to promote public awareness about autism, like the researchers did for the *Mission Wildlife* project concerning animal extinction. The community members programmed educational material around the walking path, using the geolocation coordinates provided by the landscape architects, to create a successful awareness walk for the public. The space could continue to be reprogrammed by the public, or landscape architect, to form new experiences for the public to enjoy. These AR interactions could be educational, spatially engaging, or simply just for fun. The space presents a lot of opportunities for both the public and the landscape architect. The landscape designers design approach could be as simple as providing the proper landscape aesthetics, such as trees and seating areas, to create an appealing space to interact with the AR media. The design approach may be more complex if landscape architects begin designing the AR digital media itself, using newly advanced AR software. The *MAR Exhibition Space* has some potential design concerns because of the creation of such a versatile and undefined space.

The addition of a digital media layer that requires mobile devices to activate the space, may not be enough of a stimulus for visitors to want to pull out their mobile devices to learn about the augmented information. Another concern is how will designers provoke community members to display their exhibition items in AR digital media, or let alone choose this digital method over more conventional forms, like posters? If the space solely requires mobile devices to experience the digital content within a site, the physical site may not be as aesthetically pleasing without the designed AR media. This concern can be seen from the opposite point of view, where the AR digital media is viewed by the public as distracting from the physical environment experience. Lastly, who is going to regulate the digital content that is projected,

Figure 27. Mobile Augmented Reality Signage located in the *MAR Scavenger Hunt* area. From *Photoshop*, by Lopez, R., on February 15, 2017.

either by the community members or the landscape architect? Further research by the profession into how to successfully integrate these AR design considerations will be needed to better understand the implications of designing with/for these new AR technologies. Another landscape area within the project site that also utilizes an informative AR digital layer for the community to interact with, is the *MAR Scavenger Hunt* area of the site.

The integration of an interactive MAR scavenger hunt, allows the designer to better incite the visitors to use their mobile devices through gamification and tracker-based AR projection methods. This form of AR interaction was also demonstrated by the research project called, *Minnesmark.* This design approach differs from the *MAR Exhibition Space*, because the landscape architect is required to perform more design decisions such as signage placement to design a successful AR experience. The perspective graphic shown in Figure 27, demonstrates how the AR experience would be constructed and accessed.

The existing nature trail consisting of various routes, provides the perfect setting to create this MAR experience, through the incorporation of AR signage. Signage is a landscape element that landscape architects traditionally use. Recent advancements in AR technology and projection methods, have allowed a new opportunity for landscape architects to begin enhancing the signage material using AR design methods. The entire signage board acts as the AR tracker for designers to assign additional AR information for users to scan and project the hidden digital media needed for the scavenger hunt. Perspective graphic of this experience shows users scanning the signage board outdoors, through advancements in smartphone camera recognition, and then projecting the 3-dimension dinosaur in AR, for the individuals to interact with. Research has proven that people generally like this mobile phone interactive experience, as well as, learning information in 3-demensional form, rather than a limited 2-dimensional signage board. The ability to project 3-demensional models to scale, provides another enhancement to traditional signage design approaches, that can be utilized to enhance the public's experience.

Signage is all around us. Landscape architects have many design considerations to think about when implementing this interactive augmented signage design. The profession must begin to ask questions like, what type of interaction is the public having with the digital media? Is it to increase spatial or educational knowledge, or is it a purely social experience, requiring people to work together to uncover the hidden information? Lastly, what type of setting/situation would be most appropriate to include these AR additions? Would it be best applied in a recreational, natural, urban, or entertainment style space? These are preliminary design guidelines that landscape architects will need to research further to test the validity of these AR applications.

The transformation of the existing *Relaxation Space* into a *MAR Gaming Space,* continues to present new design questions to be considered when choosing to integrate MAR experiences into a landscape design.

The *Relaxation Space* was reprogrammed with outdoor table and seating, as well as an artful combination of shaded and open areas. The transformation of the space into a *MAR Gaming Space,* involved multiple design decisions. The space applied the research findings about the popular MAR application, *Pokémon GO*, and the results from the Pew Research Study on smartphones ownership. The Pokémon GO application demonstrated how MAR applications can promote public physical fitness by requiring individuals to move around a space in which they're interacting with AR objects in the game. *Pokémon GO* also enriched places for the public and businesses to relax and collaborate with one another. The *MAR Gaming Space* has attempted to create the optimal gaming setting for MAR gaming applications that would require a multipurposed site, like *Pokémon GO*. Design considerations such as how much space is required for these AR experiences, or where seating arrangements should be located to not interfere with these interactions, are site elements landscape architects must begin to learn and understand. In addition to creating a space that caters to both mobile and stagnant usage of space, the Pew Research Study findings helped solidify the decision to transform an originally *Relaxation Space* into a space to use ones' mobile device.

The study concluded 70% of smartphone owners said their mobile device made them feel free, connected, and something they couldn't live without (Smith, 2015, 28). The study also found that people were already using their smartphone devices in public places, to keep them from boredom and escape from having to interact with other people. Smartphones ability to make people move or stay still, interact with others or not, and generate a mix of emotions, make the integration of this technology extremely difficult. The design decision to make the *Relaxation Space* a *MAR Gaming Space,* was not to annoy people who are trying to relax, but rather a beginning in which smartphones can be usedas a tool to relax and find solitude in. Therefore, the space has been designed for MAR experiences, whether they are individual, collaborative, physical, or stationary interactions. The design approaches used to successfully design these multi-programmable landscape spaces, will need to be further researched to understand how to successfully orient the landscape for this unique interaction. Figure 28 and Figure 29 demonstrate a graphical representation of how landscape designers can begin designing these MAR gaming experiences using traditional landscape materials, such as hardscape pavers.

The graphics portray two individuals playing chess on a hardscape that has been designed like a chessboard. The MAR application then projects the chess pieces using trackerless AR projection methods. Users can then play a game of chess within the landscape instead of being

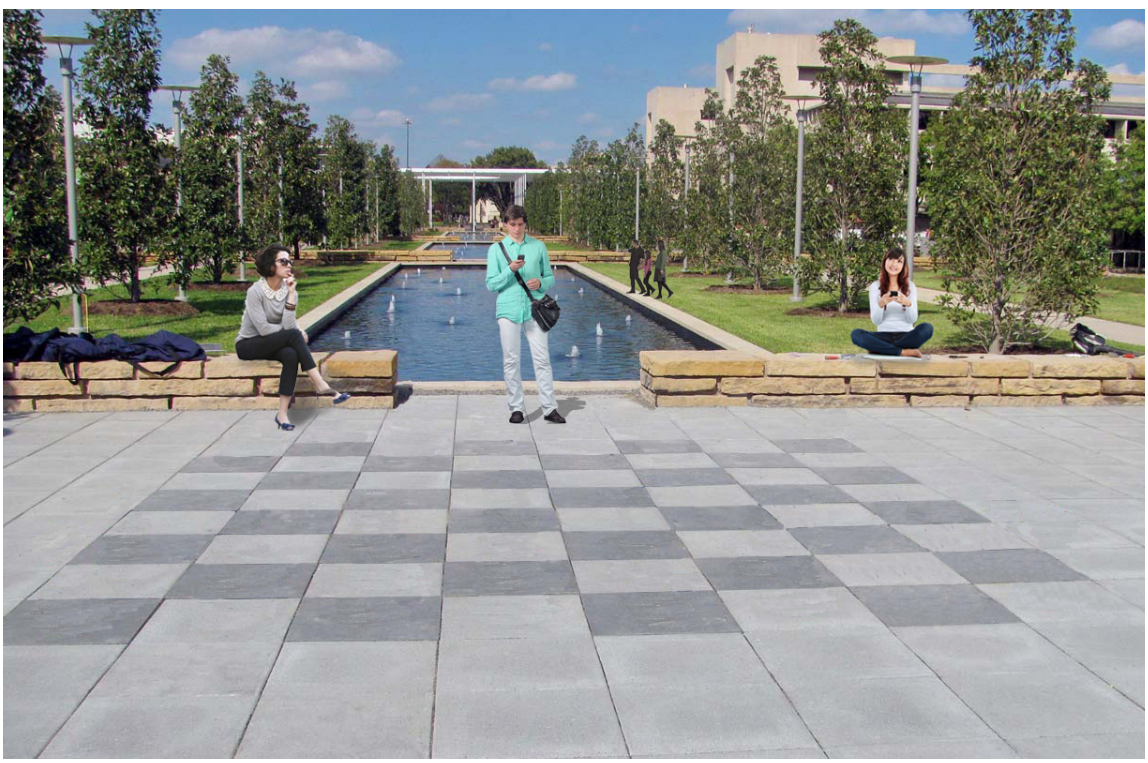

Figure 28. Showing hardscape pavers designed to be used for mobile augmented reality gaming. From *Photoshop,* by Lopez, R., on February 18, 2017.

Figure 29. Two players using their mobile devices and augmented reality application to project and play chess on the designed paver chess board. From *Photoshop*, by Lopez, R., on February 18, 2017.

limited to the boundaries of their smartphone screen. The incorporation of these simple, but hugely beneficial landscape contributions can begin to bridge the gap between technology and hugely beneficial landscape contributions can begin to bridge the gap between technology and the physical environment. Not only can users play chess using the intricate paving pattern, but since the interaction is only seen through the two games mobile devices, the game does not interfere with the experience of anyone else in the same space. Landscape designers must be more thoughtful about their landscape materials to make sure they maximize the potential of every inch of the site. Another site transformation was designed to enhance the users' interaction with the landscapes' physical aesthetics was the integration of AR digital media in the form of AR art installations.

The existing sites programmed *Open Lawn* was replanted and installed with artistic installations. AR technology presented a new opportunity to reimagine how designers think about art. In many cases, art installations can become expensive, difficult to install, or hard to find. AR art allows designers to create art installations where the physical, seen art, can be enhanced using MAR applications and through various AR projection methods. Figure 30 and Figure 31 demonstrate these various project design methods that are possible for designers to utilize when programming an interactive AR sculpture garden. Graphic Figure 30 shows a spherical art installation, which is instantly overlaid with digital AR information when one scans the artwork using an MAR application. In addition, behind the artwork, another AR art installation is projected into the planter through geolocation. The example continues to demonstrate the multiple AR projection and positioning methods possible if the profession of landscape architecture were to consider enhancing the publics experiences within the space using AR technologies. There is an increasing need for a structured set of design guidelines to act as a tool for the profession of landscape architecture to utilize in the construction of these complex

Figure 30. Graphic of traditional landscaped sculpture garden. From *Photoshop,* by Lopez, R., on February 17, 2017.

Figure 31. Graphic of augmented reality art projected onto existing art installations to enhance the users experience. From *Photoshop,* by Lopez, R., on February 17, 2017.

environments. The last design examples demonstrate the opportunity for landscape architects to utilize more advanced mobile AR technology such wearable AR headsets to create a fully immersive and programmable landscape experience.

Incorporating recreational fields with AR capabilities inspires a whole new way of physical engagement within the designed landscape. Figures 32 demonstrates how recent advancements in wearable AR technologies, such as *Google Glass,* presents a new design approach for designing recreational fields. The graphics demonstrate how the *Basketball Courts* could be instantly transformed into multiple *AR Recreation Fields* at once, using new wearable AR technologies. Players could use the head gear to program the court to the desired recreational activity. This new way of thinking about recreational fields would present a whole new array of design considerations and landscape characteristics for designers to consider. What material

Figure 32. Graphic of how the augmented reality recreation court lines, seen through wearable augmented reality headgear for basketball. From *Photoshop*, by Lopez, R., on February 20, 2017.

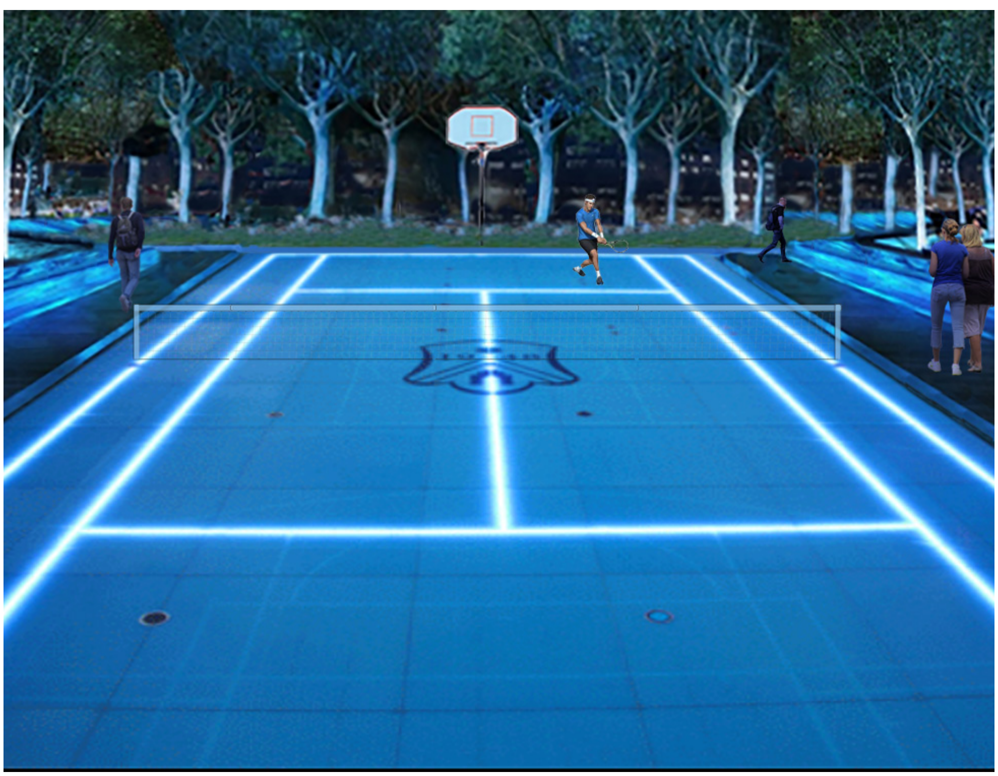

Figure 33. Graphic of how the augmented reality recreation court lines, seen through wearable augmented reality headgear for tennis. From *Photoshop,* by Lopez, R., on February 20, 2017.

would be used to provide an acceptable playing surface for multiple sports? Would the various sports equipment be stored on site, or designed into the site? These questions begin to formulate a new design thought process for recreational areas within a site. The last reprogrammed spaces begin overlapping similar findings, concerns, opportunities, and constraints as the other interactive AR landscape spaces.

The *Children's AR Playground* would require landscape architects to further research what AR technologies and interactions would be suitable for children. Just as landscape architects decide which age group to provide a playground for, AR interactions would also need to be labeled with age appropriate guidelines. Similarly, with the *Outdoor Amphitheater,* which has been transformed into a *MAR Video Space,* the digital media that is being accessed and projected would have to be regulated for the appropriate users of the space. The *MAR Observation Rooftop* creates a new discussion into what perspective or elevation would provide the most beneficial and impactful AR landscape experience. Lastly, the *MAR Imagination Field and Event Space,* will act as the new *Community Lawn and Event Space.* This space provides a central area for users of the space to congregate together and engage in similar AR interests. The complete integration of a completely interactive AR landscape experience to one given site, has presented researchers with a new design approach and thought process for designing for these AR technologies. The design considerations and landscape characteristics discussed, have been integrated into a chart to begin a new set of design guidelines for AR technologies to be incorporated within.

The chart, shown in Figure 33, represents a preliminary framework for landscape architects to continue to research and study. Based on this projects research findings, this chart consists of all the terminology, technologies, and methods covered during the duration of this

Design Guidelines for Designing Augmented Reality (AR) Landscape Experiences					
AR Design Considerations	**AR Experience Characteristics**				
Type of AR Interaction	Educational	Social	Spatial	Sensory	Gaming
AR Positioning Method	Geolocation	Tracker-Based	Trackerless	Projected	None
AR Technology Required	Mobile Devices	Auditory Devices	AR Clothing	AR headware	Built on Site
Target Number of Users	One person	Two People	Small Group	Large Group	World Wide
Design Setting	Natural	Urban	Recreational	Entertainment	Transportation
Human Senses Stimulated	Visual	Hearing	Touch	Smell	Taste
Time of Day Required	Morning	Afternoon	Evening	All Day	Event Based
Landscape Materials Required	Planting	Art Work	Hardscape	Lighting	Signage
Age Group	1 - 5 Year Olds	5 - 12 Year Olds	12 - 55 Year Olds	17 - 25 Years of Age	No Age Limit
AR Interaction Time Required	1 - 15 minutes	15 - 30 minutes	30 - 60 minutes	60 minutes & up	No Time Limit

Figure 34. Research based design guidelines for landscape architects designing augmented reality experiences. From *Excel*, by Lopez, R., on April 7, 2017.

project. The chart represents one person's view, so more experimentation, research, and discussion will need to be conducted by the profession of landscape architecture. Only then can the validity, and applicability of these new design concepts and landscape characteristics confidently be integrated into a site. The chart represents the complexity of designing for and with these AR technologies. The way landscape architects go through the design process, as well as, the way the profession thinks about space will need to be rethought as this new cultural trend becomes more and more popular.

Chapter Five: Conclusions

Augmented reality continues to be a subject heavily researched today. The ability to interact and project virtual information within an actual, existing environment, continues to be very appealing to the public. The advancements, accessibility, and mobility of mobile devices, which are equipped with all the necessary features to engage with augmented reality, has made researching augmented reality even easier. Research into the potential of augmented reality technology for landscape design has yet to be thoroughly studied and tapped into. The project design outcomes demonstrate just 9 possible landscapes that could be enhanced using AR technologies. In addition, the designs showed how simple or complex the design decisions and considerations could be if landscape architects were to continue designing these new AR equipped spaces.

The design thinking, decisions, and application methods carried out during the redesign of the landscape masterplan, utilized the AR research carried out at the start of the project. The design considerations, as well as the resulting landscape characteristics, both physical and digital, were then synthesized into a chart of design guidelines. The chart demonstrates just how complex these new landscape spaces can be. Whether one is just catering to the AR interactions through a simple readjustment of landscape aesthetics, or requires a large amount of landscape manipulation, the need to use a set of design guidelines seems apparent. There are a lot of decisions to be made when digital media is introduced into the environment.

The design considerations used or discovered when redesigning the existing masterplan, brought about a lot of opportunity for further discussion within the major of landscape architecture, as well as future research to test the validity of the chart elements. Some interesting design discoveries were needed for designers to confront the issue of what age groups were able to access this digital media. Just like designers must decide when integrating a play set into a landscape for children, landscape architects must apply the same design forethought. Another design consideration that parallels traditional design considerations for landscape architects is the decision about time of day. For example, night time may hinder mobile devices ability to scan AR trackers designed into the landscape. Therefore, a design consideration integrated into the guidelines would be AR positioning. There are landscape spaces that could benefit from a certain form of AR projection. The AR interactive experiences generate a whole new area of research including how digital media effects people within a space.

The interactive spaces programmed into the project site will need to be studied in terms of movement. Questions like, how long will the AR interaction take? How many people will be engaging with the digital media, and what type of interaction is being utilized? Landscape architects have traditionally researched how certain landscape elements, such as an archway to a courtyard, has the ability to draw users in. The research into hidden AR digital media, which requires users to actively seek and demonstrate the same kinesthetic qualities as the archway is an added bonus experience approach. Therefore, one can predict that this will be an area of research that landscape architects will have to understand before attempting to integrate a site with AR experiences. What makes a landscape successful is just as much about the function of the space as it is how aesthetically pleasing the site is. The appeal of this new landscape form that Bradley Cantrell calls *responsive landscapes*, is in the positive interactive qualities the technology can bring to space.

The research conducted for the project showed the interactive potential of AR technologies, including educational, social, spatial, sensory, and gaming experiences. Many of these interactive qualities of AR mimic the same interactions one can find in traditional landscapes. These findings solidify the fact that designing successful interactive experiences is a skill that landscape architects already have, but increasing the professions knowledge of the application of these technologies to enhance these common landscape interactions is the next step for the profession. Overall, the integration of AR technologies shows endless opportunities and possibilities of enhancing the sites. These sites, because of their complexity can result in some constraints, like the regulation of age groups accessing certain digital media.

Landscapes have the potential to soon take on many of societies ongoing efforts to regulate digital media on computers. These concerns, regulations, and restrictions may soon have to be applied to real world AR digital media. In addition, the integration of such sophisticated technology will result in the need for highly educated maintenance crews that can fix and regulate the advanced technology. Lastly, technology is an element that is changing so rapidly it will be hard for the profession to predict if AR will be as popular as it is projected to be in the future. Regardless, history has shown the profession of landscape architects to be highly adaptable to the changes in technological and social trends. The *Design Guidelines for Augmented Reality (AR) Landscape Experiences* chart will serve as a future design aid for the profession to continue to adapt and build upon.

Landscapes have always adapted to cultural trends, even when those trends lead to devastating environmental effects. Landscape architects have a new design tool using AR in which the landscape design and existing environment is positively enhanced because of its digital characteristics. Therefore, further research into what the environmental contributions AR can bring, will always be an area of high interest to the profession of landscape architecture. Programing landscapes elements has been a professional technique that has been utilized for centuries. Augmented reality allows landscape architects to begin truly *programing* the landscapes to benefit not just society and the landscape, but the environment as a whole.

Appendices

Appendix One: Citations

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Figure 26.

From *Photoshop*, by Lopez, R., on February 25, 2017.

Figure 27.

From *Photoshop*, by Lopez, R., on February 15, 2017.

Figure 28.
From *Photoshop*, by Lopez, R., on February 18, 2017.

Figure 29.
From *Photoshop*, by Lopez, R., on February 18, 2017.

Figure 30.
From *Photoshop*, by Lopez, R., on February 17, 2017.

Figure 31.
From *Photoshop*, by Lopez, R., on February 17, 2017.

Figure 32.
From *Photoshop*, by Lopez, R., on February 20, 2017.

Figure 33.
From *Photoshop*, by Lopez, R., on February 20, 2017.

Figure 34.
From *Excel*, by Lopez, R., on April 7, 2017.