REIMAGINING THE MUSEUM EXPERIENCE USING AUGMENTED REALITY: A FOCUS ON A NAMIBIAN MUSEUM

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Abstract

This study seeks to revolutionize the museum experience in Namibia through the implementation of AR Specifically, a focus was made on the National Museum of Namibia and developed an AR mobile application using ARKit and Reality Composer on the iOS platform. To gain a deeper understanding of traditional museum visits, an online survey was conducted which was targeted at various participants from different geographical areas, totaling 63 respondents. **Background**: The researcher's exploration of Namibian museums reveals the prevalence of two primary modes of visitor engagement: self-guided tours and guided tours, the latter often customized to suit the preferences and interests of international tourists. During personal visits, visitors typically rely on brief summary notes next to artifacts for supplementary information. Guided tours, while informative, often prioritize group interests, limiting individual exploration. **Methodology**: In this study, a mixed research design was employed to craft a software-based solution and gather insights from our target audience. By combining quantitative data from surveys with qualitative feedback from interviews and observations during AR application usage, we sought to gain a comprehensive understanding of user perspectives. **Findings**: This research unveiled that most museum goers had little to no prior exposure to AR applications during their museum visits, indicating an untapped potential for enhancing museum engagement through technology. The development and testing of the AR mobile application generated excitement among users, who expressed keen interest in additional features and interactive models. One challenge, however, was the application’s exclusivity to iOS devices, as it required iOS 13 or newer for full AR functionality. This limited the ability to collect feedback from a broader range of users.

This study signifies a significant stride in reshaping museum experiences in Namibia. By leveraging Augmented Reality, the aim is to elevate visitor engagement, facilitate knowledge acquisition, nurture meaningful interactions, and forge emotional connections with museum exhibits. To extend the reach and impact of AR-enhanced experiences, exploring cross-platform compatibility to engage a wider audience is recommended.

Keywords: Augmented Reality, iOS, Namibia, museum experience, mixed research design, AR mobile application, Reality Kit.

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List of Abbreviations / Acronyms

3D:	Third Dimension
4IR:	Fourth Industrial Revolution
AR:	Augmented Reality
ARKit:	Augmented Reality Kit
GPS:	Global Positioning System
IKEA:	Ingvar Kamprad Elmtaryd Agunnaryd
iOS:	iPhone Operating System
MVC:	Model View Controller
NFL:	National Football League
PSP:	Personal Software Process
PXP:	Personal Extreme Programming
UI:	User Interface
UX:	User Experience
VR:	Virtual Reality

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In God I trust, the Spirit of Success.

Dedication

I would like to dedicate this mini thesis to all the young women who are dreaming of becoming great one day. I hope that this mini thesis can be a good motivation and a practical example of a young woman, who continued to pursue excellence against all odds and still managed to excel. May this mini thesis be a steppingstone for all young women who want to pursue computer studies and make a significant difference in their own communities. The sky is the limit.

Declarations

I, Tatenda Audrey Chanakira, hereby declare that this study is my own work and is a true reflection of my research, and that this work, or any part thereof has not been submitted for a degree at any other institution.

Tatenda Audrey Chanakira	……..	April 2024
Name of Student	**Signature**	**Date**

Chapter 1: Introduction

This first chapter marks the beginning of our research journey and covers several essential aspects. It starts by explaining the research topic and gives a short history of the relevant technology. Additionally, it provides a detailed description of the research problem, outlines the research goals, highlights why this study is significant in both academic and practical terms, and clarifies the study's limitations and boundaries.

The research topic, "Reimagining the Museum Experience using AR: A Focus on a Namibian Museum" delves into the practical exploration of how AR technology influences visitors' experiences within a specific museum located in Namibia. This study aims to investigate the real-world implications of incorporating AR into the museum environment, shedding light on how it transforms traditional museum visits, enhances engagement, and enriches the overall cultural and educational experience for visitors. By focusing on a Namibian museum, this research will offer insights into the unique intersection of technology, cultural heritage, and tourism in the context of Namibia, contributing to a broader understanding of the potential benefits and challenges associated with AR adoption in museum settings.

The year 2019 ushered in a global pandemic that thrust the world into a maelstrom of social and economic upheaval. Lives were lost, jobs vanished, businesses scrambled to reinvent themselves, governments grappled with crisis management, institutions shuttered, and the very fabric of our interconnected world seemed to unravel. Three years on, the transformative force of technology has emerged as the guiding light in our lives.

In our contemporary landscape, technology has transcended its role as a mere facet of daily existence; it has become the cornerstone of modern life. The smartphone, once considered a luxury, has evolved into an indispensable necessity, shaping how we communicate and connect with one another. It is ubiquitous, a symbol of our interconnected age (Wicker, 2018). Smart homes, too, have become the norm, redefining our interactions with household electronics and fortifying our homes with enhanced safety and security measures. Simultaneously, the realm of healthcare is witnessing exponential advancements in equipment and technologies, promising improved medical care and an elevated quality of life (Sobolev et al.,2021).

Amid this ever-evolving technological landscape, AR is emerging as an integral force, poised to shape virtual realms such as the Metaverse.

A Brief History of Augmented Reality

Providing historical context about AR is of paramount importance as it serves to elucidate the evolutionary trajectory of this technology, delineating its progression over time and offering invaluable insights into its current state and prospective future advancements.

AR has historical origins dating back to the nineteen sixties, with Ivan Sutherland, a Harvard professor, pioneering the development of the inaugural head-mounted display system in 1968 (Arth et al., 2015). However, the term "augmented reality" was not officially coined until nineteen ninety by researcher Tim Caudel.

According to Bogue (2020), in the early nineteen nineties, another researcher in the United States Air Force Armstrong Research Lab, Louis Rosenburg, created one of the first fully functional AR systems. This system allowed military personnel to virtually control and guide machinery to perform tasks like training the United States Air Force pilots within a safer context.

A couple of years later, AR found its way into the entertainment industry for the first time through Julie Martin, who was a writer and producer. In the late nineteen nineties, the debut of the first virtual graphic system during a live National Football League (NFL) game broadcast by Sportsvision was witnessed.

Applications of Augmented Reality

AR is a versatile technology with a wide range of applications across various industries, enhancing user experiences and providing innovative solutions. This section explores some key applications of AR and their significance in contemporary contexts.

In the context of education and training, figure 1 takes on a new dimension when integrated with AR technology. AR overlays digital information onto the real world, offering an immersive and interactive learning experience. An iPad is used as the mobile device to transform AR visualization of the frog's muscular system.

Figure 1: Anatomical Overview of the Frog's Muscular System Enhanced through Augmented Reality in Education and Training. Source: apple.com

AR is revolutionizing education by offering immersive learning experiences. AR apps, such as Google Expeditions, enable students to explore historical sites, the human body, and complex scientific concepts in three-dimensional virtual environments (Ebadi & Ebadijalal, 2022).

Figure 2 illustrates two healthcare professionals engage with an AR system, wearing VR headsets, as they collaboratively interact with a lifelike holographic representation of a human skeleton. This transformative use of AR technology enhances medical education and training by providing an immersive and interactive platform for the study of human anatomy and clinical scenarios.

AR is reshaping healthcare by aiding medical professionals in diagnostics and surgery. Medical professionals use AR technology to simulate interactive training-based scenarios like Cardiopulmonary resuscitation, leading to better precision and outcomes (Balian et al., 2019). Additionally, as the world increasingly adopts online learning, AR-based teaching programs are revolutionizing medical education by simplifying complex information delivery, enhancing comprehension, and improving knowledge

retention, practical skills, and interpersonal abilities among medical students. Notable AR medical training programs like HoloHuman, OculAR SIM, and HoloPatient exemplify these advancements.

Figure 2: Augmented Reality Integration in Healthcare. Medical personnel interacting with a Human Skeleton Hologram. Source: freepik.com

This image, depicted in Figure 3, offers a compelling illustration of the application of AR in the context of interior design and furniture shopping. It portrays a woman who is strategically utilizing an iPad within her living room environment. Her objective is to assess the visual compatibility of a virtual, black-colored chair with her physical living space before committing to its purchase. This technology-driven approach empowers consumers with a highly immersive and informative pre-purchase experience.

In the retail sector, AR enhances customer engagement and product visualization. IKEA's AR app allows customers to preview furniture in their own homes before making a purchase. Moreover, AR is used for interactive advertising, enabling consumers to scan print materials and access additional product information or promotions (Caboni & Bruni 2022).

Figure 3: IKEA Place's Studio Mode - A revolution in Home Furnishing using AR. Source: ikea.com

Pokémon GO is an AR mobile game where players explore the real world to discover, capture, and collect virtual Pokémon creatures using their mobile devices. By leveraging Global Positioning System (GPS) and the device's camera, Pokémon are superimposed onto the player's surroundings, making it feel like they exist in the real world. Players engage in a variety of activities, including catching Pokémon, visiting Poke Stops for items, battling at gyms, evolving and powering up their Pokémon, and participating in community events.

Figure 4 offers a vivid portrayal of a user actively engaged in playing Pokémon GO on their mobile device. This depiction illustrates the immersive and interactive nature of AR gaming, exemplified by the popular mobile application.

Figure 4: Pokémon GO Mobile Gaming Experience. Source: pokemongolive.com

AR gaming has gained immense popularity, with Pokémon GO being a prominent example (Qin 2021). This form of gaming overlays digital elements on the real world, encouraging outdoor exploration and social interaction. In the entertainment industry, AR is used in live events, such as concerts and sports, to enhance audience experiences through interactive displays and real-time data (Avila et al.,2020).

Figure 5 provides an insight into the utilization of AR in the realm of navigation applications, specifically showcasing Google Maps' AR mode. This representation illustrates how AR technology enhances the process of finding directions and identifying points of interest for users.

AR-based navigation applications, like Google Maps' AR mode, assist users in finding directions and locating points of interest. These apps provide real-time visual cues on a smartphone screen, making navigation more intuitive, especially in unfamiliar urban environments (Joshi et al.,2020).

Figure 5: Augmented Reality Navigation with Google Maps. Source: theverge.com

AR is transforming manufacturing processes by providing workers with real-time information and visualizations. In assembly lines, AR smart glasses guide workers

through complex tasks, reducing errors and improving efficiency (Plakas et al.,2020). Maintenance technicians use AR to access equipment manuals and overlays for troubleshooting (Laviola et al.,2022).

In Figure 6, we witness an engineer, situated within a manufacturing plant, actively engaging with an AR system through her mobile device. This depiction vividly portrays how AR technology is revolutionizing manufacturing processes by offering real-time information and visualizations to enhance worker productivity and task precision.

Figure 6: Augmented Reality integration in the manufacturing industry. Source: freepik.com

In summary, AR has a profound impact on diverse industries, revolutionizing education, healthcare, retail, gaming, navigation, manufacturing, and more. These applications showcase the versatility and transformative potential of AR technology, offering innovative solutions that cater to various user needs and preferences.

Rationale for Choosing Augmented Reality for this study.

The decision to focus on AR in this study is supported by a variety of compelling reasons, as outlined below. These points are drawn from academic literature, emphasizing AR's transformative potential in diverse fields such as education, entertainment, and cultural heritage preservation.

I. **Enhanced User Engagement:** AR applications have been recognized for their ability to enhance user engagement by seamlessly blending digital content with the physical world (Anthes, 2017). This immersive quality of AR captivates users and fosters deeper interactions.

II. **Educational Benefits:** AR holds promise as an educational tool, making complex subjects more accessible (Irwanto et al.,2022). Recent studies highlight its effectiveness in enhancing learning experiences through interactive, context-aware content (Chang et al., 2022).

III. **Preservation of Cultural Heritage:** In the context of cultural heritage preservation, AR offers dynamic storytelling and interactive exploration (Boboc et al, 2019). It enables users to engage with historical artifacts or even people in novel and meaningful ways.

IV. **Youth Engagement:** Attracting young people to cultural institutions is a contemporary challenge. AR's interactive and technology-driven experiences resonate with the younger generation, fostering renewed interest in heritage sites (Kim et al.,2021).

V. **Alignment with Technological Advancements:** AR aligns with the rapid technological advancements of the fourth industrial revolution (4IR)

(Doorsamy et al.,2020). As 4IR disrupts industries and society through innovation, AR exemplifies the convergence of physical and digital realms.

VI. **Namibian Context:** The study's choice of AR is contextualized within Namibia's socio-economic landscape and its aspirations for technological progress (Namibia Vision 2030). AR offers a contemporary avenue to bridge cultural preservation with technological advancement (Manda & Ben Dhaou, 2019).

The Present State of Namibian Museums: A Necessity for Reimagination

Namibia, a country renowned for its diverse cultures, rich history, and breathtaking natural landscapes, boasts a network of museums dedicated to preserving its cultural heritage. However, these institutions face a host of challenges that compel us to consider a comprehensive reimagining of their role in contemporary society.

Namibia's museums, including the National Museum, Swakopmund Museum, and Tsumeb Museum, are repositories of the nation's cultural identity and historical narrative. They house a diverse array of artifacts, ethnographic collections, geological specimens, and paleontological wonders, each offering a unique perspective on Namibia's multifaceted heritage.

Despite their cultural significance, Namibian museums confront a range of pressing challenges. Firstly, there is a noticeable decline in interest, particularly among young people, in visiting museums. Traditional modes of presentation and static displays have struggled to engage contemporary audiences accustomed to dynamic and interactive experiences (Nashandi et al., 2022). Moreover, accessibility to museums is

hindered by geographical constraints and limited resources, leaving many remote regions devoid of these cultural institutions, thus denying residents the opportunity to connect with their heritage (Kirk & Owens 2023). Resource constraints also affect the preservation of invaluable artifacts and collections within Namibian museums, leading to challenges in proper conservation and maintenance. Despite their potential, museums remain underutilized for educational purposes, both formal and informal (Bekenova, 2023). Furthermore, there exists a significant technological gap in the era of the fourth industrial revolution (4IR), demanding that Namibian museums bridge this divide to remain relevant (Manda & Ben Dhaou, 2019).

The imperative for reimagining Namibian museums rests on several foundational factors. Foremost is the need for cultural preservation, with museums serving as custodians of Namibia's rich heritage. The reimagining of these institutions ensures the safeguarding of this legacy for generations to come (Gibson, 2019). Additionally, there is a pressing need to rekindle the interest of young people in museums, which can be achieved through the adoption of engaging, technology-driven experiences like AR to captivate and educate (Kim et al., 2021). A visitor-centric approach, prioritizing the enhancement of visitors' experiences, must be at the core of this transformation, with user-friendly exhibits and interactive displays fostering greater appreciation (Anderson, 2016). Embracing digital technologies, including AR, is pivotal for enhancing engagement and bridging the technological gap, aligning with the aspirations of the 4IR (Saundarajan et al., 2020).

In conclusion, Namibian museums find themselves at a critical juncture, torn between preserving the past and embracing the future. The current state of these institutions

underscores the need for a transformative vision that reimagines them as dynamic, engaging, and inclusive spaces. The subsequent chapters of this study will delve into the development of an AR mobile application, representing a concrete step toward revitalizing Namibian museums and securing their enduring relevance in the 21st century.

1.1 Background of the study

Namibia, a land of rich cultural heritage and history, boasts a museum landscape that predominantly operates through two distinct modes: personal walk-ins and guided tours (Kandjimi, 2019). These modes define the visitor experience, shaping the interaction between patrons and the invaluable artifacts and exhibits that inhabit the museum spaces.

Personal walk-ins, the first of these modes, encapsulate the essence of independent exploration. Visitors, often locals or solitary travelers, venture into the museum with a sense of curiosity, embarking on a journey of self-discovery amid the curated collections. This mode, while granting freedom, tends to limit access to detailed information about the exhibited artifacts. In this context, one might occasionally encounter a note discreetly affixed to an artifact, offering only a fleeting glimpse into its historical or cultural significance. Such encounters leave visitors yearning for deeper insights and a more profound connection with the exhibited heritage.

In contrast, *tour guided tours*, the second mode, predominantly cater to groups of international visitors. These immersive tours, led by knowledgeable guides, provide an opportunity for deeper engagement with the museum's offerings. Visitors are

guided through the exhibits, benefiting from expert insights and a cohesive narrative that weaves together the museum's treasures. However, this mode often entails a whirlwind experience, with limited time for in-depth exploration. The need to accommodate group dynamics and time constraints may leave curious minds craving a more personalized and interactive approach to learning.

The prevailing museum landscape in Namibia predominantly relies on visual presentations, where artifacts are displayed as static images or carefully positioned physical objects. While these exhibitions offer glimpses into the nation's vibrant cultural tapestry, they often fall short in fully captivating and educating visitors, particularly the younger generation.

To illuminate the path towards a more immersive and engaging museum experience, the researcher embarked on an insightful visit to a local museum in Windhoek. Here, the visitor's quest for knowledge is partially quenched by summary notes thoughtfully placed beside artifacts. These notes, though informative, represent just a fraction of the potential for engaging storytelling and interactive learning that museums can offer.

In essence, the dichotomy of personal exploration and guided tours, combined with the static nature of artifact presentations, has given rise to a burgeoning desire for an innovative approach to museology in Namibia. An approach that harnesses technology to breathe life into the artifacts, providing visitors, especially the youth, with a dynamic, interactive, and educational experience that both respects the rich heritage of the nation and nurtures the curiosity of its future custodians.

1.2 Statement of the problem

In recent times, a disconcerting trend has emerged in Namibia's cultural landscape: a discernible decline in the interest of young people in visiting museums. This issue is rooted in the conventional methods of exhibiting artifacts, recounting history, and engaging visitors in storytelling within these cultural sanctuaries. The standard museum visitation routine exemplifies this problem: whether it is a group of school learners embarking on an educational outing or individual foreign tourists exploring Namibia's cultural heritage, the experience often follows a predictable script. In the former scenario, a museum tour guide is typically assigned to shepherd the group through each point of interest. When questions arise, the guide's responses tend to be general, providing limited depth or personalized engagement. In the latter situation, solitary travelers may similarly find themselves meandering through the exhibits, occasionally pausing to read the summary notes adjacent to artifacts. While these visits may offer unique, albeit one-time experiences, they seldom foster a lasting connection or enthusiasm for museums, particularly among the youth.

This lack of engagement among young people in the museum experience carries significant repercussions. It not only hinders their exploration of the nation's cultural heritage but also diminishes their inclination to delve deeper into the rich tapestry of Namibian history. The consequence is a generation less connected to their roots, less appreciative of their cultural identity, and less eager to preserve and promote the nation's precious heritage.

Namibia's aspiration to embrace technology as a catalyst for socio-economic progress is evident through the visionary initiatives of its current leadership, notably His

Excellency, President Hage Geingob. The establishment of the 4th Industrial Revolution (4IR) task force underscores the nation's commitment to innovation and progress. While first-world countries have embarked on the journey of the 4IR, Namibia faces challenges related to internet access, infrastructure, and technological education. The 4IR, also known as Industry 4.0, promises significant socio-economic opportunities but also presents challenges as it disrupts societal norms, reshapes businesses, and influences government functions through innovation (Manda & Ben Dhaou, 2019).

This research acknowledges the timely synergy between the transformative power of AR and Namibia's aspirations within the 4IR, ultimately seeking to position museums as dynamic hubs of interactive learning, cultural preservation, and technological advancement.

1.3 Objectives of the study

The primary objective of this study is to leverage AR technology to enhance the museum experience in Namibia, addressing a research gap related to the limited research on AR applications in Namibian museums. We aim to reimagine museum visits for both local and international visitors, making them more immersive, educational, and enjoyable. The below sections I, II and III outlines the specific sub-objectives guiding this study.

I. **Designing a User-Centric AR Prototype:** Develop a high-fidelity AR prototype using Adobe XD, considering the preferences and needs of diverse

museum visitors in Namibia. This sub-objective is essential in addressing the research gap related to tailoring AR experiences to the local context and visitor demographics.

II. **Developing an Interactive AR Application:** Utilize cutting-edge AR technologies such as Reality Kit and ARKit to create an iOS-based AR application. This application will seamlessly integrate with museum exhibits, aligning with the literature's emphasis on the integration of AR with physical artifacts. By achieving this sub-objective, we aim to contribute to the understanding of how AR can complement traditional exhibits in a specific cultural context.

III. **Enriching User Experience through Sensory Augmentation:** Implement environment sensory augmented technology within the AR application to enrich the user experience. This sub-objective aligns with the literature's research gap related to preserving and presenting the cultural significance of artifacts and traditions specific to Namibia. By incorporating sensory augmentation, we intend to foster a deeper connection between visitors and the cultural heritage on display, which is vital for addressing the gap in understanding how AR can align with and enhance cultural narratives in Namibian museums.

1.4 Significance of the study

AR is a transformative technology that offers a fresh perspective on presenting three-dimensional models (3D) and reshaping user interactions within mobile applications.

This study ventures into uncharted territory by harnessing high-performance rendering software tools, as delineated in the study's objectives, to demonstrate the implementation of AR in a technically proficient manner. The approach aligns with recommended software development processes, as elucidated in the methodology section within Chapter 3, ensuring a robust and effective execution of AR technology.

While AR has garnered international attention and application, this study sets itself apart by providing context-specific insights tailored to the unique cultural fabric of Namibia. It transcends the mere replication of global solutions that may not resonate with Namibia's distinct cultural ethnicity, its people, and their perceptions of museum experiences. In doing so, this research unveils novel perspectives on how AR can be integrated into the Namibian context, particularly within the realm of museums. The study concentrates on several critical aspects, including museum setup, user engagement with the mobile app, and the establishment of best practices to underpin the development of a stable and high-quality AR mobile application. As such, this research seeks to set a benchmark for future AR applications within Namibia.

Furthermore, this research takes on a pioneering role in advancing the vision of the fourth industrial revolution (4IR) that Namibia has embraced. The 4IR promises to revolutionize various sectors by harnessing innovation, and this study stands at the forefront of this transformative wave, illustrating how AR technology can be employed as a catalyst for socio-economic development in Namibia.

In the pursuit of a prosperous and industrialized nation, this research aligns harmoniously with the objectives outlined in Namibia's Vision 2030, contributing to the following crucial dimensions:

I) **Sustainable Socio-economic Development**: By harnessing technology, particularly augmented reality, this research endeavors to preserve cultural heritage and introduce new, enriched experiences across multiple sectors of the economy, including tourism, healthcare, and education.

II) **Innovative Problem Solving**: This study is dedicated to discovering innovative solutions that address the unique interests and needs of developing countries like Namibia, paving the way for technological progress and socio-economic advancement.

III) **Youth Engagement with Cultural Heritage**: AR Technologies hold the potential to rekindle youth engagement with their cultural heritage. The research showcases not only the technical skills available locally but also the means to inspire and educate the younger generation about their cultural roots.

In summary, this research embodies a commitment to technological advancement, cultural preservation, and socio-economic progress, all with the ultimate aim of propelling Namibia towards a prosperous future in alignment with its visionary goals.

1.5 Limitation of the study

It is essential to acknowledge the limitations inherent in this research endeavor. Firstly, this study offers insights into the integration of AR technology within the museum context in Namibia; however, it does not encompass the entirety of museums within the country. Instead, it concentrates its focus on a singular museum as a representative reference point. While this museum provides a valuable case study, it's important to

recognize that the findings may not comprehensively represent the diverse landscape of museums across Namibia.

Secondly, the scope of the AR mobile application developed for this study is limited to the iOS platform. Although iOS offers a stable and well-supported environment for AR applications, it's worth noting that this restricts the accessibility of the app to a specific user base. Nevertheless, it's important to emphasize that the design and development principles employed in this study can readily be adapted and extended to other platforms like the Android platform, ensuring a more inclusive reach for future implementations.

In summary, while this study provides valuable insights and a robust foundation for the integration of AR in the museum context in Namibia, it is essential to recognize that its scope is bound by the selection of a specific museum and the initial focus on the iOS platform. Future research and development efforts may explore a broader spectrum of museums and platforms, extending the reach and impact of AR applications in the cultural heritage sector.

1.6 Delimitation of the study

The delimitation of a research study serves as a critical demarcation, delineating the boundaries and confines within which the study operates. It articulates the specific parameters and exclusions that define the scope and focus of the research. In the case of this study, centered on the development of an AR mobile application to enhance the museum experience in Namibia, a comprehensive understanding of its delimitations is imperative.

The study's focus is primarily on AR technology and its specific application within the museum context, deliberately excluding consideration of alternative technological solutions. The intent is to concentrate solely on the conceptualization, design, and deployment of AR as a transformative tool for preserving cultural heritage. Geographically, the study is confined to Namibia, eschewing exploration beyond its borders to ensure a focused examination of the country's unique cultural heritage. The decision to limit the AR mobile application to iOS-based devices reflects a pragmatic approach, choosing platform stability while acknowledging the potential for future expansion. Within the expansive realm of museums, this research narrows its scope to the interaction between visitors and museum artifacts, deliberately avoiding broader considerations of museum management or operations. Temporally, the study is bounded to the contemporary era, providing a snapshot of AR technology's current impact in museums without delving extensively into its historical development. Culturally, while attuned to Namibia, the study maintains a focused approach by not extensively exploring dimensions beyond those directly relevant to the AR application's objectives. In essence, the study's intentional limitations serve to ensure a precise and targeted examination of AR's role in enhancing the museum experience.

In summary, these delineations provide a clear map of the research's confines, allowing for a focused and purposeful exploration of the development and application of AR technology within the specific context of Namibian museums. They underscore the deliberate choices made to ensure that the research remains coherent, manageable, and directly aligned with its defined objectives.

Chapter 2: Literature Review

This chapter, replete with scholarly inquiry and systematic synthesis, serves as the compass guiding us through the academic terrain of AR technology's intersection with museums. It reflects our commitment to scholarly rigor, as we traverse a landscape of knowledge and inquiry, ultimately seeking to innovate and enhance the museum experience within the vibrant context of Namibia.

2.1 The Foundations of Augmented Reality

AR stands as an innovative technology that seamlessly merges elements of the real world with virtual content, resulting in interactive and immersive user experiences. As described in the widely accepted definition by Wang et al., (2022), AR is characterized by three fundamental requirements originally outlined by researcher Ron Azuma in nineteen ninety-seven (Sünger & Çankaya, 2019):

I. **Integration of Real and Virtual Elements:** AR technology combines physical surroundings with digital information and objects, enhancing the real-world environment with interactive virtual content.
II. **Real-Time Interactivity:** AR systems empower users to engage with virtual elements in real time, allowing for dynamic interactions and responses to user inputs within the physical world.
III. **3D Registration:** AR ensures that virtual objects appear firmly anchored in the real-world context, creating a seamless fusion of physical and digital components.

These criteria underscore the essential features of AR technology, including the necessity for a display capable of blending real and virtual imagery, a computer system proficient in generating real-time interactive graphics, and a tracking system that accurately determines the user's perspective to maintain the stability of virtual objects within the physical environment (Wang et al., 2022).

2.1.1 Components of Augmented Reality System

In the realm of augmented reality, both hardware and software components play pivotal roles in creating immersive experiences. Davidavičienė et al., (2012) elaborate on the necessary components for an AR system, emphasizing the significance of both hardware and software aspects.

Hardware Components:

I. **Computer or Mobile Device:** The foundation of an AR system is a computer or mobile device that serves as the platform for processing and rendering virtual content.
II. **Monitor or Display Screen:** A display screen is essential for presenting the AR experience to users, allowing them to see the blend of real and virtual elements.
III. **Camera:** Cameras are integral for capturing real-world visuals, enabling the system to superimpose virtual objects seamlessly into the user's view.

IV. **Trackers and Sensors:** Trackers and sensors, such as Global Positioning System (GPS), compasses, and accelerometers, provide vital data for spatial tracking and orientation, ensuring precise alignment of virtual objects with the physical environment.

V. **Network Infrastructure:** Network connectivity is crucial for accessing real-time data and enabling collaborative AR experiences.

VI. **Pointer:** Input devices like pointers enhance user interactions within the augmented environment, allowing for precise selections and actions.

It's worth noting that various researchers categorize AR hardware components differently. For instance, Tacgin (2020) categorized AR hardware as trackers, microprocessors, display units, and input devices, while Villa et al., (2021) categorized them as microprocessors, screens, and sensors. These variations in categorization highlight the multifaceted nature of AR hardware components (Sünger & Çankaya, 2019).

Both Tacgin (2020) and Wang et al., (2022) agree on the symbiotic relationship between hardware and software within AR. Tacgin emphasizes that AR development encompasses both hardware and software, with hardware forming the foundation and software delivering the interactive AR experience. This perspective aligns with Billinghurst et al.'s viewpoint, reinforcing the idea that the immersive and interactive nature of AR applications relies on the seamless integration of hardware and corresponding software. In essence, both authors underscore the interdependence of hardware and software in the AR ecosystem.

In addition to the core components of hardware and software, modeling tools also play a vital role in the AR landscape (Sünger & Çankaya, 2019). These tools, encompassing both software and hardware, facilitate the creation of detailed 3D digital representations of real-world objects. Prominent software examples in this category include Unity3D, SketchUp, Blender, Cinema 4D, 3ds Max, and Sweet Home 3D. Furthermore, 3D engines such as WebGL, Unity3D, Papervision3D, Away3D, and Sandy3D contribute significantly to AR environments by enabling real-time rendering of virtual objects, thereby providing users with a lifelike view of virtual spaces (Sünger & Çankaya, 2019). The inclusion of these modern tools highlights the intricate interplay of hardware, software, and modeling tools within the contemporary AR landscape, emphasizing the multifaceted nature of AR development.

2.2 Augmented Reality in different contexts

The study of Augmented Reality (AR) across diverse contexts reveals its multifaceted and transformative nature. AR has the potential to significantly impact various sectors like education, architecture and design industries, healthcare and navigation amongst many others. Additionally, exploring AR in the African context sheds light on its potential applications in the previously mentioned sectors or industries. This section discusses these various use cases of AR.

2.2.1 Education and Training

In the realm of education and training, AR continues to evolve as a transformative tool. It enables educators to create engaging and immersive learning experiences. For instance, the study by Avila-Garzon (2021) discusses various cases, places, and

potentials of AR in education, highlighting its effectiveness as a pedagogical tool. The LearnAR resource center, for example, offers a package of 10 marker-based AR learning experiences covering subjects such as biology, physics, languages, English, mathematics, and religious education. These experiences provide students with interactive and immersive learning opportunities, making complex subjects more engaging and understandable. Moreover, it has been integrated into vocational training, where workers can practice procedures in a risk-free virtual environment before applying them in real-world settings (Chiang, 2018). The gamification of educational content through AR apps motivates learners and facilitates knowledge retention (Argo et al., 2019).

2.2.2 Architecture and Design

Architects and designers utilize AR to streamline their workflow and enhance client presentations. By superimposing digital architectural models onto physical sites, stakeholders can visualize the end result with unprecedented clarity (Delgado et al., 2020). Additionally, AR enables real-time collaboration among design teams, allowing for immediate feedback and design adjustments (Kerr& Lawson, 2020). It has also been instrumental in urban planning, where city planners can assess proposed changes in their real-world context through AR simulations (Stancato et al., 2023).

2.2.3 Healthcare

In the healthcare sector, AR is used for surgical planning, medical education, and patient care. Surgeons can overlay 3D reconstructions of patients' anatomy onto their

real-time view during surgery, improving precision and reducing risks (Gerup et al., 2020).

AR applications in healthcare extend beyond surgery and medical education. It plays a crucial role in patient rehabilitation. For instance, AR-based rehabilitation exercises can provide real-time feedback to patients, making the recovery process engaging and motivating (Viglialoro et al., 2019). AR is also employed in telemedicine, allowing remote specialists to virtually assist in surgeries or consultations. This technology has proven especially valuable in ensuring medical care access in underserved or remote areas (Ara et al., 2021).

2.2.4 Tourism and Navigation

AR-based navigation apps provide real-time information about landmarks, historical sites, and points of interest, enhancing tourists' experiences. These apps often incorporate GPS and object recognition technologies (Yao et al., 2021).

Beyond landmark recognition, AR-based navigation is evolving to provide users with rich cultural and historical insights. Tourists can use AR to overlay historical images and stories onto the current landscape, turning a simple walk through a city into an immersive historical journey (Jingen & Elliot 2021). Additionally, AR has shown promise in indoor navigation, guiding users through complex indoor spaces like airports, shopping malls, and museums (Joshi et al., 2020).

2.2.5 Gaming and Entertainment

The gaming and entertainment industry continues to push the boundaries of AR experiences. In addition to mobile games like Pokémon GO, AR is making its mark in the realm of immersive and location-based entertainment. Theme parks and entertainment venues are adopting AR to create captivating experiences. For instance, AR headsets are used to transform theme park rides into interactive adventures, where visitors become part of a dynamic storyline (Avila et al., 2020). Moreover, live performances and concerts are increasingly integrating AR effects, enabling artists to craft visually stunning and interactive shows that blur the line between the virtual and the real (Jung et al., 2022). These innovations underscore AR's capacity to redefine entertainment and offer audiences engaging and memorable experiences that were once inconceivable.

2.2.6 Retail and Marketing

In the retail sector, AR continues to revolutionize the shopping experience. Virtual try-on solutions have evolved beyond clothing and accessories to include cosmetics and even furniture. Customers can use AR applications to visualize how products will look and fit in their real-world environments before making a purchase (Bonetti et al.,2019). Furthermore, AR advertisements have become increasingly interactive and engaging. Brands are leveraging AR to create immersive campaigns that allow consumers to explore products, play games, and participate in virtual experiences through their mobile devices (Gu et al.,2023). These AR-driven marketing strategies not only captivate audiences but also offer valuable insights into consumer behavior,

preferences, and engagement, shaping the future of advertising and sales in the digital age.

The dynamic and evolving landscape of AR applications is a testament to its versatility and transformative potential. As technology continues to advance, AR's influence will likely expand even further, impacting how we entertain ourselves, shop, and engage with the world around us.

2.3 Case Studies of Augmented Reality in Museums

The subsequent case studies will be comprehensively examined through three primary dimensions: providing an overview, delineating their distinctive features, and elucidating the discernible impact.

In the realm of museum innovation, The Cleveland Museum of Art spearheaded a transformative experience with the introduction of the ArtLens application. This AR-powered app allows visitors to scan artworks, unlocking a wealth of additional information, including audio and video content, historical context, and artist biographies. The incorporation of AR overlays further enhances the understanding of artistic techniques, resulting in increased visitor engagement and an innovative approach to interacting with the museum's collection (Pollalis et al., 2018).

Across the pond, The British Museum forged a collaboration with Samsung to establish the Samsung Digital Discovery Centre, an interactive space designed for families and school groups. Utilizing AR technology, this initiative breathes life into historical artifacts. Visitors can explore 3D models and animations of ancient objects

through tablets, delving into details otherwise invisible to the naked eye. The impact has been significant, rendering the museum's collection more accessible and engaging for younger audiences (Sabiescu & Charatzopoulou 2015).

In the Smithsonian National Museum of American History, the "Muppet Babies: The Next Generation" AR app caters specifically to young visitors. This playful application allows children to interact with Muppet Babies characters as they navigate the museum, revealing AR elements like 3D characters and animations when pointing their devices at specific locations. The app's success lies in making museum visits entertaining for children and families, fostering exploration and learning about American history in an engaging way (Majorek & Du 2016).

Paris' Louvre Museum took a bold step in enhancing the experience around the iconic Mona Lisa through the introduction of "Mona Lisa: Beyond the Glass." This AR experience involves visitors using AR glasses to view a 3D representation of the Mona Lisa, exploring intricate details and gaining insights into Leonardo da Vinci's techniques. The impact is profound, offering a deeper understanding of this famous masterpiece and providing visitors with a unique perspective on art history (Sovhyra 2020).

The Museum of London collaborated with the Guildhall School of Music & Drama to craft the "Beasts of London" AR experience. This initiative invites visitors to don AR headsets, immersing themselves in the history of London through the eyes of animals. The AR technology brings historical stories to life, allowing visitors to hear the voices of creatures and witness key events. Praised for its innovation and storytelling, "Beasts

of London" successfully makes history engaging and accessible to a diverse audience (Pirandello 2021).

The case studies discussed above exemplify how AR has been applied in museum settings to enhance the visitor experience. These real-world examples showcase the versatility and effectiveness of AR technology in various museum contexts, from art exhibitions to historical displays and scientific collections. Each case study provides valuable insights into the ways AR can be used to engage visitors, offer immersive learning opportunities, and breathe new life into traditional museum exhibits. Furthermore, these studies underscore the positive impact of AR on visitor engagement, learning outcomes, and overall satisfaction, suggesting its potential as a valuable tool for museums seeking to stay relevant and captivating in the digital age.

2.4 Use of Augmented Reality in the African Context

In the African context, the utilization of AR remains relatively nascent but holds immense promise. In South Africa, for instance, an exploratory venture was undertaken to gauge the potential of AR within the educational framework (Jantjies et al., 2018). The focal point of this endeavor was to employ AR and virtual reality (VR) technologies to facilitate experiential learning within South African educational institutions. Notably, while AR-related initiatives are pervasive in more developed regions, the untapped potential of AR in preserving cultural heritage within African museums is conspicuous.

In Egypt, AR has been employed to digitally recreate and preserve historical sites and artifacts. The "King Tut VR" project, for instance, uses AR to bring the treasures of

King Tutankhamun's tomb to life, allowing visitors to explore and interact with the ancient artifacts in a virtual environment (Wong et al., 2019).

In Nairobi, Kenya, AR technology has been integrated into medical training. Medical students use AR applications to visualize complex anatomical structures, enhancing their understanding of human anatomy and surgical procedures (Oduor et al., 2023).

Ghana has embraced AR as a tool to enhance tourism experiences. The "See Ghana" AR app provides tourists with real-time information about historical sites, landmarks, and cultural events, enriching their exploration of the country's heritage (Haligah, 2021).

Nigerian universities have incorporated AR into educational programs. AR-powered learning modules and applications are used to engage students in interactive and immersive learning experiences across various subjects (Ojo & Oladipo, 2017).

In Senegal, AR has been employed to promote cultural heritage and tourism. AR applications offer virtual tours of historical sites, museums, and cultural events, enabling both locals and tourists to engage with Senegal's rich heritage (Sabie et al., 2023).

These examples underscore the growing interest in AR technology across Africa, spanning diverse sectors such as heritage preservation, education, tourism, and healthcare. While these initiatives are in various stages of development, they reflect

the continent's increasing recognition of the potential of AR to transform experiences and address unique challenges.

2.5 Use of Augmented Reality in the Namibian Context

In Figure 7, we gain insight into an exhibition at the Franco-Namibian Cultural Centre that underwent a captivating transformation through AR technology. This augmentation unfolds through a seamless integration of audio commentary, activated when users hover over an image, facilitated by the user-friendly mechanism of QR Code scanning (Rasmeni, 2018, as cited in The Economist Namibia Newspaper). This innovative use of AR technology elevates the museum-goer's experience by providing insightful audio commentary that deepens their understanding and engagement with the exhibited artworks or artifacts. By a simple gesture of hovering over an image, visitors are immersed in a world of context and information, adding depth and dimension to their cultural exploration within the Franco-Namibian Cultural Centre

Figure 7: Wakpon - The Museum Off the Wall

One noteworthy project centered around the augmentation of printed magazine articles showcasing Namibian lodges, with a particular focus on the Onjala Lodge near Windhoek. In this initiative, AR was employed to breathe life into printed materials, including magazines, postcards, and game drive booklets, offering readers an interactive and immersive encounter with the lodge's offerings (Ajibola et al., 2018).

Moving from lodges to cultural heritage, the Brandberg AR experience emerges as a fascinating endeavor. This project delved into the historical and contemporary narratives surrounding the Brandberg mountain, particularly its prehistoric rock art. The study proposed a prototype mobile application that revolved around image triggers, revealing rich information about specific rock art when scanned using QR Code technology. This innovative use of AR aimed to bridge the gap between past and present realities, offering users an engaging journey through time (Mosha et al., 2018).

Another study focused on empowering urban San youth, a marginalized tribe in Namibia, through co-created personal AR accessories. These unique accessories were designed with the aim of enhancing social well-being within the community. By leveraging AR technology, this initiative sought to create individualized solutions that could foster a sense of connection and well-being among the youth (Kauhondamwa et al., 2018).

In the context of Namibia, AR has primarily manifested itself through visual pop-ups which refer to digital elements or information that appear to "pop up" or overlay onto the physical world when viewed through an AR-enabled device, such as a smartphone or AR glasses, offering tantalizing glimpses of its potential. These applications of AR

aim to magnify value, alleviate cognitive overload, provide distinctive customer experiences, and enhance our perception of the real world. However, it is evident that the full extent of AR's capabilities within the Namibian context is yet to be fully realized. This research endeavor seeks to unlock the untapped potential of AR technology, offering new and innovative ways to enrich experiences, connect communities, and celebrate Namibia's diverse cultural heritage.

2.6 Gaps in Literature

The preceding literature review has illuminated several notable gaps in the current research landscape pertaining to AR within the context of Namibian museums. These research gaps are particularly pertinent, given the unique cultural and geographical attributes of Namibia, and they underscore the necessity for comprehensive exploration and inquiry.

In the realm of Namibian museums, AR stands as an underexplored tool in academic discussions. It is like a hidden gem awaiting scholarly investigation, yet not enough attention has been given to how AR can bring excitement to Namibian museums. Research mainly comes from faraway places, overlooking the unique aspects of Namibian cultural institutions. This gap calls for dedicated research to uncover the experiences, challenges, and potential benefits of integrating AR in Namibian museums. When it comes to the impact of AR on visitors and learning, studies mostly focus on other places. But the mystery lies in how AR uniquely shapes learning experiences for both locals and international visitors in Namibian museums. This

becomes a crucial next chapter considering Namibia's diverse demographics and rich cultural heritage.

Namibian museums, as keepers of cultural narratives and artifacts, face the challenge of adapting AR to preserve and present the nation's heritage. Current literature lacks exploration of methods to blend cultural narratives with AR's transformative capabilities. New narratives are needed to explore how AR can enhance Namibian museums. As we delve into the technical side of AR, there is a lack of thorough examination of technical infrastructure and accessibility challenges in Namibian museums. This requires careful investigation to ensure the smooth integration of AR and address potential access barriers. Exploring the demographics and preferences of museum visitors in Namibia is a largely uncharted territory. The absence of insights into how different groups respond to AR-based exhibits highlights the need for dedicated research. This is vital to tailor AR experiences to the diverse audience in Namibian museums.

Considering the lasting impact of AR initiatives, current literature mostly looks at immediate effects. However, there is an unexplored gap in understanding the long-term sustainability of AR experiences in museums. Investigating whether AR continues to engage and educate visitors over time is crucial to grasp its enduring impact. The seamless integration of AR with traditional exhibits is a critical gap in Namibian museums. Best practices for combining digital and physical elements are insufficiently explored. This emphasizes the need for guidance on effective approaches to blend AR and traditional elements in Namibian cultural institutions.

The academic discussion concludes with a challenge in evaluating AR's impact in Namibian museums. Current evaluation methods are underdeveloped, lacking appropriate frameworks and metrics tailored to the Namibian museum context. Addressing this gap is essential for creating effective evaluation tools aligned with the unique characteristics of Namibian museum experiences.

In summary, the academic discourse on AR in Namibian museums requires dedicated efforts to uncover its potential impact. The narrative may pause for now, but there is an ongoing adventure, inviting scholars to contribute new chapters that reveal the magic of AR in Namibian museums, ensuring each visit becomes an indelible journey.

Reimagining museums, particularly in the context of Namibia, is essential to adapt to changing societal dynamics, foster cultural preservation, and enhance visitor engagement. Contemporary museum-goers increasingly expect dynamic and immersive experiences, and emerging technologies like AR can help meet these expectations. AR technology enables museums to provide interactive and educational encounters, making cultural heritage more accessible and engaging for diverse audiences. This shift towards innovative museum experiences is well supported by recent research.

For instance, a study by Hammady et al., (2020) emphasized the need for museums to embrace new technologies, including AR, to remain relevant and engaging for visitors. Similarly, Falk and Dierking (2016) highlighted the importance of dynamic and participatory museum experiences in their research on visitor-centered learning.

Furthermore, the work of MacLeod and Dodd (2015) emphasized the potential of AR in enhancing visitor engagement and learning outcomes in museums.

In the Namibian context, where cultural diversity and rich heritage are central, the transformation of museums through AR can play a pivotal role in preserving and celebrating this unique cultural tapestry. It aligns with the broader trend of leveraging technology to create more meaningful and accessible museum experiences, ensuring that Namibian museums remain vibrant and relevant in the digital age.

In conclusion, Chapter 2 has served as an extensive exploration of the multifaceted realm of AR technology and its diverse applications, both globally and within the unique context of Namibia. By delving into the foundations of AR, surveying its expansive landscape of applications, scrutinizing its integration within museum settings, and identifying gaps and opportunities in the literature, this chapter has laid a solid foundation for the subsequent phases of our research. The synthesis of key insights, trends, and debates not only reflects our commitment to scholarly rigor but also highlights the transformative potential of AR in redefining the museum experience, particularly within the vibrant cultural tapestry of Namibia. As we embark on the empirical journey ahead, we carry with us the invaluable insights garnered from this chapter, which will guide our pursuit of innovation and enhancement in the museum experience through the lens of AR technology.

Chapter 3: Research Methods

In this chapter, we embark on a methodological journey through the intricate terrain of our research, equipped with a compass of critical inquiry and systematic exploration. This chapter illuminates the path from the foundational principles of our research design to the practical implementation of our study. Our objectives are to elucidate the research methods chosen, explain their relevance, and demonstrate their alignment with our research goals.

3.1 Research Design

In the exploration of the transformative potential of AR within the museum context of Namibia, a mixed research design was employed. This methodological choice was driven by the need to comprehensively investigate the multifaceted dimensions of the research problem.

A mixed research design, as articulated by Mulisa (2022), represents an approach in educational research that seeks to transcend the historical paradigm conflict between quantitative and qualitative methodologies. It is characterized by the deliberate integration of both quantitative and qualitative research approaches within a single study or a series of studies. This design aims to harness the strengths of each approach, offering a more comprehensive and nuanced understanding of research phenomena in educational inquiry. The choice to employ a mixed research design is guided by a dynamic consideration of distinct research questions, the underlying paradigmatic views, and the specific needs of the research context.

The selection of a mixed research design over alternative methods is justified by its capacity to offer a comprehensive comprehension of the AR technology's potential in enhancing the museum experience in Namibia. This approach harmoniously integrates quantitative data for assessing AR application effectiveness and qualitative insights into visitor experiences, ensuring a holistic understanding. Moreover, it addresses the specific research gap regarding the adaptation of AR to the local context, as it combines user preferences and cultural insights. By using multiple data collection methods, it enhances research validity and reliability while providing stakeholders with well-rounded insights for informed decision-making.

Quantitative research methods, primarily involving structured questionnaires, played a crucial role in gathering numerical data and insights for this research. The online questionnaire aimed to measure various aspects of AR technology's impact on the museum experience. Participants were invited to share their perspectives, preferences, and experiences regarding museums and AR technology. The survey served as a valuable tool for quantitatively assessing the influence of AR on visitor engagement, satisfaction, and other measurable aspects of the museum experience.

Qualitative research was conducted subsequent to the development of the AR mobile app, aimed at gaining insights into user experiences while using an AR application. This phase involved the use of focus group discussions and interviews with a diverse range of participants, resulting in a comprehensive understanding of the perceptions, experiences, and motivations of museum visitors in Namibia.

3.1.1 Sampling Methods

The study employed purposive sampling, selecting participants with diverse backgrounds, including age, gender, educational levels, and cultural affiliations. This approach was chosen to capture a holistic perspective on the use of AR in museums among various visitor demographics. Purposive sampling, as described by Sibona et al., (2020) in their paper "A Guide for Purposive Sampling on Twitter," is a method that allows researchers to intentionally select participants who are relevant to a specific topic of interest. This approach aimed to capture a holistic perspective on the use of AR in museums among various visitor demographics.

The choice of purposive sampling in this study is well-justified for several reasons. By selecting participants with diverse backgrounds, including age, gender, educational levels, and cultural affiliations, the study ensures that a broad spectrum of perspectives and experiences is represented. This diversity is essential when studying the use of AR in museums because it allows for a more comprehensive understanding of how different visitor demographics engage with this technology. Purposive sampling aligns with the research objective, which is to gain insights into the use of AR in museums. By intentionally selecting participants who are relevant to this topic, the study increases the likelihood of collecting data that directly addresses the research questions and objectives. The reference to Sibona et al., paper on purposive sampling demonstrates that this choice is grounded in established research methodology, adding credibility to the sampling

approach. Furthermore, by intentionally including a variety of participant demographics, the study is better equipped to provide a holistic perspective on the topic, acknowledging that different groups of museum visitors may have unique experiences and perceptions, and seeking to capture these differences comprehensively.

3.1.2 Participants Demographics

Participants in the quantitative phase of the study included individuals from different age groups, ranging from young adults to seniors. Gender diversity was also maintained to ensure a well-rounded sample. In the qualitative phase, focus group discussions involved participants from various educational institutions and professionals from the technology industry, creating a diverse group of stakeholders.

3.1.3 Data Collection Instruments

A structured online questionnaire was designed to quantitatively assess the impact of AR on the museum experience. The online questionnaire drew from validated instruments used in prior AR studies while adapting questions to the Namibian context. Qualitative data was collected through focus group discussions and interviews guided by semi-structured protocols.

3.1.4 Data Analysis

Quantitative data analysis involved the utilization of Google Forms for data processing and visualization. Descriptive statistics and correlation analyses

were conducted to explore the relationships between AR technology and visitor experiences. The data collected from the online questionnaires was effectively processed and presented using pie charts and histograms within the Google Forms platform.

Qualitative data, on the other hand, was subjected to a rigorous thematic analysis process. This involved systematic coding and thematic grouping of responses to identify recurring patterns and emergent themes within the qualitative dataset. The analysis was conducted to gain a deeper understanding of the qualitative insights gathered from focus group discussions and interviews, providing valuable qualitative perspectives on the impact of AR in Namibian museums.

3.1.5 Ethical Clearance

This study received ethical clearance from the University of Namibia Ethics Committee (Ethical Clearance Reference Number: SOS-0060, Date: 27 April 2022). Ethical approval was obtained following the University's Research Ethics Policy and Guidelines. The ethical evaluation by the committee ensured that the research adhered to established ethical standards, including participant informed consent and confidentiality.

3.1.6 Data Validation and Trustworthiness

To enhance data validity and trustworthiness, member checking was employed in the qualitative phase, where participants had the opportunity to review and validate the findings. Additionally, a reliability analysis was conducted for the survey instrument to ensure the consistency of responses.

3.1.7 Limitations

One notable limitation of this study is the potential lack of full generalizability of the findings to all museum visitors in Namibia. This limitation arises primarily from the relatively small sample size used in the research. The sample size, while diverse, may not fully represent the entire population of museum visitors in Namibia, which could include individuals with varying backgrounds, interests, and experiences. Therefore, the findings should be interpreted with the understanding that they may not apply universally to all potential museum visitors in the country.

One contributing factor to the limited sample size was the challenges faced in recruiting participants for the online questionnaires. The researcher published the questionnaire links on various online platforms, including LinkedIn, Facebook, and Twitter, to reach a broader audience. However, the responses received were not as numerous as anticipated. To address this, the researcher also took advantage of events attended during the study period to encourage more participants to take part in the survey. Despite these efforts, the response rate remained relatively low, as survey participation can often be limited due to time constraints and varying levels of interest among potential respondents.

Additionally, as with any self-report surveys, response bias may exist. Participants who chose to respond to the survey may have different motivations, perspectives, or levels of interest compared to those who did

not participate. This potential bias should be considered when interpreting the survey results.

While the small population size and recruitment challenges are limitations, they were addressed with the resources and opportunities available during the study. These limitations do not invalidate the insights gained from the research but should be considered when assessing the generalizability of the findings. Future research endeavors in this area may explore alternative recruitment strategies to mitigate these limitations and enhance sample representativeness.

As we navigate the intricacies of AR technology's transformative potential within the context of Namibian museums, our research journey takes us deeper into the realm of development. In the preceding section, we elucidated the methodological underpinnings of our mixed research design, seamlessly blending quantitative and qualitative approaches to comprehensively investigate the dynamic interplay between AR technology and the museum experience. Yet, our research journey is not confined solely to the realms of inquiry and analysis. It extends beyond, venturing into the realm of creation, where we converge our findings, insights, and methodologies into the design and development of an AR mobile application.

In this trajectory, the creation of a persona emerges as an indispensable and purposeful compass guiding our development strategies. But why do we need a persona, and how does it synchronize with our research design? Let us embark on this next section,

where we unveil the rationale, methods, and implications of persona development in the pursuit of crafting an AR application that resonates with its intended users.

3.2 Persona Development

In the realm of system development, a multitude of crucial components coalesce to culminate in a successful software product. Among these components, personas hold a distinctive and pivotal role, serving as instrumental pieces in the puzzle of implementing a complex system. The concept of personas was initially introduced by Cooper in the late 1990s. It was forged through the crucible of ethnographic observation, contextual inquiry, and focus group interactions, among other research methodologies. These comprehensive research activities yielded a rich tapestry of behavioral patterns and user needs, which were carefully distilled and encapsulated in the creation of fictional characters – personas.

In essence, a persona is a fictional character meticulously crafted during the early stages of software development. Typically wielded by User Interface (UI) and User Experience (UX) Designers, personas are a powerful tool to shift the development focus from the designers' own perspectives to a user-centric approach. They enable developers to consciously design and refine the software based on the authentic needs and expectations of the end-users (Bowen et al., 2020). In the context of this research, the creation of a persona played a crucial role in anchoring the development strategies and ensuring the alignment of the AR mobile application with user preferences and expectations. Below were the created personas.

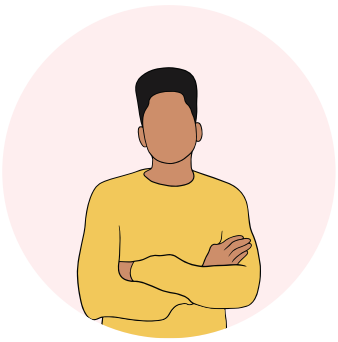
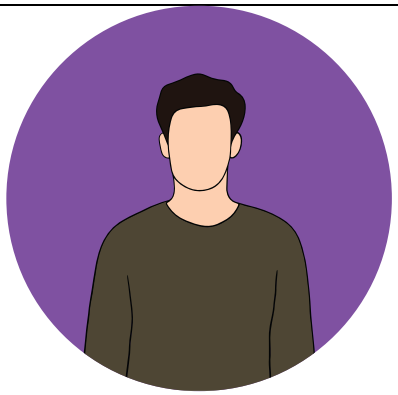
Persona	Profile Details
 *Figure 8: Image Source - freepik.com*	**<u>Persona 1</u>** **Name**: Michael Werner **Age**: 17 **Institution**: Windhoek High School Michael is a young man who interested in historical studies at his current school. However, he feels that he is not being inspired much in that area. He occasionally visits museums that are near him but easily gets bored because the content is always the same at the museums he visits. Some of his hobbies are playing video games on his mobile phone like Pokémon Go and he uses social media platforms like Instagram and Twitter frequently. Michael wants a cool app that can help him enhance his museum experience and motivate him to further pursue his interest in historical studies as well.
	<u>Persona 2</u> **Name**: Fatima Ndeapo **Age**: 21 **Institution**: University of Namibia

 *Figure 9: Image Source - freepik.com*	Fatima is a university student majoring in cultural heritage and museum studies. She has a deep passion for preserving and promoting Namibia's rich cultural heritage and is particularly interested in indigenous art and artifacts. Fatima often visits museums and heritage sites to conduct research for her studies. In her free time, she enjoys attending cultural festivals and exhibitions to expand her knowledge. She is also an active member of various cultural preservation organizations and follows related blogs and social media accounts. Fatima is looking for an AR app that can provide in-depth information about the cultural significance of museum artifacts. She values accuracy and authenticity in the content and hopes the app can assist her in her academic pursuits.
	<u>Persona 3</u> **Name**: David van Wyk **Age**: 25

 *Figure 10: Image Source - freepik.com*	**Institution**: Namibia Institute of Technology David is a young professional working as a tour guide in Namibia. He is passionate about showcasing the beauty and history of his country to tourists from around the world. He frequently leads groups of international tourists on tours to museums and cultural sites. As a tech-savvy individual, David is always looking for innovative ways to make the tourist experience more engaging and informative. He often uses educational apps and digital tools to enhance his tours. David is interested in an AR app that can enrich his guided tours by providing real-time historical information, engaging stories, and interactive experiences for tourists. He believes such an app can help him stand out as a tour guide and improve overall visitor satisfaction.

Opting to develop personas instead of randomly seeking real potential users for our AR app is a strategic choice driven by several compelling factors. First and foremost,

it allows us to efficiently capture a diverse spectrum of user characteristics and preferences. Moreover, it provides us with a structured and comprehensive understanding of our target audience, which can be challenging to achieve through random sampling. Creating personas enables us to envision and address specific user needs and pain points, ultimately resulting in a more user-centric and effective design and development process. Additionally, it offers a cost-effective and time-efficient way to gain insights that inform our app's features and functionalities, ensuring that we meet the varied expectations of our potential users. By leveraging personas, we can better tailor our AR app to a wide range of user profiles, leading to a more successful and inclusive product.

In the diverse landscape of potential users for our AR mobile application, we encounter three distinctive personas, each offering valuable insights into the design and functionality of the application.

Firstly, we meet Michael Werner, a representative of the primary target audience—a young and tech-savvy demographic. Michael's proficiency in utilizing mobile phones for gaming and navigating various social media platforms provides crucial insights into the digital literacy and expectations of our intended users. His expressed desire for a "cool app" indicates a quest for engaging features, guiding developers to leverage familiar elements to enhance the user experience. Moreover, Michael's tendency to easily get bored directs design choices toward incorporating visually appealing and interactive features, ensuring the application captures and sustains user interest. Recognizing Michael's familiarity with social media apps emphasizes the importance

of ensuring the AR application's accessibility on platforms like the AppStore for seamless downloading and engagement.

Next, we encounter Fatima Ndeapo, representing university students and individuals passionate about cultural heritage and museum studies. Fatima's academic pursuits underscore her interest in the AR application, emphasizing the need for accurate and in-depth information regarding the cultural significance of museum artifacts. Her persona highlights the importance of delivering culturally rich and meaningful content within the app, catering to users with a deep interest in heritage preservation.

Lastly, we meet David van Wyk, embodying young professionals and tour guides enthusiastic about showcasing Namibia's cultural and historical attractions to tourists. David's persona emphasizes the potential for the AR app to enhance guided tours by providing real-time historical information, engaging stories, and interactive experiences for tourists. Meeting the expectations of experienced tour guides like David not only enhances the quality of guided tours but also contributes to improved tourist satisfaction, creating a symbiotic relationship between guides and tourists.

In weaving these personas together, a comprehensive understanding of the diverse user base emerges, guiding the development of an AR application that seamlessly caters to the needs, preferences, and expectations of young, tech-savvy individuals, passionate cultural enthusiasts, and professional tour guides alike.

Persona development served as the bridge between our research phase and the subsequent development phase. During the research phase, we conducted surveys and

collected qualitative data to gain a deep understanding of potential users' preferences, needs, and expectations. These insights guided the creation of personas, which are fictional representations of different user profiles. These personas, such as Michael, Fatima, and David, are integral in shaping the AR mobile app's development strategy.

Persona development emphasized our commitment to a user-centric approach in designing the AR mobile application. By creating personas, we ensured that our development efforts were focused on meeting the specific needs and preferences of different user groups. Personas provided actionable insights that directly influenced design decisions.

Each persona represented a distinct user profile with unique requirements, enabling us to make informed choices about app features, content, and overall user experience. The personas derived from our research findings helped us align the development process with the data collected. They served as a tangible representation of our target audience, reinforcing the connection between research and development.

3.3 Software Development Methodology

The software development methodology section builds upon the foundation laid by persona development. It outlines the systematic approach we adopted to transform user insights and persona characteristics into a functional AR mobile application. Our software development methodology is inherently persona-driven, with the personas we created serving as the guiding compass for every aspect of the development process, from feature prioritization to user interface design. Each persona informs how we tailor the user experience within the AR app. For example, Michael's persona

influences the inclusion of engaging and visually appealing elements, while Fatima's persona underscores the importance of delivering in-depth cultural content. The personas also play a crucial role in user testing and feedback integration, ensuring that the AR app resonates with our target audience and effectively addresses their needs.

In the development and implementation of the AR mobile app, we employed Personal Extreme Programming (PXP) as the chosen software development methodology. The selection of PXP was motivated by the fact that the researcher took on the role of an autonomous developer throughout the app's development journey. As defined by Iyawa (2020), PXP is a software development process designed for individual software developers. The primary aim of this development methodology is to streamline the software development process, making it more manageable to follow while adhering to the fundamental principles of the Personal Software Process (PSP). In the context of our project, PXP provided a structured and adaptable framework that allowed the researcher to efficiently navigate the development landscape. Below, we provide a visual representation outlining the key processes involved in PXP.

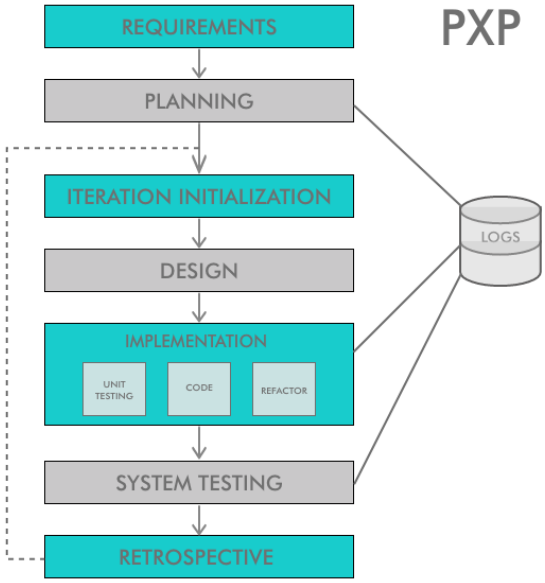


Figure 11: Personal Extreme Programming - An Agile process for Autonomous Developers

Each phase outlined in Figure 11 will be explained in the context of the AR Mobile app to expose how the software development methodology was applied for this study.

3.3.1 Requirements

The requirements phase plays a pivotal role in connecting our research design, personas, and development methodology. It involves documenting both functional and non-functional aspects that guide the development of the AR mobile app. It is important to note that these requirements are not directly gathered from users' explicit requests but are instead informed by our research findings, which include the needs and preferences expressed by our personas.

Functional Requirements	Non-Functional Requirements
3D Rendering: The system must be able to render 3D objects to enhance the user's experience with interactive museum exhibits.	**Performance and Responsiveness**: The app should perform well, delivering fast response times to ensure a seamless user experience and inspire users, as per the inspirational requirement.
Inspirational User Experience: The app should be able to influence how the user experiences the museum in an inspirational way by using creative and immersive elements.	**Usability and Accessibility**: The user interface must be easy to use, meeting the intuitive design criteria, and accessible to users with varying technical knowledge.
No Mandatory Sign-Up: Users should be able to use the app without the need to sign up or sign in, facilitating quick access and engagement, especially for users with minimal technical knowledge.	**Security**: Data security is critical, especially for users who do not want mandatory sign-up; therefore, robust security measures must be in place.
Intuitive User Interface: The app must be intuitive and designed to be user-friendly, ensuring users can get	**Content Accuracy**: Content must be accurate to meet the academic needs of users like Fatima, ensuring reliable and valuable information.

started easily, as per Michael's preferences.	
Minimal Navigation: App navigation should be minimal and straight to the point, allowing users to access information and experiences efficiently.	**Cross-Platform Compatibility**: The app should be compatible with various mobile devices and operating systems, enabling access for a diverse user base.
Artifact Safety: The app must be designed in such a way that it does not interfere with any exhibiting artifacts in a manner that might cause damage or disruption.	**Reliability**: The app should be reliable, ensuring a consistent and dependable experience during guided tours, which is vital for users like David.
	Cultural Sensitivity: Content should be culturally sensitive and respectful of local customs and traditions to meet the needs of users interested in cultural heritage like Fatima.
	Non-Intrusiveness: The app should be designed to avoid interfering with the museum's artifacts, aligning with

	the requirement for minimal interference with exhibits.
	Onboarding Process: The app must show an onboarding process to guide users on quickly getting started, making it user-friendly, as well as inspirational, as required.

3.3.2 Planning

During the Planning phase of PXP, the focus shifts to defining sets of tasks that directly align with the requirements collected in the initial phase of the project. As a solo developer in this study, the adoption of a modular approach to the solution implementation was essential. To streamline this phase and enhance project management, the researcher leveraged the capabilities of ClickUp, a robust project management tool. This tool served as a pivotal asset in organizing tasks, establishing timelines, and ensuring that all aspects of the project were effectively managed and executed. Figure 12 illustrates the functionality and structure of ClickUp, showcasing how it facilitated the planning process, ensuring that tasks were well-organized and met the project's objectives efficiently.

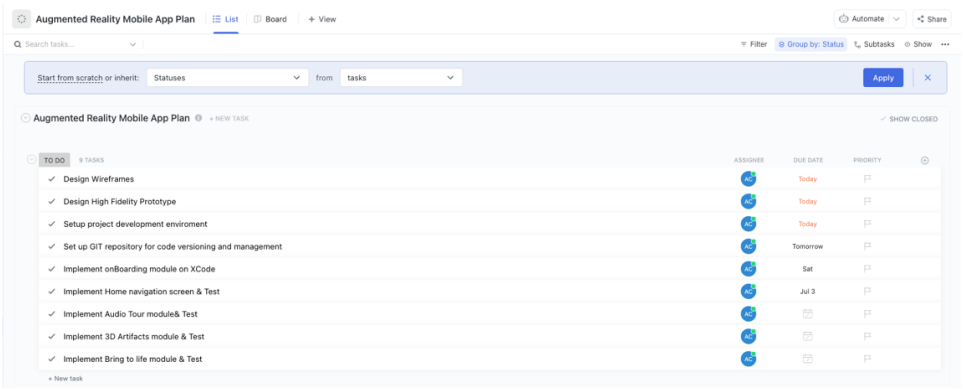


Figure 12: ClickUp - A project Management tool

3.3.3 Iteration Initialization

In the Iteration Initialization phase of the PXP process, the project takes a structured approach to ensure the smooth execution of tasks. During this phase, each task's commencement is clearly defined, and specific deadlines are set for all tasks that have been identified. It is important to note that in some cases, certain implementations may require testing before progressing to the next iteration. This phase emphasizes the importance of careful planning and setting clear milestones to maintain a systematic and well-organized project flow. Figure 2 visually illustrates this phase, highlighting its significance in the project's iterative development process.

3.3.4 Design

The central Design phase is critical, involving meticulous system modeling, architecture definition, and the use of Adobe XD for wireframes and a high-fidelity app prototype. Figure 13 and 14 depicts this process, transforming concepts into tangible user interface elements. This ensures the product meets functional

requirements and offers a user-friendly experience. Moreover, Figure 15 illustrates the systematic approach to system modeling, class/module definition, and object identification. Adobe XD played a key role in this process. The adoption of the Model-View-Controller (MVC) approach is another notable aspect, enabling the storage of models locally and contributing to a self-contained AR App, which streamlined the development process.

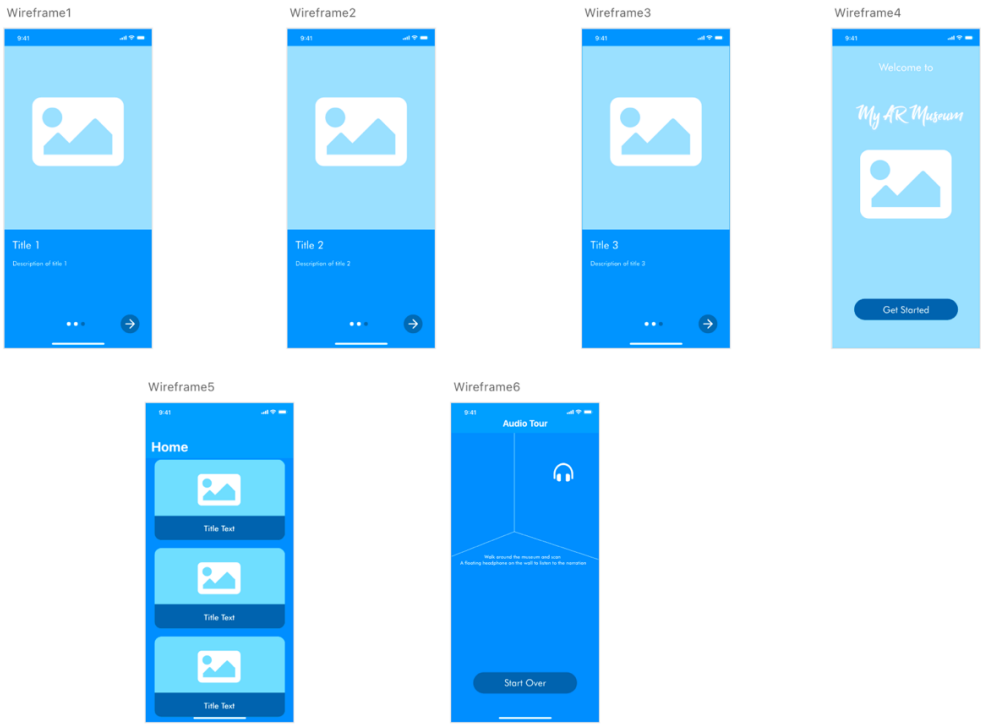


Figure 13: AR Mobile App wireframes

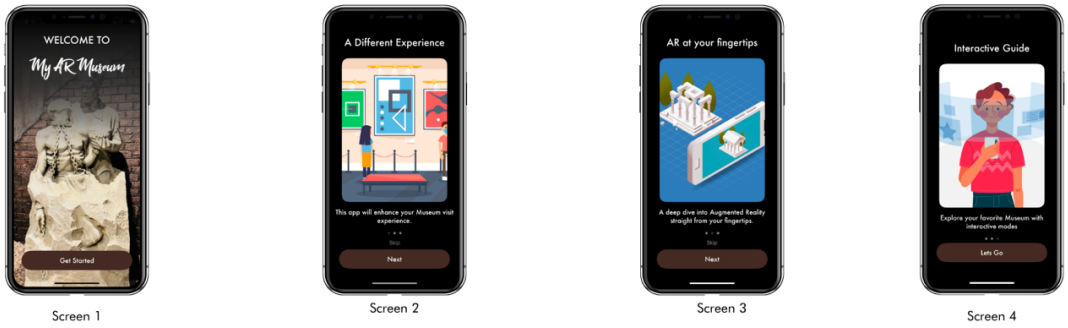


Figure 14: AR Mobile App High Fidelity Prototype, iOS version

3.3.4.1 System Architecture

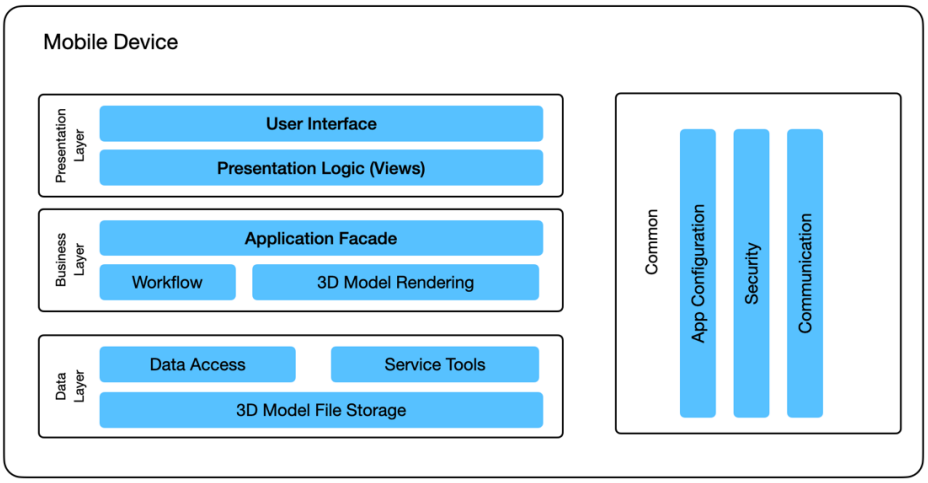


Figure 15: AR Mobile App System Architecture Overview

3.3.5 Implementation

The Implementation phase signifies the transition from design to code generation. During this stage, all previously defined objects and modules are translated into actual code, and rigorous testing is carried out to ensure their functionality and reliability. To streamline this process, a range of carefully selected implementation tools were employed in this study, enhancing the efficiency and effectiveness of the development efforts. Below, a comprehensive table details the specific tools utilized during the implementation phase, underlining their significance in bringing the project from the conceptual stage to a tangible, functional reality.

The selection of XCode, Swift, ARKit, Reality Kit, and Bitbucket for the development of the AR App was a deliberate choice grounded in the researcher's professional expertise and personal preference. As an experienced iOS developer, it was imperative to harness the tools and technologies that were intimately familiar to ensure a seamless

and efficient development process. XCode and Swift offered a robust and highly integrated development environment for iOS, providing a familiar and powerful platform to build upon. The choice of ARKit and Reality Kit, as Apple's AR frameworks, was a natural fit for crafting an immersive AR experience on iOS devices. Additionally, the selection of Bitbucket over GitHub was driven by personal preference, highlighting the importance of using tools that align with the workflow and preferences. This strategic tool selection not only expedited the development process but also ensured a high level of proficiency and quality throughout the AR App's development lifecycle.

Software Tool	**Description**
XCode 	The development environment to develop the AR Mobile App.
Swift 	The programming language used to write the code.
ARKit 	An iOS development sdk for creating AR experience within iOS applications.
RealityKit 	An iOS sdk that enables more customization and rendering of complex 3D models.
BitBucket 	A code versioning control system used for code management

3.2.6 System Testing

Integrated and automated testing methodologies, often esteemed in software development, were not explicitly incorporated in this particular project due to its relatively modest scale and scope. Typically, such testing methods find greater utility in larger, more complex projects where an extensive array of test cases and components necessitates a more automated and integrated approach. In the context of this project, a deliberate choice was made to adhere to a more straightforward testing approach, predominantly featuring app functionality tests.

Moreover, with respect to the responsibility for conducting these tests, it is pertinent to note that most testing tasks were undertaken by the developer and a few were done by the participants who later on had to use the app during the focus group sessions. This choice was motivated by the unique circumstances and constraints of the project, notably the need for rapid feedback and iterative development within a compressed timeline. The direct involvement of the developer in the testing process allowed for the immediate identification and resolution of issues, thereby streamlining the testing procedure.

3.3.7 Retrospective

The Retrospective phase signifies the culmination of the iterative process. It serves as a critical juncture for the developer to conduct a thorough review of the project's progress. During this phase, the developer verified whether the predefined task deadlines were successfully met. Additionally, the phase entailed a reflective analysis of any delays that occurred during the implementation or testing stages, aiming to

discern the underlying reasons for these setbacks. This introspective process served as a platform for deriving valuable lessons from the project's execution.

The Retrospective phase goes beyond mere reflection; it sets the stage for concrete and actionable improvement proposals. These proposals are instrumental in refining the development process, enhancing project efficiency, and addressing any issues or challenges that surfaced during the previous iteration. This phase, therefore, functioned as an essential feedback loop that not only facilitated continuous learning but also drove an ongoing cycle of enhancement in subsequent project iterations.

3.3.8 Logs

In the Logs phase, side notes were maintained throughout the iteration process, with the aim of identifying areas where improvements could be made for subsequent iterations, particularly concerning tasks and deadlines. These notations served as a retrospective record of the project's progress, aiding in the formulation of strategies to enhance project management and efficiency in future iterations.

3.3.8 Procedure

For this study, data was collected through a combination of methods. Firstly, an online survey was conducted to gather insights from the general Namibian population about their perceptions of the traditional museum experience and their expectations regarding the integration of AR in this context. The online survey was designed using Google Forms, and a link to the survey was generated and widely distributed across various social media platforms, including Twitter, Facebook, and LinkedIn. The

choice of leveraging popular social media platforms was motivated by the objective of reaching a broad and diverse target audience, thus enriching the research's scope.

In addition to the online survey, a practical aspect of user testing was integrated into the research methodology. A select group of users was chosen to actively engage with and test the AR mobile app within a real-world museum context. This testing aimed to provide deeper insights into the actual museum experience, as well as to gather valuable feedback on the app's usability and overall quality. The combination of these data collection approaches, encompassing both online survey responses and real-world user testing, contributed to a comprehensive understanding of the potential impact of AR technology on the museum experience and user perceptions.

3.4 Importance of a Software Development Methodology

The term "importance" in the context of this study pertains to the significance of emphasizing software development methodologies, a crucial aspect that was often underrepresented or insufficiently addressed in prior AR research. This importance lies in the need to provide a structured and well-documented approach to the creation of AR applications. In many AR papers, the focus has predominantly been on the final AR product or application, often neglecting the detailed technical software development procedures, guidelines, or methodologies employed during implementation.

In this particular study, the importance of elucidating the software development methodology is paramount because it fills a notable gap in the existing literature. It serves as a means to comprehensively articulate how the AR mobile application was conceptualized, designed, and implemented. By providing insights into the methodologies and technologies utilized, this study aimed to offer a valuable reference for future AR projects, thereby contributing to a more rigorous and standardized approach to AR development.

This emphasis is of critical importance to ensure that the AR application not only meets the intended objectives but also adheres to best practices in software development, which are integral for creating robust, user-friendly, and scalable AR solutions.

3.7 Use Case for the AR Mobile App

Following the creation of our fictional characters, Michael, Fatima, and David, we proceeded to establish a Use Case for the AR Mobile App. This Use Case diagram precisely defined the functionality of the AR mobile application, delineating the roles of actors who corresponded to the users, each responsible for performing distinct tasks. By aligning the Use Case with the personas developed earlier, the AR mobile application's features and functionalities were tailored to cater to the specific needs and expectations of our target users. This integration ensured that the application was designed with the user experience of Michael, Fatima, and David in mind, facilitating a more user-centric and engaging museum experience.

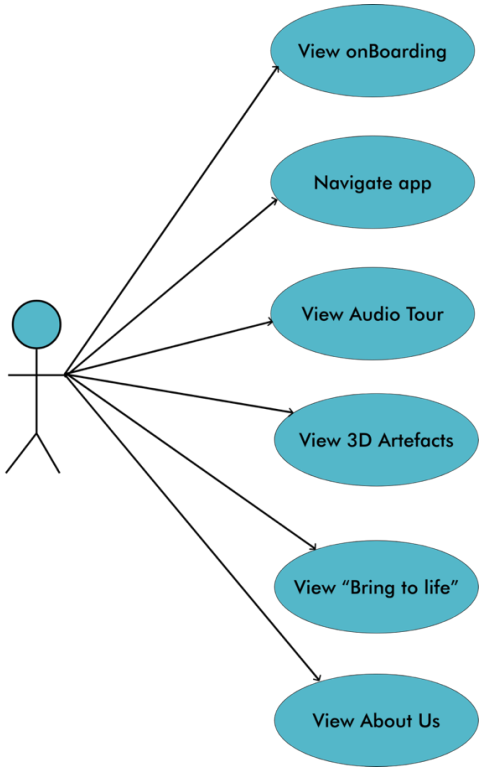


Figure 16: Use Case for the mobile user.

3.7.1 View onboarding

Upon launching the app, the user's initial interaction begins with the onboarding screens. These screens serve as a succinct introduction to the mobile application, elucidating its functionality and operation. This preliminary exposure provides the user with a clear understanding of what to anticipate while using the app.

3.7.2 Navigate App

The AR mobile application was intentionally designed to offer user-friendly navigation. Users can seamlessly access essential tasks and calls to action via a straightforward list-based navigation structure. Key actions and features are prominently outlined, ensuring ease of use.

3.7.3 View Audio Tour

Within the app, users have the option to engage with an Audio Tour feature. By selecting the Audio Tour item, users are transported into a sonic exploration of the museum. Tapping on specific audio tour items allows users to listen to sounds of the war related to artifacts or images, enriching their understanding of the museum's context. This audio tour feature also operates as a virtual tour guide, enhancing the overall museum experience.

3.7.4 View 3D Artifacts

Users can delve into an immersive experience by exploring 3D-modeled artifacts within the museum. These 3D artifacts are not only viewable but also interactive, offering users the opportunity to discover in-depth information and the compelling narratives behind these objects.

3.7.5 View Bring to Life

A distinctive feature of the app enables users to digitally "bring to life" historical objects or individuals. By hovering over a recognized object or image, users can trigger the augmentation of characters or the playback of videos relevant to the object. This captivating functionality adds an interactive dimension to the museum visit, further enhancing user engagement.

3.7.6 View About Us

The "About Us" view provides users with a concise overview of the museum they have chosen to visit. This section offers valuable insights into the museum's identity and background, contributing to a more informed and enriched museum experience.

3.8 Process of implementing the AR Mobile App

The following figure explains how this process was achieved using the tools that were chosen for developing this kind of system. For the purpose of this study some of the objects that where 3D modelled were collected naturally given that there where restrictions in actually augmenting some of the historic artefacts found in the actual museum, with that in mind assumptions were made on 3D objects for demonstration purposes.

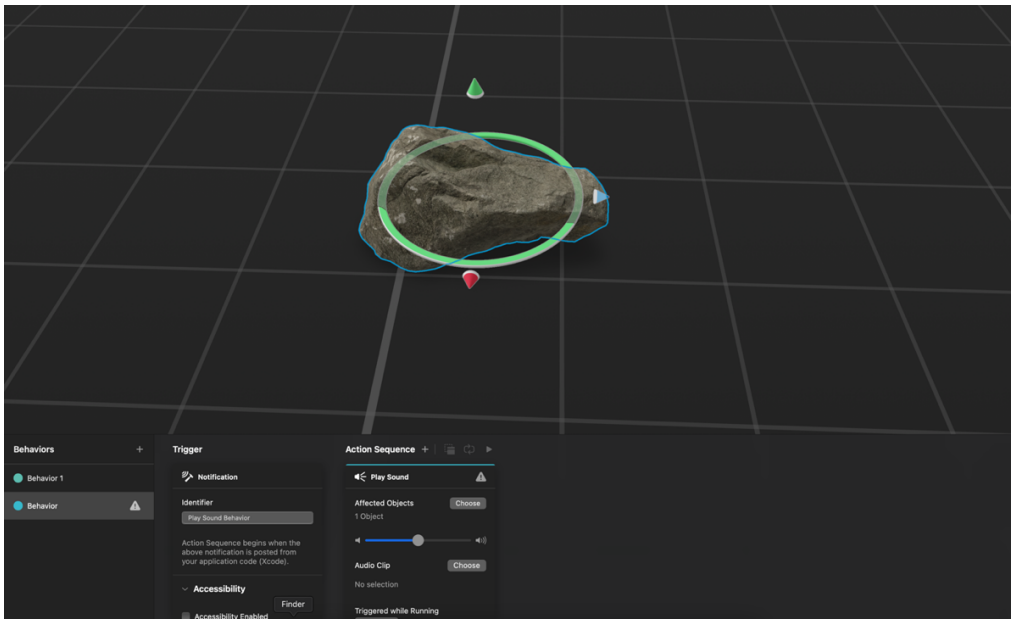


Figure 17: Using Reality Composer experience environment used to add behaviors to 3D models.

The 3D Stone was packaged as an experience, meaning defining the behaviors of the object, how it behaves when a user taps or moves closer to it in the real-world context. After defining the experience, the object file is then moved to XCode for further integrations with the mobile application through code. Figure 18 shows how 3D modelled objects are used in code for further app integration. The red pane shows the basic folder structure of the development environment as indicated by number 1. The blue pane shows the actual code and how the 3D model is being loaded for usage within the app. Lastly the yellow pane gives a preview of how the object will be viewed using an actual device. In this case our device is a simulated iPhone 13 Pro.

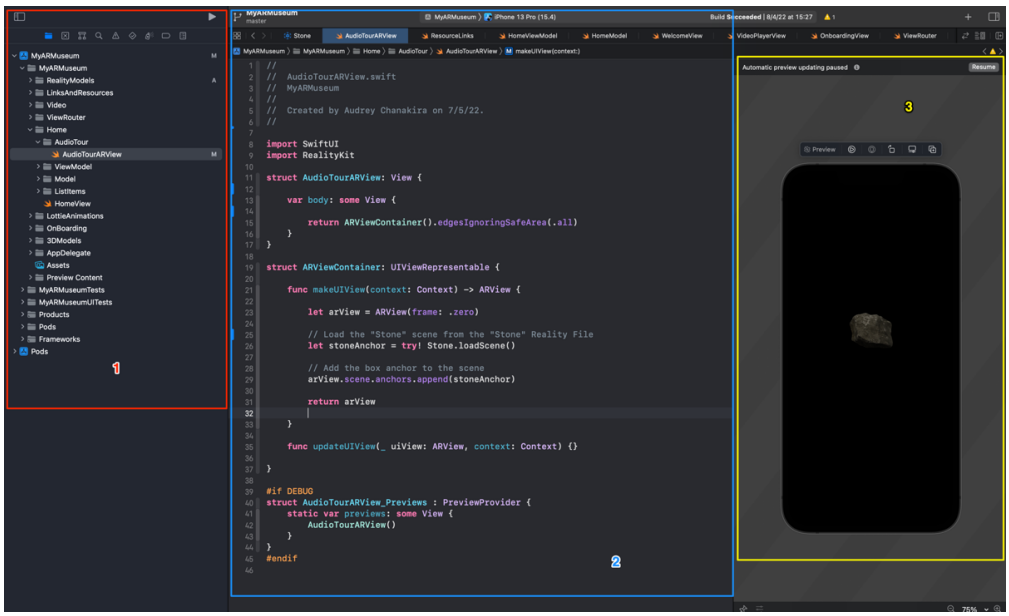


Figure 18: Integration of code and the defined object augmentatio

In concluding this chapter, we find ourselves at the culmination of an intricate and methodologically guided expedition. Our voyage through the methodological landscape has been marked by a commitment to scholarly rigor, a dedication to innovation, and an unwavering aspiration to elevate the museum experience in Namibia. The path we have traversed has not merely been a linear progression, but rather an intellectual odyssey characterized by meticulous planning, diligent execution, and thoughtful reflection.

Our choice of methodological tools and techniques was not arbitrary but rather a deliberate selection, guided by the aspiration to create an AR mobile application that seamlessly intertwines technology and cultural heritage. The personas, painstakingly crafted and tailored to reflect diverse user demographics, underscore our commitment to designing a user-centric experience.

The recognition of the significance of integrated software development methodologies within the AR landscape was a pivotal juncture. By filling a critical gap in the literature, we underscored the importance of elucidating the intricacies of the AR mobile application's creation. This emphasis extended into the development of a clear and structured use case, ensuring the alignment of our project with the unique needs and expectations of our intended users. The embodiment of our work can be witnessed in the deliberate selection of tools, from Xcode and Swift to ARKit and Reality Kit, each chosen for its familiarity and proficiency. This choice was emblematic of a developer's wisdom, utilizing tools well-known and trusted to ensure efficiency and effectiveness.

Throughout this chapter, we have adhered to a methodological compass, ever watchful of the need for precision and thoroughness. The aim was not only to navigate the methodological terrain but to chart a course toward a reimagined museum experience that is informed, engaging, and user centric. Our expedition is not just a journey but a testament to the meticulous planning and diligent execution that underscore this work's academic and practical significance.

With the insights and methodological wisdom acquired in this chapter, we now set our sights on the forthcoming phase of our research journey, the results chapter. Armed with a deep understanding of the methodology, we are poised to unravel the outcomes of our endeavors. As we transition into the realm of results, our commitment to reimagining the museum experience in Namibia remains unwavering.

The compass of methodological rigor and user-centric design that has guided us thus far will continue to illuminate our path, ensuring that the transformation we seek is not merely a vision but a tangible reality. In the pages of Chapter 4, we shall witness the tangible fruits of our labor, where data converges with insights to shape the future of the museum experience.

Chapter 4: Results

In our scholarly expedition, we have navigated through the intricate terrain of research design, methodological choices, and the collection of data to unravel the transformative potential of AR technology within the museum context of Namibia. Our journey has been marked by a commitment to methodological rigor, a dedication to innovation, and an unwavering aspiration to enhance the museum experience in Namibia. The path we have traversed was not a mere academic exercise, but an intentional exploration designed to uncover the insights and understandings needed to elevate the cultural sanctuaries of Namibia to new heights.

This chapter represents a critical juncture in our journey. It is here that we unveil the tangible outcomes of our research efforts. Our primary objective in this chapter is to present and describe the findings obtained through a mixed research design, which thoughtfully integrates both quantitative and qualitative research approaches. These findings provide a foundational understanding of the impact of AR technology on the museum experience in Namibia.

As we present and describe these findings, we remain steadfast in our commitment to addressing the objectives and sub-objectives that have guided our work. The journey is far from over, but this chapter marks a significant milestone in our pursuit of reimagining the museum experience.

4.1 Quantitative Results

We begin by presenting the results related to the age groups of the study participants. The age distribution of survey respondents as shown in Figure 19, reveals important insights. The majority, 47.1%, were between the ages of 25 and 34, while approximately 34.3% were aged 24 or younger. A smaller group, 9.8%, fell in the 35-44 age category, and 4.9% represented those between 45 and 54. The least represented group, comprising 3.9% of respondents, consisted of individuals aged 55 or older.

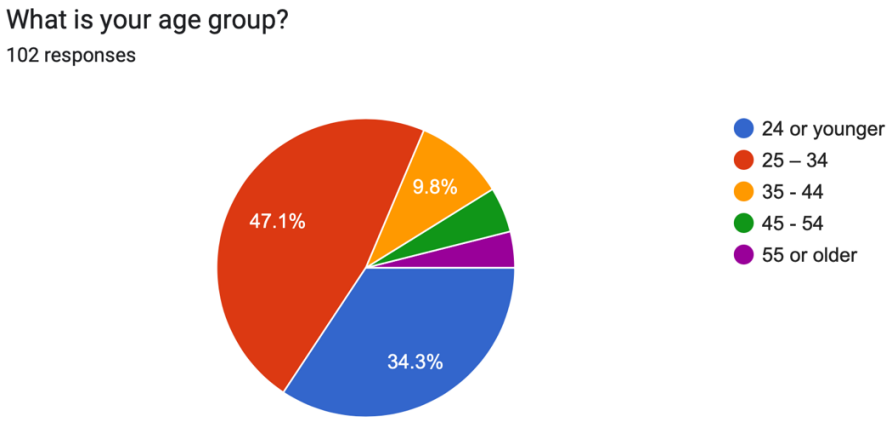


Figure 19: Age group distribution

The gender distribution of survey respondents as shown in Figure 20 reveals that 68.6% of participants identified as male, while 31.4% identified as female. This

information provides a clear understanding of the gender composition of the survey sample.

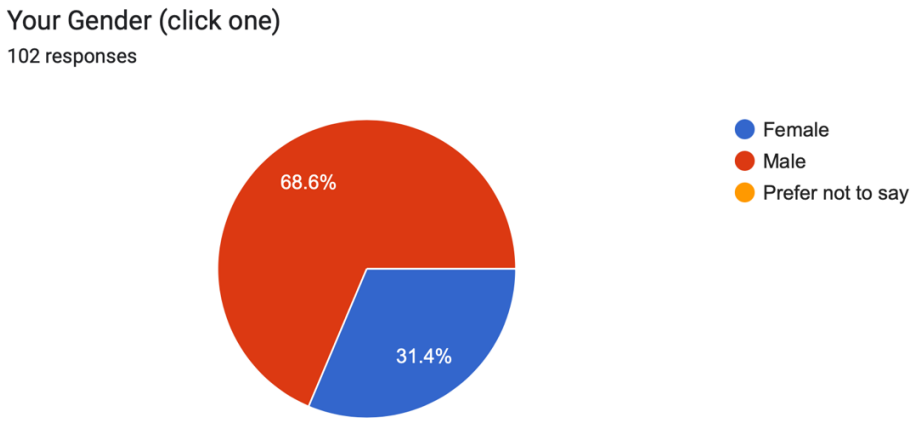


Figure 20: Gender Distribution

The survey as depicted in Figure 21 captured a diverse occupational background among the participants. Students comprised the largest occupational group, representing 45.1% of the sample. Entrepreneurs accounted for 8.8% of the participants, while consultants constituted 12.7% of the survey respondents. Senior employees made up 10.8% of the sample, and mid-career employees represented 8.8%. Trainees or early career employees constituted 5.9% of the participants, and individuals looking for a job accounted for 7.8% of the respondents. The selection of these occupational categories in our survey aimed to capture a wide spectrum of participants from various professional backgrounds, with a focus on those likely to visit museums in Namibia.

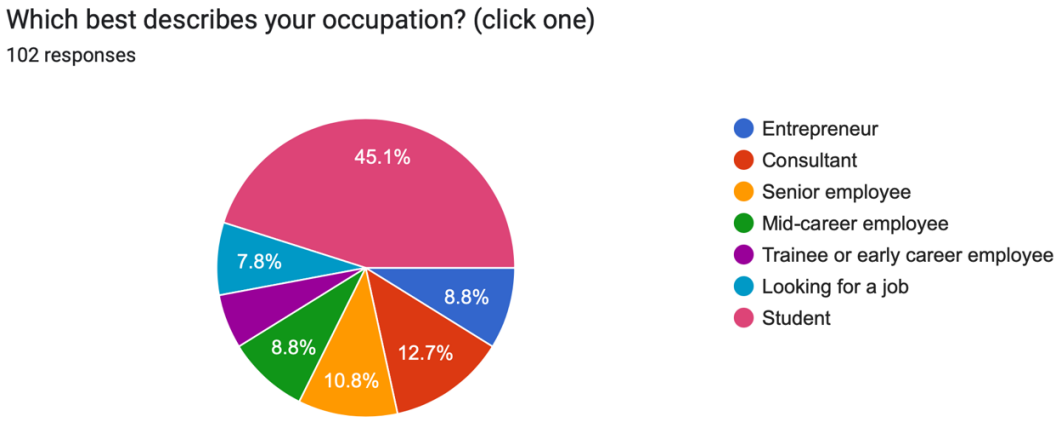


Figure 21: Occupation Distribution

A significant proportion of the survey participants reported having experience with local museums, with 96% of respondents indicating that they had visited a local museum at some point. In contrast, a small minority, constituting 4% of the participants, reported not having visited a local museum as shown in Figure 22 below.

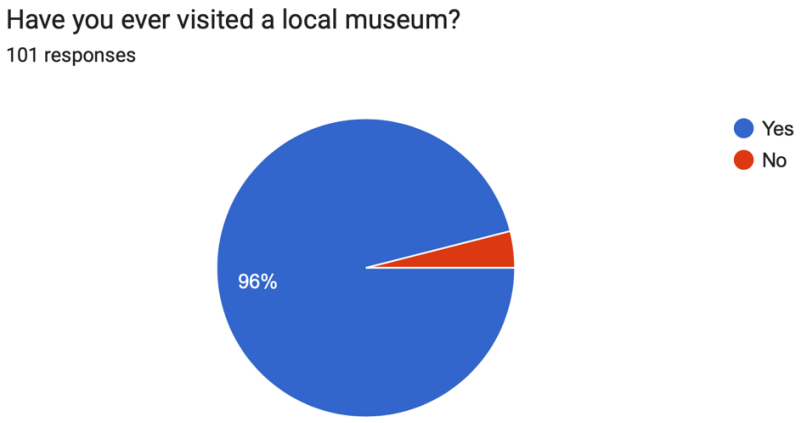


Figure 22: Participant's museum visit experience

Throughout their museum visits, a substantial majority of the survey participants, accounting for 96% of the respondents, reported not having used any form of AR application to enhance their experience. Conversely, only a small fraction, representing 4% of the participants, reported having used AR applications during their museum visits.

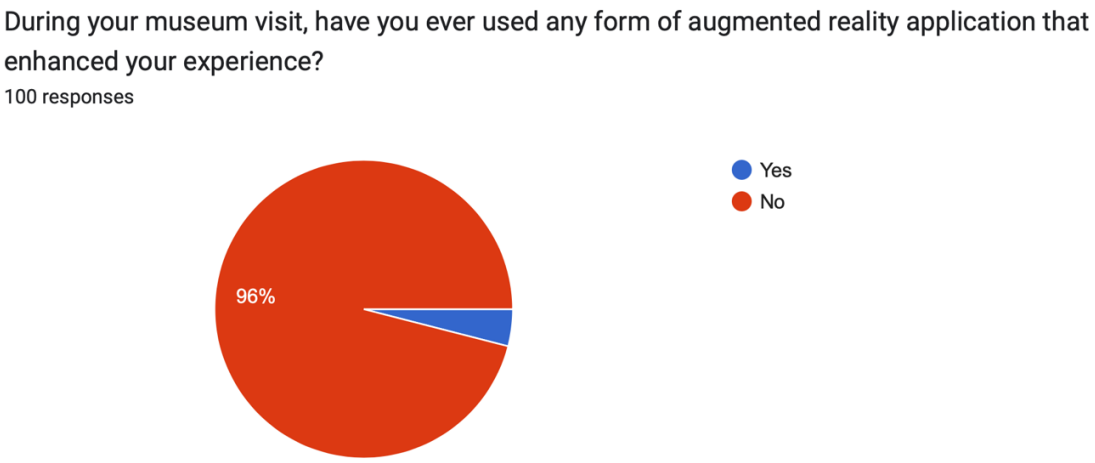


Figure 23: Participant's AR experience at a museum visit

Among participants who indicated having used AR applications during their museum visits, the experiences encompassed a variety of functionalities. Some visitors described applications that provided additional information about the displays, catering to those with a curiosity for more knowledge. A subset of respondents mentioned the use of VR glasses, adding a visual dimension to their experience. Another highlighted feature was audio narration, which guided users through the artifacts on display. Additionally, one participant recounted an application that offered a mini tour, utilizing VR goggles for an immersive and educational exploration of the museum (see appendix C).

Participants as shown in Figure 24 were asked to describe their experiences during their museum visits. The responses indicate that 43.8% of the participants found their experiences to be average (so, so). A significant proportion, 37.1%, reported that their museum visits were quite boring. On the other hand, 19.1% of respondents described their experiences as very exciting.

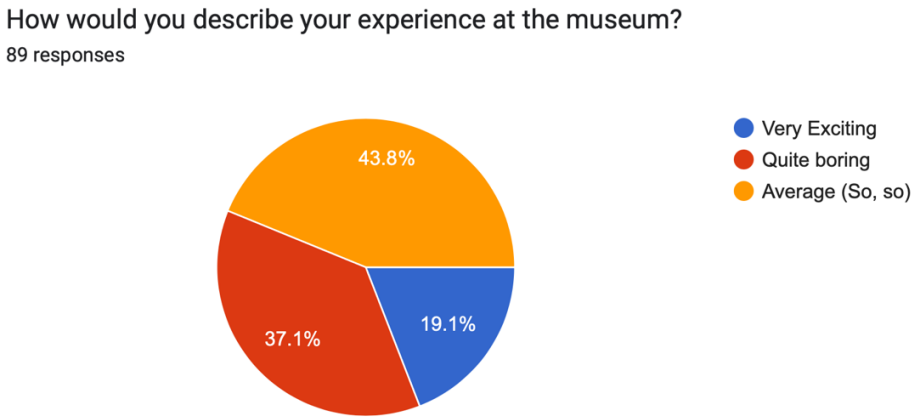


Figure 24: Participant's museum experience

Participants shared the types of museums they had visited, with 67.7% having experienced history museums, making it the most frequently visited category among the respondents. Art museums were visited by 29.3% of the participants, while natural history museums and cultural museums were each visited by 28.3% and 25.3%, respectively. A smaller portion, 4%, reported not having visited any museums as shown in Figure 25 below.

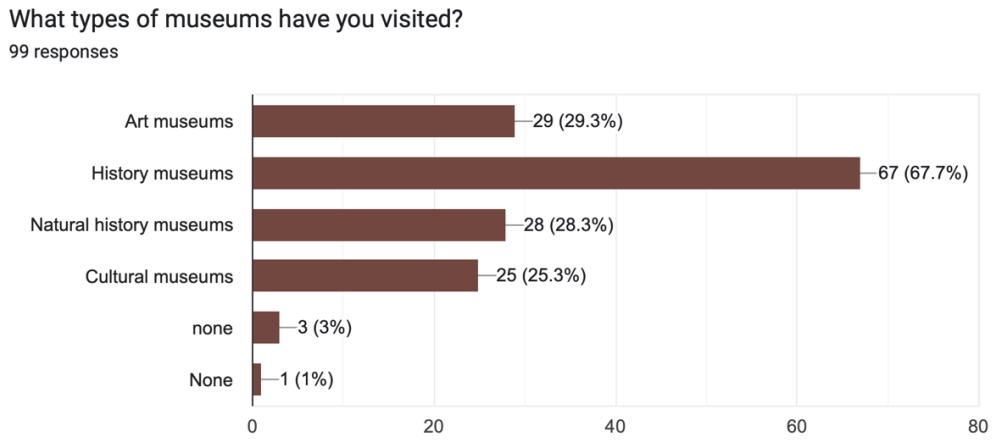


Figure 25: Participant's type of museum visited.

Survey participants shown in Figure 26 below expressed a variety of motivations for visiting museums, often selecting multiple options. A significant majority, 55.4%, indicated that their interest in history or culture was a motivating factor for museum visits. Educational purposes closely followed, with 51.5% of participants citing a desire for learning as a motivation. For some, museums served as sources of entertainment and leisure, as noted by 28.7% of the respondents. Additionally, 19.8% mentioned socializing with friends or family as a motivating factor for their museum visits.

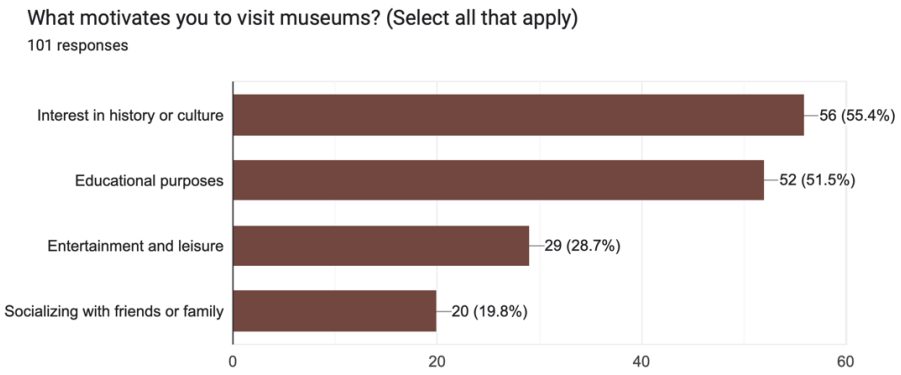


Figure 26: Participant's motivation to visit museums.

Survey participants provided a range of insights into the challenges or limitations they have encountered during museum visits and how AR technology could address these issues. These challenges include difficulty understanding the historical context, limited access to information about artifacts, crowded exhibits, language barriers, lack of engagement for young visitors, inadequate signage, limited interaction with exhibits, and the difficulty in visualizing ancient ruins. Respondents also pointed out challenges such as finding specific exhibits in large museums, lack of hands-on experiences, inadequate accessibility for people with disabilities, and long wait times for museum general guides to assist them. In addition, some respondents shared that they faced challenges in deciphering ancient scripts, understanding complex scientific concepts, and maintaining visitor interest. AR technology could potentially address these challenges by providing deeper explanations, interactive experiences, guided tours, and enhanced accessibility (see appendix D).

Survey participants as shown in Figure 27 displayed a high level of comfort with using technology in a museum setting. The majority, 60.4%, reported feeling "very comfortable" using technology in museums. Additionally, 29.7% indicated that they were "comfortable" with such technology. Only a small proportion expressed discomfort, with 5.9% feeling "neither comfortable nor uncomfortable," 2% "uncomfortable," and another 2% "very uncomfortable."

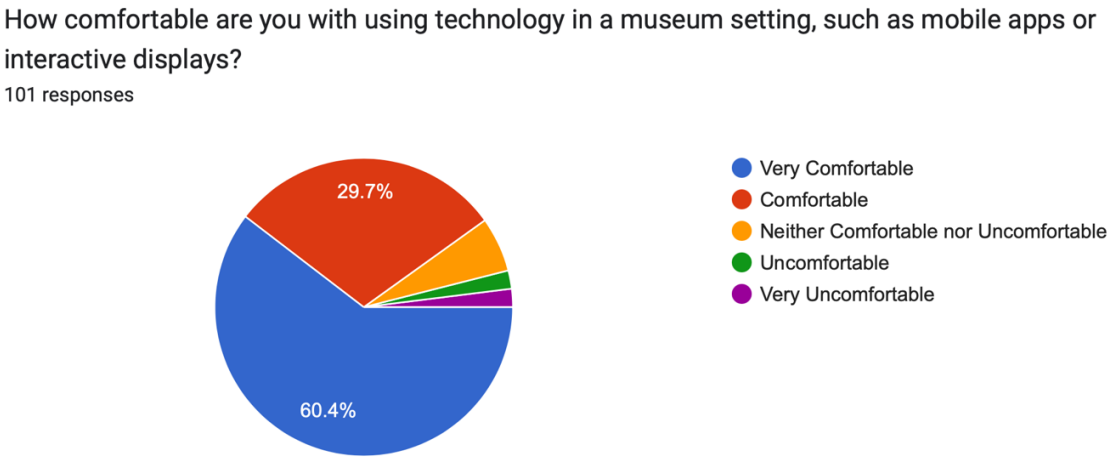


Figure 27: Participant's feeling towards using technology within a museum.

The survey results indicate that the majority of respondents hold a positive view of the potential impact of incorporating AR in museums on their perception and understanding of exhibits and artifacts. A substantial 58.9% "strongly agree" that AR technology has the potential to alter their perception and comprehension of museum exhibits, while an additional 27.4% "agree" with this notion. Only a small proportion expressed neutral or opposing views, with 9.5% selecting "neither agree nor disagree," 2.1% "disagree," and another 2.1% "strongly disagree." See Figure 28 below.

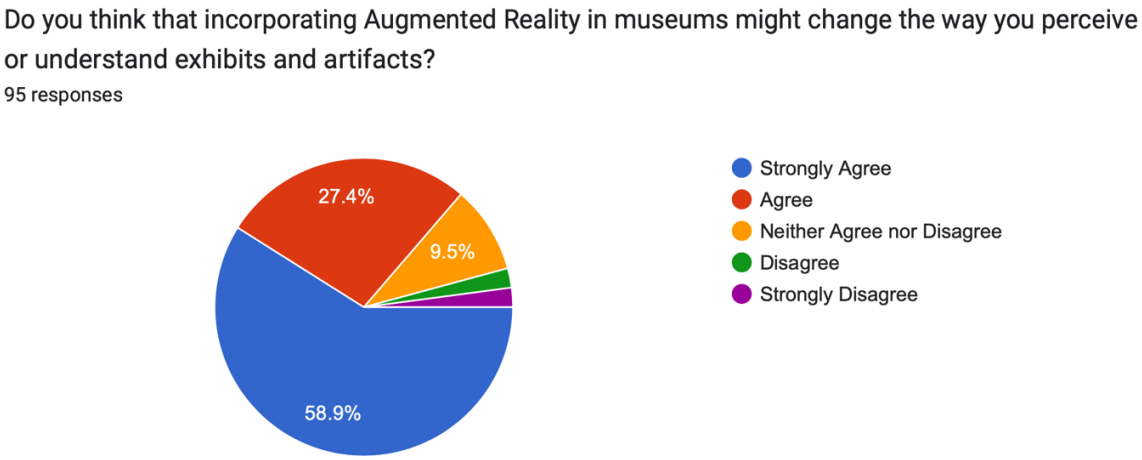


Figure 28: Participants thoughts on incorporating AR in museums.

The responses to concerns about using AR in museums encompass a range of apprehensions. One participant expressed concerns about the potential for AR addiction, indicating a worry about the addictive nature of this technology. Compatibility issues with various devices were raised as a concern, emphasizing the importance of ensuring the smooth functioning of AR applications on different platforms. The need to strike a balance between AR and conservation efforts emerged as another apprehension, highlighting the importance of preserving artifacts and heritage while embracing technology.

Some respondents voiced concerns about the accuracy of AR content, particularly the reliance on foreign-based content rather than locally generated information. Visitor learning effectiveness was also raised as a concern, with a query about the extent to which AR experiences contribute to meaningful learning outcomes.

Concerns about visitor reluctance to use AR due to the lack of AR-capable devices, unless provided by the museum, were mentioned. Ethical considerations in AR content creation and storytelling were highlighted as a significant concern, underlining the need for responsible and sensitive use of AR technology.

Additionally, the potential impact on museum staff roles was seen as a concern, suggesting that the integration of AR might alter the traditional roles within a museum. Worries about the intrusiveness of AR and the quality of AR applications were also brought up, with participants indicating a desire for high-quality AR experiences. These responses reflect a thoughtful consideration of the challenges and ethical dimensions associated with the use of AR in a museum context (see appendix D).

Participants expressed a diverse array of preferences for experiencing AR in their local museums. These preferences encompassed a desire for interactivity with displays, 3D reconstructions of ancient artifacts, and making all artifacts more engaging. There was a strong emphasis on entertainment and education, with suggestions ranging from interactive historical reenactments to immersive art analysis through AR overlays, as well as the implementation of treasure hunts for educational purposes. Many respondents also highlighted the importance of personalized AR-guided tours, multi-language support, real-time translation of inscriptions, and interactive learning experiences through gamified history quizzes and time-travel simulations. While privacy concerns related to user-generated content were noted, participants expressed enthusiasm for AR-enhanced storytelling, archaeological digs, virtual meetings with historical figures, 360-degree views of art, and immersive event experiences. Other ideas included art creation workshops, wildlife exploration, historical architectural

demonstrations, and inclusive AR experiences, such as tactile options for the deaf. These responses collectively demonstrate a strong interest in accessible, engaging, and educational AR applications in museums (see appendix F).

Participants displayed a favorable attitude toward the potential of AR applications to enhance their museum visits. The majority, comprising 51.5%, strongly agreed that incorporating AR would make their visits more enjoyable. An additional 30.7% agreed, reflecting a significant overall positive sentiment. A smaller percentage remained neutral, with 8.9% neither agreeing nor disagreeing, while only 3% expressed disagreement. A parallel 8.9% strongly disagreed with the notion that AR applications could contribute to a more enjoyable museum experience. See Figure 29 below.

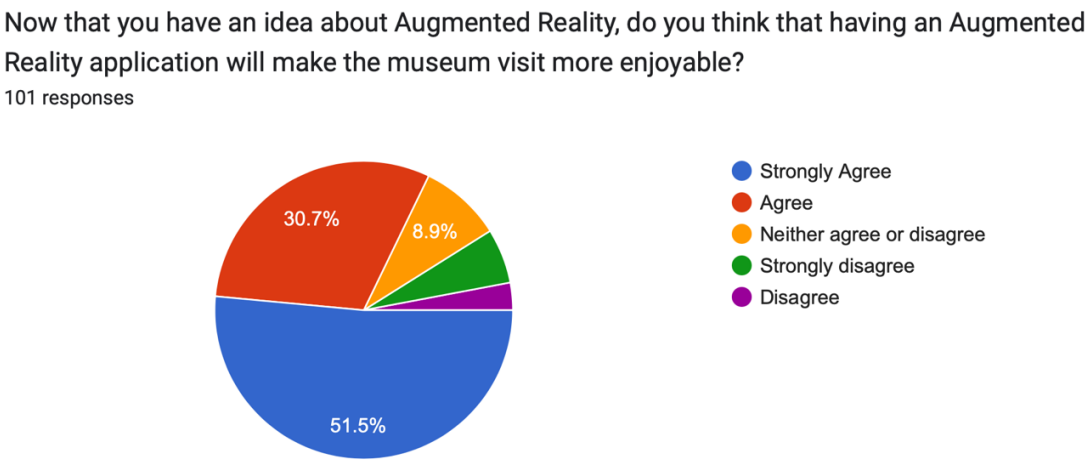


Figure 29: Participants thoughts towards using AR in museums.

4.2 Qualitative Results

In this section, we delve into the qualitative findings derived from participants who engaged with the AR mobile app developed for the museum experience. These qualitative results offer valuable insights into user engagement, learning, and the transformative potential of AR technology within the museum context. Participants' feedback and perceptions illuminate the impact of AR technology in redefining the traditional museum visit and enhancing the overall experience.

The foundation for our study's two distinct groups was laid through a mixed research approach detailed in Chapter 3. To understand the user experiences, we held focus group discussions and interviews with a diverse range of participants. This allowed us to gain a comprehensive understanding of how museum visitors in Namibia perceive, experience, and what motivates them during their visits. Using these insights, we formed our two groups. Group 1 represents those who explored the museum the traditional way, and Group 2 includes those who used our AR mobile app to enhance their experience. Our study compared these two groups to see how AR technology impacts the museum experience. Group 1 which consisted of 6 participants adhered to the traditional approach, and we prompted these participants to envision a hypothetical visit to a local museum while reflecting on their expectations for such a visit, while Group 2 which consisted of 7 participants used the AR mobile app. Figure 22 shows a notable difference in user engagement, with the AR group being significantly more engaged.

User engagement is vital because it promotes active learning. When users are more engaged, they tend to learn better. Figure 30 highlights a clear difference in engagement between the non-AR and AR groups, suggesting that AR technology has the potential to boost engagement. Our findings also show that the AR app can motivate museum visitors to learn more and expand their knowledge about the exhibits and cultural heritage. This technology not only makes museum visits more exciting but also offers opportunities for visitors to dive deeper into the nation's rich heritage.

In terms of knowledge and learning, the AR app significantly improves the experience. It provides audio and visual elements that make learning more effective. The positive feedback and emotional responses we received show that AR can transform the traditional museum experience into something more engaging. This indicates that integrating AR into museums can create a positive impact on the overall experience.

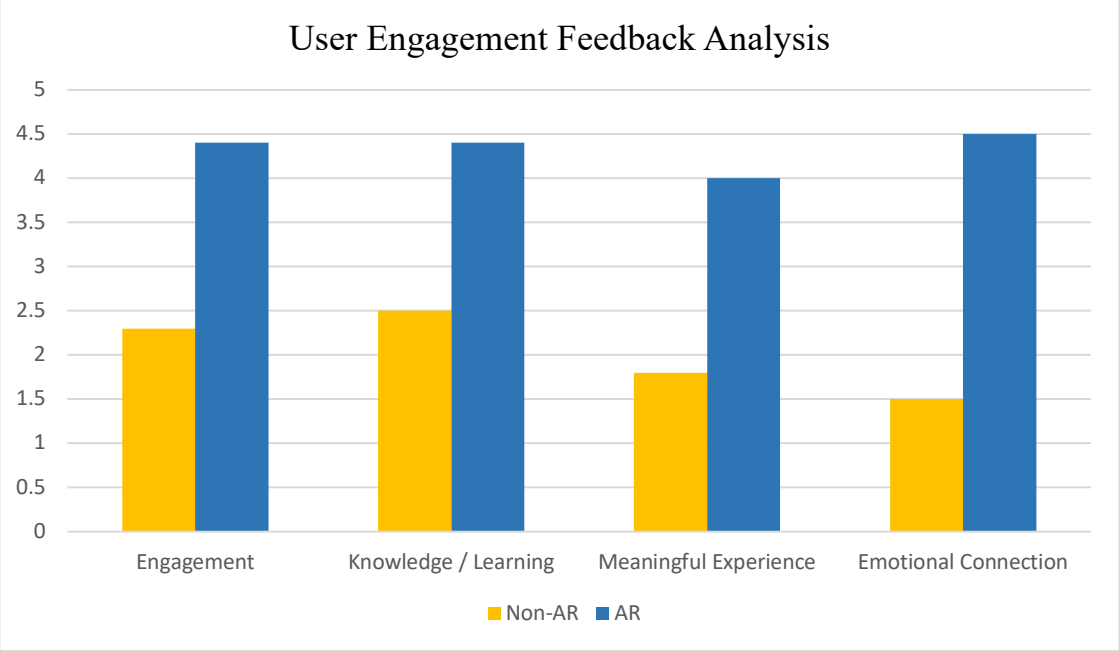


Figure 30: Participants responses

In this chapter, we presented the results of our study, which involved both quantitative and qualitative research methods. Through a comparative analysis, we explored the impact of AR technology on the museum experience in Namibia. The quantitative results revealed essential demographic data, including age, gender, occupation, and prior museum experiences, providing a foundational understanding of our participants. Additionally, we discussed how comfortable participants were with technology in a museum setting, their perceptions of AR's potential to enhance the museum visit, and any concerns they might have about its implementation.

In the upcoming chapter, the Discussion, we will delve deeper into the results presented here. This section will not only describe the findings but will also critically analyze them, providing insights and understanding of the outcomes. We will place these results in context, linking them to existing literature and the stated research objectives. Our discussion will address the objectives and questions of our study, offering a comprehensive analysis of how AR technology can reframe the museum experience and the implications it holds for museum visitors.

Chapter 5: Discussion

Chapter 4, an integral stage in our scholarly expedition, was dedicated to the presentation of the findings derived from the empirical research that sought to unlock the impact of AR technology on museum experiences. Our diligent analysis of the survey data shed light on the diverse demographic characteristics of our participants and provided us with insights into their museum-going tendencies, technological comfort, and perceptions regarding the incorporation of AR. As we now transition into Chapter 5, our journey ventures further into the heart of our research, delving deep into the nuances and implications of our findings.

5.1 Introduction

In this pivotal chapter, we embrace the role of explorers, not merely content to describe our findings but committed to the meaningful interpretation and analysis of those results. We embark on a voyage of intellectual discovery, forging connections between our empirical observations and the established theories, models, and literature within the realms of user engagement, technology-enhanced learning, and AR app development. Our purpose in this journey is twofold: first, to elucidate the significance of our findings in the broader context of educational and museum research; and second, to underscore the transformative potential of AR technology for museums and heritage sites in Namibia.

Our path through this chapter will traverse three main destinations: user engagement and learning, technical aspects of the AR app, and the implications for museums and

heritage sites. We will anchor our discussion in the shores of well-grounded theory, relying on the literature's guiding beacons to navigate the terrain of AR's impact. By journey's end, we hope to illuminate the uncharted territories of knowledge where our study makes a distinct contribution, bridging gaps, challenging assumptions, and opening new horizons in the quest to reimagine the museum experience.

As we prepare to set sail, our compass is calibrated towards a thorough analysis of our results, guided by the objectives of our research and the questions it sought to answer. The essence of our quest is to provide a critical, thoughtful, and insightful discussion that not only connects our findings to the academic conversation but also sets the stage for the transformative potential of AR technology in Namibia's cultural sanctuaries.

5.2 Understanding Our Audience: Demographic Insights from Chapter 4 Results

The demographic insights provided in this section, drawing from Figures 19, 20, and 21 of the previous chapter, serve as a foundational lens through which we examine the transformative potential of AR technology within Namibia's museum landscape. Our exploration of these findings paints a picture of the age, gender, occupational diversity, museum visitation, and AR application usage among our survey participants. As we delve into the specifics, we will discern the implications of these demographics, offering a deeper understanding of the context and potential for AR technology to enhance museum experiences in Namibia.

The age distribution among survey participants, revealed in Figure 19, is a pivotal starting point. Notably, 47.1% of respondents fell within the 25-34 age group, indicating a significant presence of young adults among museum-goers. Moreover, approximately 34.3% were aged 24 or younger, reflecting a substantial youth presence within this audience. This demographic insight underscores the importance of catering to the younger generation, which constitutes a considerable portion of the museum-visiting population. However, the older age groups (35-44, 45-54, and 55 or older) were less represented, implying a potential need for tailored AR experiences for these segments.

Our findings reveal a substantial presence of young adults, particularly those aged 25-34 and 24 or younger, among museumgoers. This aligns with the evolving use of AR as an educational tool to engage and motivate learners (Avila et al., 2020). The availability of AR learning experiences for subjects like biology, physics, and languages, as highlighted in our literature review, resonates with the potential to harness AR for educational and immersive learning experiences within museums.

Turning to gender distribution depicted in Figure 20, our data indicates a higher representation of male participants at 68.6% compared to female participants at 31.4%. This composition suggests a gender disparity that must be considered when designing AR applications, as it raises questions about the differing levels of engagement and interaction with AR among museum visitors. An exploration of this divide can guide the creation of inclusive AR experiences that resonate with all, regardless of gender.

Occupational diversity, as depicted in Figure 21, offers further insights. Students represent the largest group at 45.1%, highlighting the relevance of aligning AR content

with educational objectives to enhance learning experiences within museums. The presence of entrepreneurs, consultants, senior employees, mid-career employees, trainees or early career employees, and job seekers underscores the importance of tailoring AR content to the diverse knowledge and interests of professionals across various fields. Understanding this occupational diversity is pivotal for creating AR content that resonates with the varied expertise and expectations of museum visitors.

Significantly, 96% of survey participants reported prior visits to local museums (Figure 22), indicating a keen interest in cultural and historical experiences. This suggests an opportunity for AR applications to deepen and enrich these visits. However, it also signifies a need to acknowledge existing expectations and experiences related to conventional museum visits among this audience.

Conversely, the data pertaining to AR application usage during museum visits (Figure 23) highlights a significant growth potential. With 96% of participants reporting no prior use of AR applications during museum visits, the market for AR adoption appears relatively untapped. This underscores the potential for introducing AR applications that enhance museum experiences. The 4% of participants who have used AR applications are a small yet invaluable segment, providing insights into their experiences and preferences that can guide the development of AR solutions.

The experiences of participants who reported using AR applications during their museum visits reveal the diverse functionalities offered by these applications.

These findings echo the potential for AR to enrich and diversify the museum experience, in line with our literature review, where we explored several case studies of AR applications in museums. It's noteworthy that visitors' descriptions of their AR

experiences encompassed a variety of functionalities. For instance, some participants mentioned applications that provided additional information about the displays, catering to those with a curiosity for more knowledge. This is consistent with the instance of The Cleveland Museum of Art and their ArtLens app, where the visitor experience is enriched through the provision of information, audio, and video content, along with historical context and artist biographies via AR overlays (Pollalis et al., 2018). While our findings align with some aspects of the literature on AR applications in museums, particularly in terms of enhancing visitor engagement and providing educational content, it is important to note that there is a significant gap in addressing accessibility issues, especially for people with disabilities. This aspect is particularly crucial because our survey raised concerns from some participants about the limited consideration of special needs in the development of these innovative solutions. Although AR has shown great potential in transforming the museum experience, previous literature often lacks evidence of inclusive design that accommodates individuals with special needs.

The concern raised by some of our survey participants highlights the necessity of developing AR applications that are not only engaging and informative but also accessible to a wide range of visitors, including those with disabilities. Inclusivity and accessibility should be at the forefront of AR application development, aligning with the principles of universal design to ensure that everyone, regardless of their abilities, can enjoy and benefit from the museum experience.

The survey results shed light on participants' experiences during their museum visits, which provide valuable insights into the motivations behind museum visits and, in

turn, how the AR app that we developed addressed some of the challenges faced by visitors.

The survey results emphasize the need for reimagining the museum experience, particularly in Namibia, where a significant proportion of participants found their museum visits to be quite boring (37.1%) or average (43.8%). These findings highlight the opportunity to introduce innovative solutions to transform relatively passive museum experiences into exciting and informative ones. This reimagining is central to the primary objective of the study, which is to leverage AR technology to enhance the museum experience in Namibia.

Objective I, "Designing a User-Centric AR Prototype," is reinforced by the survey findings. The participants' varied experiences during museum visits underscore the importance of tailoring AR experiences to the preferences and needs of diverse museum visitors in Namibia. By addressing the challenge of visitor engagement, the developed AR app prototype can contribute to creating user-centric experiences that cater to a broad audience, aligning with the goal of making museum visits more exciting and educational.

The second objective, "Developing an Interactive AR Application," is substantiated by the diverse types of museums visited by participants. The findings reveal that history museums were the most frequently visited (67.7%), but art museums, natural history museums, and cultural museums were also popular choices.

This variety in museum types emphasizes the need for an AR application that can seamlessly integrate with different museum exhibits. By achieving this objective, our AR app had the potential to enhance the user experience by offering interactive and informative content across various museum categories, aligning with the literature's emphasis on integrating AR with physical artifacts and providing insights into different subjects, much like the AR applications in various contexts discussed in the literature.

The third objective, "Enriching User Experience through Sensory Augmentation," is reinforced by the motivations for visiting museums reported by participants. A significant majority expressed their interest in history or culture (55.4%), with a desire for learning (51.5%) closely following. The educational aspect and the interest in historical and cultural content align with the goal of enriching the user experience through sensory augmentation. By incorporating sensory augmentation within the AR application, enabled us to foster a deeper connection between visitors and the cultural heritage on display. This approach aligns with the literature's research gaps related to preserving and presenting the cultural significance of artifacts and traditions specific to Namibia, contributing to a more engaging and educational museum experience. Having gained a nuanced understanding of the participant demographics, we now delve into the technical intricacies of the developed AR app.

5.3 Technical Aspects of the Developed AR App

The development of the AR app represents a critical technical component of this study, and this section will delve into the technical aspects, linking them to established

industry standards and best practices. As we have discovered through our thorough examination of the existing literature, there has been a notable gap in the comprehensive exploration of the technical aspects of AR app development. Specifically, there has been limited attention given to whether these AR apps adhere to the best practices and standards within software development. This research aims to bridge this gap by providing a detailed and insightful account of the technical intricacies involved in the development of our AR app.

5.3.1 Programming Language and Frameworks

The choice of Swift as the programming language for developing the AR app stems from its prominence and alignment with industry standards, particularly in the realm of iOS app development. Swift, introduced by Apple, has rapidly gained traction since its inception due to its modern syntax, performance efficiency, and safety features. In the context of iOS app development, Swift has become the preferred language, supplanting Objective-C in many new projects. Swift offers several advantages for developing AR applications. Its readability and conciseness facilitate a more streamlined development process, enhancing code maintainability and reducing the likelihood of errors. The strong type of system in Swift provides a robust foundation for building complex and interactive AR features, crucial for creating immersive experiences within the app.

ARKit, a key framework provided by Apple, played a pivotal role in the development of the AR app. ARKit is specifically designed to streamline the integration of AR

features into iOS applications, making it an indispensable tool for developers seeking to create immersive AR experiences.

ARKit offered a wide array of functionalities that significantly contribute to the app's capabilities. One of its core features is world tracking, which enables the app to understand and interact with the surrounding environment in real time. This is crucial for anchoring virtual objects to the real world seamlessly. Additionally, ARKit provided support for motion tracking, enabling the app to respond dynamically to the user's movements, enhancing the overall user experience.

The use of ARKit aligns with industry best practices in AR app development for iOS, ensuring a standardized and optimized approach. By leveraging ARKit, the app benefits from continuous updates and improvements provided by Apple, staying current with advancements in AR technology. Moreover, ARKit simplifies complex tasks, such as surface detection and lighting estimation, making it more accessible for developers to create sophisticated AR applications. In the development of augmented experiences, SwiftUI, Reality Kit, and Reality Composer collectively contribute to creating rich and interactive content.

SwiftUI, Apple's declarative UI framework, was employed for building the user interface of the AR app. Its simplicity and real-time previews facilitated the design process, allowing for rapid prototyping and adjustments. SwiftUI seamlessly integrates with ARKit, enabling a cohesive development approach for both the app's interface and augmented experiences.

The Reality Kit framework was instrumental in rendering 3D content and managing the AR experiences within the app. Reality Kit simplified complex tasks such as scene composition, animation, and interaction, offering an intuitive and powerful toolset for creating engaging AR content. Its integration with ARKit ensured a seamless connection between the app's user interface and augmented elements.

Reality Composer was used in conjunction with Reality Kit, Reality Composer provided a user-friendly interface for designing and prototyping AR experiences. Its drag-and-drop functionality and pre-built assets empower developers to efficiently create dynamic and interactive content. The integration of Reality Composer contributed to the overall accessibility and creativity in crafting augmented experiences for the app.

In Figure 31, we present a practical demonstration of the implementation of our AR app using the Swift programming language. Here, we showcase a Grid layout featuring the Early Resistance Leaders exhibited at the Independence Memorial Museum in Windhoek, Namibia. Moving forward to Figure 32, we illustrate the augmentation of each leader, in this case Keptein Hendrik Witbooi, incorporating a voice narration enhancement to their facial representation. This strategic augmentation aims to elevate the museum experience, providing visitors with an immersive and informative encounter, particularly for those seeking in-depth insights into the stories of each distinguished leader. For more details of this AR App, please use this link to view a short demo: AR App Demo Link

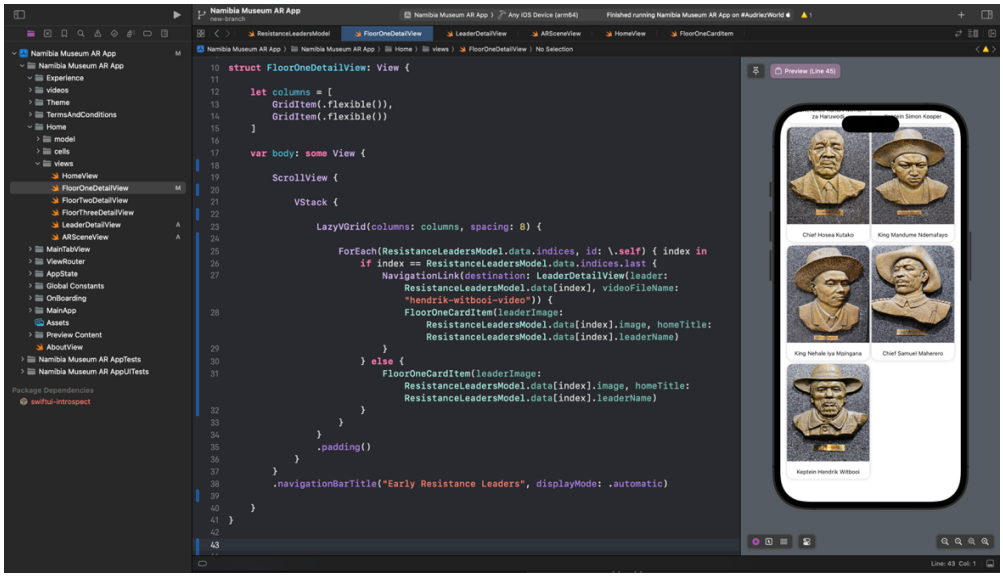


Figure 31: AR Museum App coding flow

Figure 32: Keptein Hendrik Witbooi Augmented Face sculpt.

5.3.2 An AR App for the Independence Museum of Namibia

Our research, titled "Reimagining the Museum Experience Using AR: A Focus on A Namibian Museum," involved selecting the Independence Memorial Museum in Windhoek, Namibia, as a model for our AR app. Drawing inspiration from this well-presented museum, the AR app has the potential for adaptation to other museum settings. The Independence Memorial Museum, with its three floors dedicated to narrating the colonial history of Namibia, served as a rich source for developing a comprehensive and immersive AR experience.

Figure 14, which showed the high-fidelity prototype offers a glimpse into the app's initial launch, providing users with a guided onboarding experience to familiarize them with the app's features. Notably, our design philosophy excludes complex sign-in flows, addressing concerns raised by survey participants regarding privacy and quick access. The app's simplicity ensures that museum visitors can seamlessly explore the augmented content without the need for individual data input.

Upon reaching the home screen, users encounter three list items representing each floor of the museum along with its corresponding theme. For instance, Figure 33 illustrates that Floor 1 focuses on content related to colonial repression. This intuitive design allows users to navigate the app efficiently and choose specific thematic areas of interest.

Clicking on the Floor 1 list item transports users to the "Early Resistance Leaders" screen, where augmented faces of the featured leaders provide a unique storytelling

perspective. Augmenting their faces enables these historical figures to recount their narratives, offering visitors a compelling and personalized experience. For a demonstration of Hendrik Witbooi's story, refer to the provided demo link video, showcasing the effectiveness of this augmentation technique. As users traverse the museum, certain images trigger augmented sounds that recreate the wartime experiences of our forefathers. This practical implementation demonstrates how the AR app engages users with immersive content triggered by physical exhibits, effectively blending historical context with technological innovation to enhance the overall museum experience.

While attempting to augment numerous artifacts at the Independence Memorial Museum, we utilized a tool that allowed us to augment specific objects, see figure 33. However, due to the delicate nature of the artifacts, we were prohibited from physically interacting with or approaching them. This restriction was both reasonable and comprehensible.

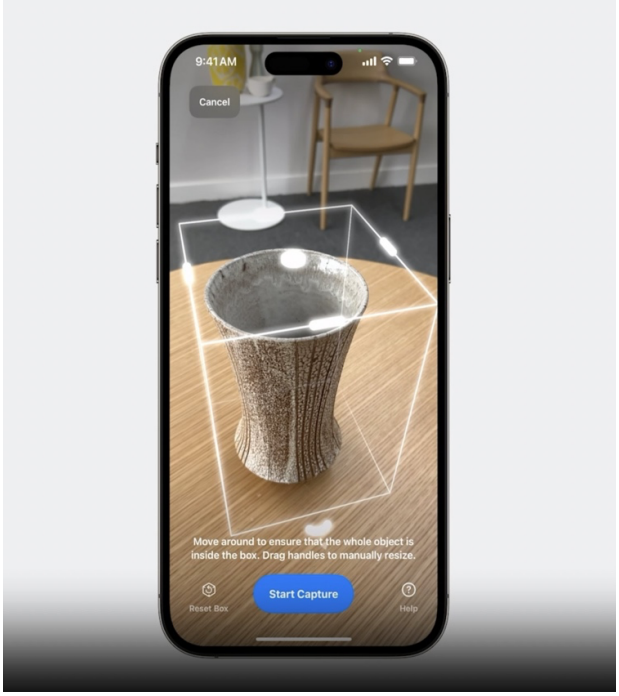


Figure 33: Apple's Object Capture App which allows taking numerous images and convert them to 3D objects.

Our aspirations for 3D modeling encountered challenges, particularly concerning specific artifacts that we initially anticipated augmenting. Figure 34 below illustrates a selection of artifacts that proved challenging to convert into 3D models, deviating from our initial expectations.

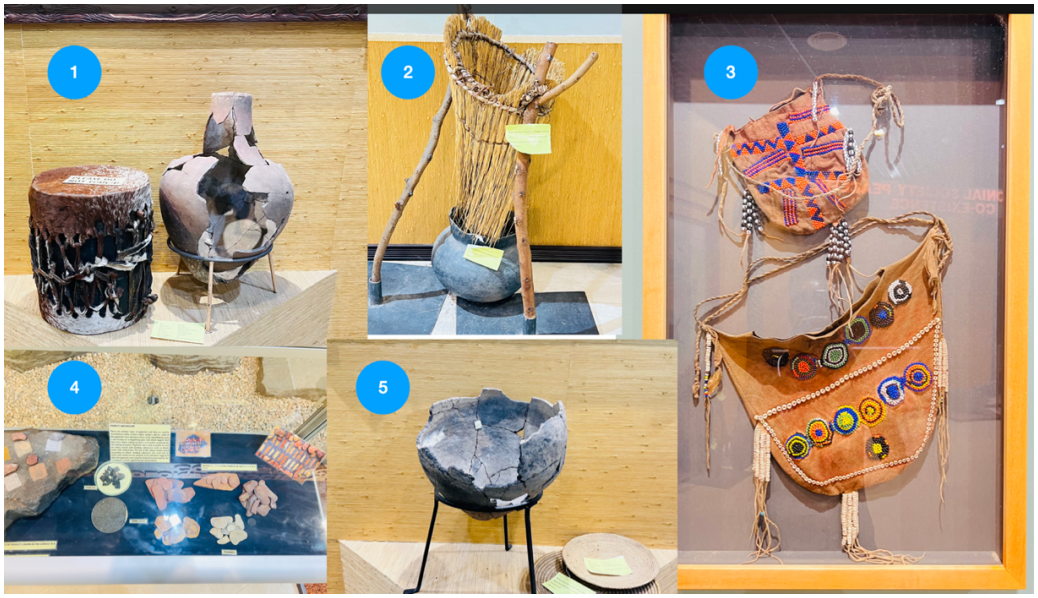


Figure 34: Independence Museum Artifacts that could not be augmented to 3D objects

As we conclude this chapter, we reflect on the broader implications of our study. The AR app, designed and implemented with a user-centric and technically robust approach, holds promise not only for the Independence Memorial Museum but also for museums across Namibia. The intersection of user engagement, technical proficiency, and thematic richness positions our research as a catalyst for reimagining and enhancing the museum experience.

Chapter 6: Conclusion

In summarizing the key discoveries of this study, it became clear that creating an AR app is indeed a viable undertaking. However, an interesting revelation emerged from survey participants, as some expressed a desire for an abundance of features on the app, potentially deviating from the study's intended purpose. Furthermore, the ambition to convert a substantial number of museum artifacts into 3D models encountered practical challenges, primarily stemming from the delicate nature of the artifacts housed in the chosen museum, the Independence Museum. The literature review underscored a positive trend worldwide, showcasing how museums have embraced AR technology to enhance visitor experiences. Notably, participant feedback highlighted a strong appreciation for innovative apps that prioritize inclusivity, particularly catering to individuals with disabilities. This valuable insight serves as a catalyst for future improvements to the AR app developed for this study. A pivotal moment in this research was the on-site visit to the Independence Museum in Windhoek, affirming assumptions about the untapped potential of museum storytelling. The narratives exist, yet the conventional methods of communication fall short. The incorporation of AR technology emerged as a promising avenue to transform museum visits into profoundly memorable experiences, aligning with the overarching goals of this study.

In accordance with the primary goals of the study, the conclusions derived from this research directly speak to the three essential sub-objectives established at the beginning.

The primary goal was the successful design of a User-Centric AR Prototype, achieved through the development of a high-fidelity AR prototype using Adobe XD. This prototype was meticulously crafted, considering the preferences and needs of diverse museum visitors in Namibia. By doing so, the research addressed a critical research gap, focusing on tailoring AR experiences to the local context and the specific demographics of museum-goers.

Moving on to the second objective, the creation of an Interactive AR Application using cutting-edge technologies such as Reality Kit and ARKit for iOS devices was a significant accomplishment. This application seamlessly integrates with museum exhibits, aligning with existing literature that emphasizes the importance of intertwining AR with physical artifacts. Through this achievement, the study contributes valuable insights into how AR can enhance and complement traditional exhibits within the unique cultural context of Namibia.

The third sub-objective, centered around enriching the User Experience through Sensory Augmentation, was met by implementing environment sensory augmented technology within the AR application. This step not only corresponds with existing literature's research gap related to preserving and presenting the cultural significance of Namibian artifacts but also aims to foster a deeper connection between visitors and the displayed cultural heritage. This emphasis on sensory augmentation addresses a critical gap in understanding how AR can align with and enhance cultural narratives in Namibian museums.

The research conducted in this study has made significant strides in addressing the identified problem or research question—namely, the potential for AR to enhance the museum experience in Namibia. The successful implementation of the AR app marks a noteworthy achievement in demonstrating the feasibility of integrating cutting-edge technology into the cultural heritage sector.

While the study has effectively showcased the technical capability to develop and test the AR app, the larger challenge lies in ensuring the practical application of this innovation within a local museum setting. The research question initially posed sought to explore the possibilities and implications of employing AR in Namibian museums, and the developed app serves as a tangible solution to this exploration.

However, it is crucial to emphasize that the resolution of the identified problem doesn't end with the development of the AR app; rather, it extends to the practical adoption and implementation of this technology within the cultural landscape of Namibia. The insights gained from this investigation underscore the potential transformative impact of AR on museum experiences. This, in turn, prompts a call to action—encouraging the continuation of this pioneering effort beyond the confines of academic research.

It is acknowledged that the success of this study should not culminate in the mere archival of findings. Instead, the wish is for this research to serve as a catalyst, paving the way for the practical incorporation of innovative technologies, such as AR, within local museum settings in Namibia. By doing so, this study aspires to be a trailblazer, inspiring a broader embrace of innovative research practices in the cultural and heritage sectors of Namibia. The resolution of the immediate research question propels

us toward a broader goal of fostering a culture of innovation and advancement within the realm of Namibian museums.

The research process has provided valuable lessons and insights, particularly in navigating the intersection of technical expertise and effective communication with non-technical audiences. While my proficiency in implementing software-based solutions served as a solid foundation, a significant challenge emerged in translating technical jargon into accessible language for laypeople. This challenge became a catalyst for me to engage in more meaningful discussions with participants and stakeholders involved in the study. Learning to convey complex technical concepts in a manner that resonates with a broader audience became a crucial skill that contributed to my personal and professional growth during the course of this study.

Another notable lesson pertained to the intricacies of participant recruitment. Convincing individuals to allocate their limited time to participate in the study proved to be a formidable task. Recognizing the scarcity of time as a valuable resource, I gained a deeper appreciation for the willingness of participants to contribute to the research. This experience highlighted the importance of clear communication and establishing the significance of the study to potential participants.

Additionally, physical visits to the local museum presented a unique set of challenges. Explaining the research aspirations to museum staff revealed an unexpected lack of excitement on their part, which initially felt discouraging. However, upon reflection, this response likely stemmed from the difficulty in articulating a complex idea in layman's terms. This realization underscored the importance of refining

communication strategies to ensure that the significance of the research is comprehensible and engaging, even to those less familiar with technical concepts. In essence, the research journey has not only enhanced my technical skills but also fostered a deeper understanding of the importance of effective communication and the challenges associated with bridging the gap between technical and non-technical perspectives. These lessons will undoubtedly shape future endeavors, emphasizing the need for clear and accessible communication in research endeavors.

One notable weakness in the study revolves around the limited accessibility of the AR app to a diverse range of participants. Specifically, the constraint arose from the exclusive compatibility of the developed app with iOS devices. As a result, not everyone had an iPhone to test the AR application, introducing a potential bias in the participant pool. This limitation affected the overall population size available for testing, thereby restricting the diversity of insights that could have been garnered from a more extensive and varied group. The methodological constraint of platform exclusivity underscores the importance of addressing accessibility concerns in future research endeavors to ensure a more inclusive and representative sample, ultimately enhancing the robustness and generalizability of the study's findings.

In conclusion, this study on leveraging AR to enhance the museum experience in Namibia signifies a significant step towards bridging technological innovation with cultural heritage preservation. The successful development and testing of the AR app underscore the transformative potential of integrating cutting-edge technology into the realm of museums. Despite certain limitations, such as platform exclusivity, the study lays the groundwork for future endeavors aiming to make museum experiences more

engaging, educational, and accessible. The insights gained from this research contribute to the growing body of knowledge on the implementation of AR in cultural institutions, particularly in the Namibian context. By emphasizing the importance of inclusive and user-centric design, this study not only addresses the specific challenges faced but also serves as a catalyst for broader discussions on the intersection of technology and cultural heritage. As museums navigate the digital age, this research advocates for the thoughtful integration of AR to create memorable and meaningful visitor experiences, fostering a deeper connection between individuals and the cultural narratives preserved within these institutions.

Chapter 7: Recommendations

Chapter 7 offers valuable recommendations derived from the insights garnered during the study on leveraging AR to enhance the museum experience in Namibia. These recommendations aim to guide future developments and implementations of AR applications within the cultural heritage sector.

Addressing concerns raised by participants regarding accessibility, it is recommended that future AR applications prioritize inclusivity. Developers should adhere to universal design principles, ensuring that AR experiences are accessible to individuals of varying physical abilities. This commitment to inclusivity aligns with the broader goal of making cultural institutions and technological advancements accessible to a diverse audience.

A pivotal recommendation underscores the importance of collaboration between AR developers and museums. To create meaningful and contextually relevant experiences, AR applications should be designed in consultation with museum curators and educators. This collaborative approach ensures that AR aligns seamlessly with the goals and objectives of the institution, fostering a harmonious integration of technology and cultural preservation.

Responding to user concerns about privacy, developers are urged to prioritize user privacy in AR applications. Transparent communication about data usage, implementation of privacy controls, and adherence to clear data practices are crucial.

By addressing privacy considerations, developers can enhance user trust and acceptance, facilitating a more positive and secure AR experience.

To enhance and refine AR applications, researchers and developers are recommended to establish mechanisms for continuous user feedback. Regular updates and iterations based on user input serve to improve the overall user experience and address emerging challenges. This iterative approach ensures that AR applications evolve in response to user needs and preferences.

This study opens avenues for further research, particularly within the Namibian context. Future studies are encouraged to delve deeper into the specific preferences and expectations of Namibian museum visitors. By conducting more nuanced research, scholars can provide valuable insights that inform AR development tailored to the unique cultural landscape of Namibia.

In essence, this research significantly contributes to the broader understanding of AR applications in cultural and educational settings. The recommendations provided serve as practical guidelines for the future development of AR in museums, not only in Namibia but also on a global scale. By addressing challenges and embracing these recommendations, the transformative potential of AR in reimagining the museum experience can be fully realized, ensuring a more inclusive, collaborative, and privacy-conscious approach to technology integration in cultural institutions.

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APPENDICES

Appendix A (Ethical Clearance Certificate)

UNAM
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ETHICAL CLEARANCE CERTIFICATE

Ethical Clearance Reference Number: SOS-0060 Date: 27 April 2022

This Ethical Clearance Certificate is issued by the University of Namibia Ethics Committee (REC) in accordance with the University of Namibia's Research Ethics Policy and Guidelines. Ethical approval is given in respect of undertakings contained in the Research Project outlined below. This Certificate is issued on the recommendations of the ethical evaluation done by the ethics committee.

Title of Project: REIMAGINING THE MUSEUM EXPERIENCE USING AUGMENTED REALITY: A FOCUS ON THE NATIONAL MUSEUM OF NAMIBIA

Student: TATENDA CHANAKIRA

Student Number: 201401550

Supervisor(s): MRS. VICTORIA HASHEELA-MUFETI

Centre for Research Services

Take note of the following:

1. Any significant changes in the conditions or undertakings outlined in the approved Proposal must be communicated to the ethics committee. An application to make amendments may be necessary.
2. Any breaches of ethical undertakings or practices that have an impact on ethical conduct of the research must be reported to the ethics committee
3. The Principal Researcher must report issues of ethical compliance to the ethics committee (through the Chairperson) at the end of the Project or as may be requested by the ethics committee
4. The ethics committee retains the right to:

i) Withdraw or amend this Ethical Clearance if any unethical practices (as outlined in the Research Ethics Policy) have been detected or suspected,

ii) Request for an ethical compliance report at any point during the course of the research.

The ethics committee wishes you the best in your research.

Dr. Zivayi Chiguvare (Chairperson Ethics Committee)

Prof. Davis Mumbengegwi (Head, Multidisciplinary Research)

Appendix B (Online Questionnaire)

Link to Questionnaire: Online Questionnaire

Section 1 of 4

Re-imagining the Museum experience using Augmented Reality Questionnaire.

Greetings,

We are embarking on a research journey exploring the exciting potential of Augmented Reality (AR) in Museums. We cordially invite you to share your valuable insights and experiences regarding museums, and to envision the possibilities AR can bring to these cultural spaces.

The study is led by Audrey Chanakira and has ethics approval (**Ethical Clearance Reference Number: SOS-0060**) from the University of Namibia.

Introduction to Augmented Reality (AR): Augmented Reality (AR) is an innovative technology that transforms the physical world into an interactive digital experience. For a glimpse of what AR entails, watch this brief video illustration: Link to Video.

This questionnaire forms a crucial part of our research, aiming to gain a deeper understanding of people's interactions with local museums.This questionnaire will take about 20 mins to complete.

Voluntary Participation: Participating in this survey is entirely voluntary, and your contribution is immensely appreciated. If you have any questions or concerns, please feel free to contact me at tate.audrie.charks@gmail.com or my supervisor at vhasheela@unam.na.

Your input will play a significant role in advancing our understanding of the potential of AR in the context of museums. Thank you for considering participation in this research.

Section 2 of 4

Participant Information

Gathering information about participants' age, gender, and occupation helps the researcher in understanding the composition of the survey respondents. This demographic data can later be used to analyze if there are any patterns or preferences based on these factors.

What is your age group?

- ○ 24 or younger
- ○ 25 – 34
- ○ 35 - 44
- ○ 45 - 54
- ○ 55 or older

Your Gender (click one)

- ○ Female
- ○ Male
- ○ Prefer not to say

Which best describes your occupation? (click one)

- ○ Entrepreneur
- ○ Consultant
- ○ Senior employee
- ○ Mid-career employee
- ○ Trainee or early career employee
- ○ Looking for a job
- ○ Student

After section 2 Continue to next section

Section 3 of 4

Participant Museum Experience

Collecting information about your museum experience is essential because it allows us to gain valuable insights into your background and preferences as a participant.

Understanding your past interactions with museums, the types of museums you visit, and your motivations for doing so helps us tailor our research to better address the specific needs and expectations of museum-goers like you.

This data enables us to explore how Augmented Reality can enhance your museum visits and ultimately contribute to a more immersive and enjoyable cultural experience in museums. Your input in this regard is instrumental in shaping the future of museum experiences with AR technology.

Have you ever visited a local museum?

- ◯ Yes
- ◯ No

During your museum visit, have you ever used any form of augmented reality application that enhanced your experience?

- ◯ Yes
- ◯ No
- ◯ Other...

If your answer was "Yes" to the previous question, briefly describe the application you used.

Long-answer text

How would you describe your experience at the museum?

- ◯ Very Exciting
- ◯ Quite boring
- ◯ Average (So, so)

What types of museums have you visited?

- [ ] Art museums
- [ ] History museums
- [ ] Natural history museums
- [ ] Cultural museums
- [ ] Other...

What motivates you to visit museums? (Select all that apply)

- [ ] Interest in history or culture
- [ ] Educational purposes
- [ ] Entertainment and leisure
- [ ] Socializing with friends or family

After section 3 Continue to next section

Section 4 of 4

Participant Deeper Insights

Collecting this additional information is crucial as it enables us to delve deeper into your museum experiences and preferences, helping us tailor the integration of Augmented Reality (AR) technology in local museums more effectively.

Section 4 of 4

Participant Deeper Insights

Collecting this additional information is crucial as it enables us to delve deeper into your museum experiences and preferences, helping us tailor the integration of Augmented Reality (AR) technology in local museums more effectively.

Your insights on memorable exhibits, challenges faced, and your willingness to engage with technology provide valuable guidance on how AR can enhance your cultural visits.

Furthermore, understanding your expectations and any concerns you may have about AR ensures that we can address potential issues and create a seamless, engaging, and informative museum experience for all visitors. Your input is invaluable in shaping the future of local museums.

Are there any specific challenges or limitations you have encountered during museum visits that you believe Augmented Reality technology could address?

Long-answer text

How comfortable are you with using technology in a museum setting, such as mobile apps or interactive displays?

- ○ Very Comfortable
- ○ Comfortable
- ○ Neither Comfortable nor Uncomfortable
- ○ Uncomfortable
- ○ Very Uncomfortable

Do you think that incorporating Augmented Reality in museums might change the way you perceive or understand exhibits and artifacts?

- ○ Strongly Agree
- ○ Agree
- ○ Neither Agree nor Disagree
- ○ Disagree
- ○ Strongly Disagree

What concerns, if any, do you have about using AR in museums? (e.g., privacy, distraction)

Long-answer text

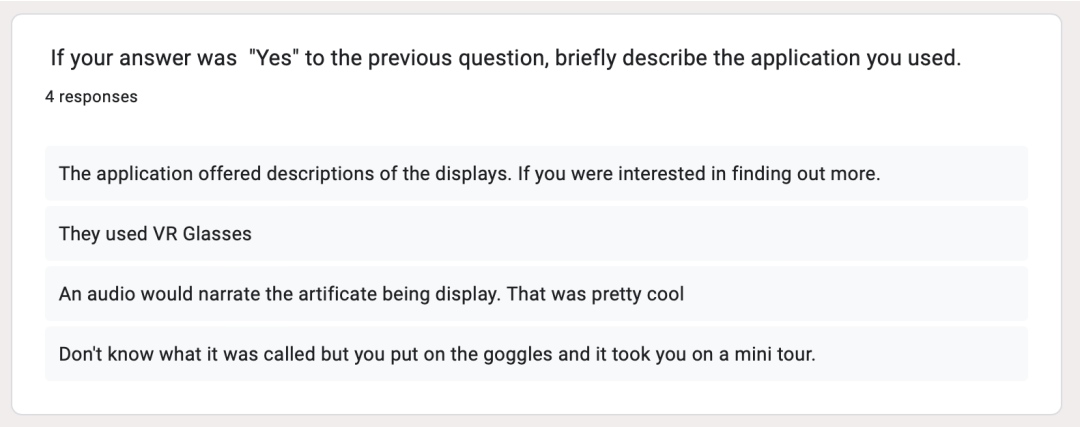
How would you like to experience Augmented Reality in your local Museums? (Please give as much detail as you can).

Long-answer text

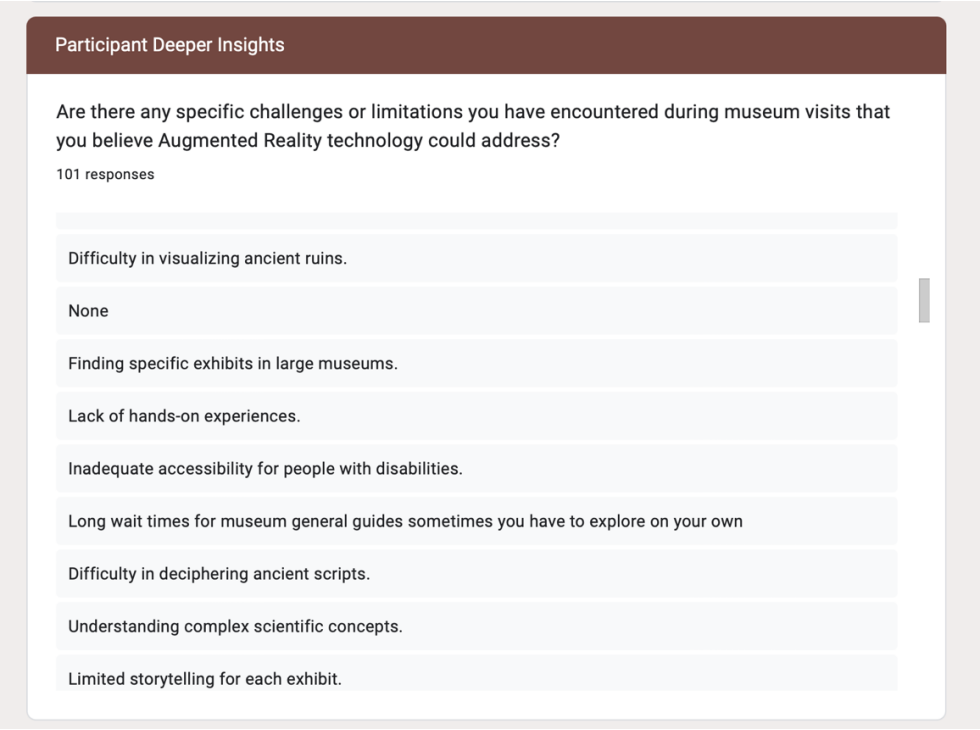
Now that you have an idea about Augmented Reality, do you think that having an Augmented Reality application will make the museum visit more enjoyable?

- ○ Strongly Agree
- ○ Agree
- ○ Neither agree or disagree
- ○ Strongly disagree
- ○ Disagree

Appendix C (Raw Data)



Appendix D (Raw Data)



Appendix E (Raw Data)

What concerns, if any, do you have about using AR in museums? (e.g., privacy, distraction)

99 responses

Visitor learning effectiveness. I mean its fun and cool to have such apps but do people actually learn anything from the experience ?

Visitor reluctance to use AR. not everyone has an AR capable device or phone unless the museum provides that.

Ethical considerations in content creation

Impact on museum staff roles

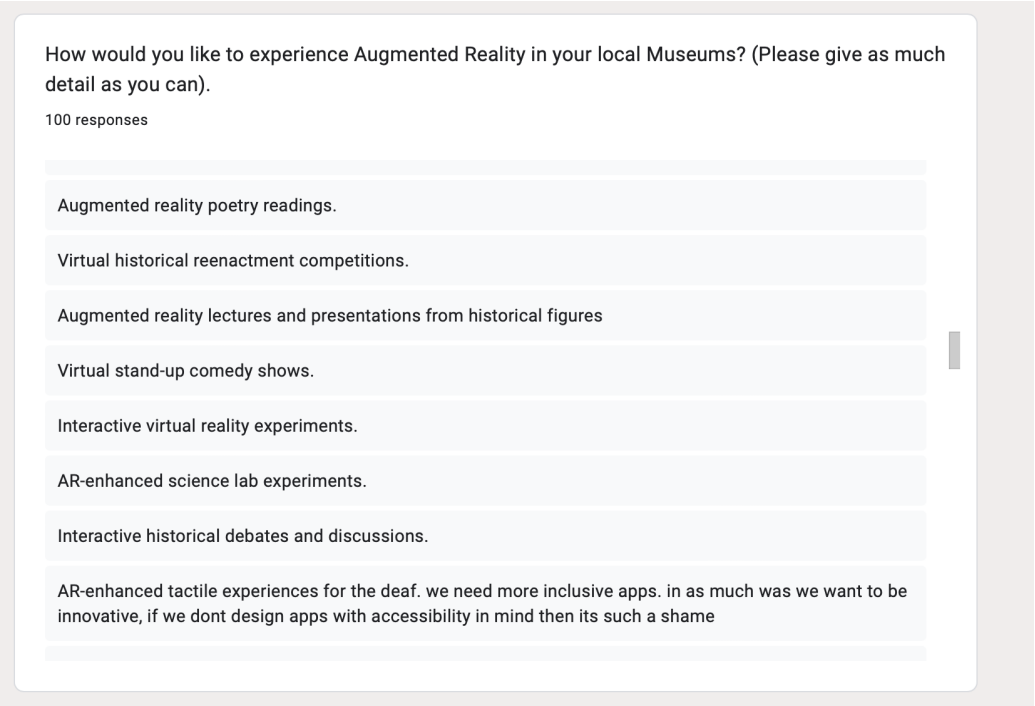
Concerns about augmented reality intrusiveness

Ethical considerations in AR storytelling

Concerns about AR app quality. I know sometimes we like nice things but to be honest some of these apps are quite dissapointing in terms of quality

Balancing technology and history

Appendix F (Raw Data)



How would you like to experience Augmented Reality in your local Museums? (Please give as much detail as you can).

100 responses

Augmented reality poetry readings.

Virtual historical reenactment competitions.

Augmented reality lectures and presentations from historical figures

Virtual stand-up comedy shows.

Interactive virtual reality experiments.

AR-enhanced science lab experiments.

Interactive historical debates and discussions.

AR-enhanced tactile experiences for the deaf. we need more inclusive apps. in as much was we want to be innovative, if we dont design apps with accessibility in mind then its such a shame