TITLE

DEVELOPMENT AND USABILITY EVALUATION OF A MOBILE-BASED CROSS-PLATFORM INTERACTIVE MUSEUM GUIDE- iMuseum

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DECLARATION

I, **Herman Kandjimi**, born on the **12th of November 1987** at **Namutuntu, Kavango West, Namibia** hereby declare that the work contained in the Thesis for my Master **of Computer Science** project, entitled: **DEVELOPMENT AND USABILITY EVALUATION OF A MOBILE-BASED CROSS-PLATFORM INTERACTIVE MUSEUM GUIDE- iMuseum** is my own original work and that I have not previously in its entirety or in part submitted it at any university or other higher education institution for the award of a degree.

I further declare that I will fully acknowledge any sources of information I will use for the research in accordance with the Institution rules.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF CODES

LIST OF ACRONYMS

API - Application Programming Interface
AR - Augmented Reality
BLE - Bluetooth Low Energy
CMS - Content Management System
ERD - Entity-Relationship Diagram
FAQ - Frequently Asked Question
GLAM - Galleries, Libraries, Achieves and Museums
GPS - Global Positioning System
HTML - Hypertext Markup Language
ICOM - International Council of Museums
IDE – Integrated development environment
IMM - Independence Memorial Museum
IT – Information Technology
JSON – JavaScript object notation
LCD - Liquid Crystal Display
MAN - Museums Associations of Namibia
NFC - Near-Field Communication
PDA - Personal Digital Assistant
PWA - Progressive Web Application or Progressive Web App
QR - Quick Response
RFID - Radio-Frequency Identification
SPA - Single-Page Application
UI - User Interface
UML - Unified Modelling Language
URL – Uniform Resource Locator
VR - Virtual Reality
VSCode - Visual Studio Code
WLAN - Wireless Local Area Network
XP- Extreme Programming

ABSTRACT

Public participation and visitor satisfaction in museums are directly related to the experience of learning, discovery and involvement in motivating learning behaviours. In most cases, visitors' experiences are significantly improved if they gain substantial knowledge on each artefact of interest from the museum guides and this is critical to user satisfaction, however, the ratio of human guides to visitors is grossly inadequate. A visitor touring in a group is hardly taken care of individually by the human guide. In addition, existing information systems for museums guides are often limited to museum-based gadgets or platform-specific smart devices provided by the museums, but not always familiar to the visitor. This study explored alternative ways that avail museum content to a broader user base while offering an increasing and personalised interactive content through multiple visitors' own smart devices. A constructive research methodology that uses quantitative and qualitative data plus incremental software prototyping development and testing were used in this study, with the main objective of producing a location-aware interactive virtual guide that is easy to use, stable and able to run on a broad range of mobile device operating systems.

The outcome systems were developed with AngularJS Framework (Web application) and Ionic Framework (cross-platform mobile application), these two combined constitutes an overall museum's mobile guide system-iMuseum. The system aims to offer the museum a platform that will enable more visitors to have individual experience and interact with historical artefacts, plus additionally offer relevant information when and wherever a visitor needs it without having an employee going around with everyone. This study was contextualized to Namibian museums using the Independence Memorial Museum (IMM) as a testing site. The contributions of this study can then be used to implement related systems in other learning and cultural heritage institutions like galleries, libraries, achieves and museums(GLAM).

Keywords – Museums; Culture; Location-aware; Virtual guide; Wireless; Smart devices, Interactive systems; Cross-platform; Usability

1. INTRODUCTION / BACKGROUND

1.1. Introduction

Museums as defined by the International Council of Museums –ICOM (2007) are non-profit, permanent institutions in the service of society and its development, open to the public, which acquire, conserve, research, communicate and exhibit the tangible and intangible heritage of humanity and its environment for education, study, cultural identity building and enjoyment purposes. These institutions are rich in cultural artefacts which are in most cases part of history that is hidden and they have a crucial role in development through education and democratization, while also serving as witnesses of the past and guardians of humanity's treasures for future generations (ICOM, 2007).

A typical day at the museum involves many visitors that are usually grouped and limited to one human-museum guide. Being guided leads to limited individual movements, thus offering a minimal experience coupled with ineffective use of time. It is highly unlikely that the human guide for a group of visitors considers the actual visit expectations of an individual visitor within the group. Hence, allowing rich visitors experience that meets their expectations is a continuous challenge because by following the museum guide schedule the visitors are restricted to what the guide deems interesting to know and usually, in big groups, visitors do not get all the relevant information.

Museums offer informal learning through the participatory engagement of visitors with the artefacts. Visitors' participation and satisfaction as indicated by Ahmad, Abbas, Taib and Masri (2014) are directly related to the experience of learning, discovery and involvement in motivating learning behaviours. Other critical aspects of visitors' experience and expectations as listed by Sheng and Chen (2011) includes relaxation, personal identification, historical reflections and escapism.

The main purpose of this study is to look at practical and user-friendly ways on how museums can broaden the user base of visitors with enhanced individual experience by integrating multiple platform-based interactive communication technologies in the museum's setting without distorting the artefacts' arrangement. This study considers some of the most crucial individual factors of visiting guests such as visitors' time, personal area communication resources and interests (Sheng & Chen, 2012), and looked at a system that could work on a broad spectrum of personal communication devices.

1.2. Problem Statement

Museums are rich in history/historical and cultural content. However, these institutions are profoundly challenged (Li, 2012) on ways to best present artefacts to large groups of visitors while preserving the interest of each individual, since on one side the ratio of human guides to visitors is grossly inadequate, and on the other hand, the existing hand-held devices for guide application are platform-specific (El-Kassas, Abdullah, Yousef, & Wahba, 2014).

A day at a well-frequented museum involves many visitors that are grouped and limited to each museum guide and in most cases, visitors' experience is noticeably enhanced if they get a detailed explanation on each artefact of interest from the museum guides and this is critical to user satisfaction (Ahmad et al., 2014). An increase in the number of guides could mean more content delivery but increased human capital cannot be justified due to the cost that will be incurred by the museum which usually does not have own sufficient income and is financially subsidized (ICOM, 2007).

In this study's observation, the concern on how best to present and offer personalised views of artefacts based on the current location of visitors touring museum alone or as large group in the Namibian museum context is a problem, and there is a need to address it. There is also a need to explore alternative ways to provide a broad-based community of visitors a similar exposure that a visitor with the state-of-the-art device would experience and in turn, it will help to ensure a certain acceptable level of turnout.

A personalised guide by using devices from the museum or visitors' own devices is an existing approach to the above-mentioned issues. Chivarov, Ivanova, Radev, and Buzov, (2013) provide an example of such a guide that uses QR codes. However, museum's owned devices might not be familiar to visitors, and the museum's owned single platform application would limit visitors from using their personal devices for that purpose, hence the consideration is to design and develop a cross-platform system in this study. This alternative way should then keep the visitors' individual satisfaction and expected experience at the core. Therefore, considering the core business of a museum and available resources, a detailed usability evaluation of such alternative solution is also needed to cement the necessity and its usefulness.

1.3. Research Questions

Main research question: How can a mobile information system device regardless of its platform provide a personalised view of the artefacts in a Namibian museum and be able to build an interactive knowledge medium following the specific visitor's interest and location?

These will, in turn, lead us to explore some possible interactive systems that have been implemented elsewhere in hopes of answering the following sub-questions:

(a) What are the challenges faced by human museum guides in terms of service to visitors and how can these be overcome?

(b) How do the type and level of expectations of museum visitors in Windhoek influence their overall experience?

(c) How can an interactive system interoperate with most available Windhoek museums visitor's devices and how is the data transfer handled on both ends.

(d) How can client application in phones with different and fast-changing versions of operating systems personalise a server application content to enhance visitors experience in museums?

(e) What are the latest interactive and location-based wireless technologies on smart devices best suited in Namibia context, and how does this affect the experience of non-smartphone user?

1.4. Research Objectives

The main objective of this study is to explore possible broad-based ways for enhancing expected museum visitors' individual experience and satisfaction across a wide range of visitors' social class by designing and developing a location-aware interactive and content delivery virtual guide that is both easy to use and stable across multiple mobile platforms. To address this, the following sub-objectives, related to the research questions, need to be met:

(a) To analyse issues currently faced by museums guides due to large numbers of visitors, establish visitors' expectations and their relation to the museum's core values and services.

(b) To evaluate and integrate wireless communication technologies suitable for micro-location and triangulation of visitors on mobile devices.

(c) To design and implement a mobile cross-platform client application with a data server, then

(d) To evaluate the usability and performance of the proposed system plus its benefits and drawbacks for museums.

1.5. Research Delineations and Limitations

This study looks at the enhancement of museum visitors' overall experience, individual inclusion and interaction of the visitor with artefact content. This study is hence exclusive to Namibian context with the Independence Memorial Museum (IMM) as the implementation site. The implementation of a complete and up to date museum system further faced the following limitations:

(a) Lack of digital information for artefacts in museums

(b) Lack of IT infrastructure and human resources to be involved in the development, maintenance and management of content in the overall system.

(c) Lack of concrete requirements for the overall system

(d) Limited visitors' engagement or willingness to contribute to the improvement or development of the system.

(e) Lack of funds and plans to enhance or improve overall artefact to visitors' presentation.

Due to the time allocated to the research, this study only focused on three mobile platforms, namely iOS, Android and Windows Mobile. These three platforms were selected following the study to understand the distribution of smartphone usage in

Windhoek done by (Kandjimi,2015) on 30 visitors of the IMM, which shows about 46% Android users, 23% Windows Phone users and 15% IOS users (See figure1.5-1).

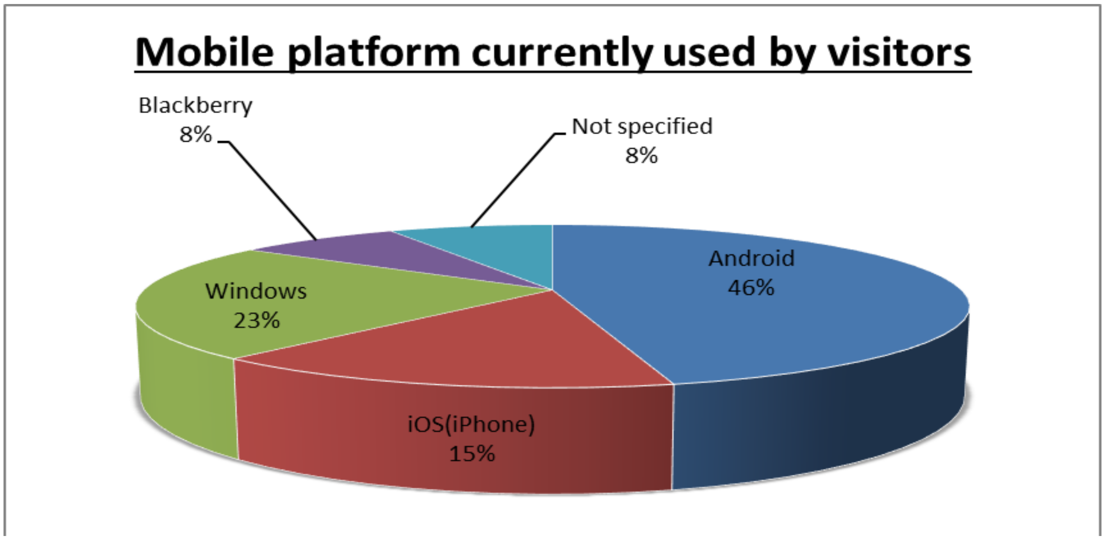


Figure 1.5-1: Mobile platform used by IMM visitors (Kandjimi, 2015)

The initial approach included the use of feature phones and the use of other alternative ways to transfer information between such phones and the server. However, such approach could lead to a whole new study on its own as now we also need to consider ways to possibly locate the visitors and transfer data, with as little prompt as possible from the users but rather an increased interactivity.

The study later disregarded the use of Windows Mobile due to the undetermined future of the Windows phone, by mid-year 2017 it was clear that Microsoft had no intention to support or develop anything with the Windows phone (Reilly, 2017). This is mainly due to the low volumes of users and developers interested or involved in Windows phone apps.

Global statistics ("Mobile Operating System Market Share Worldwide", 2019) on mobile platforms market share further confirmed that Android and iOS are the two most used mobile platforms. The statistics also apply in the Namibia market share, with a substantial increase in Android operating systems, see figure 1.5-2 and figure 1.5-3 below.

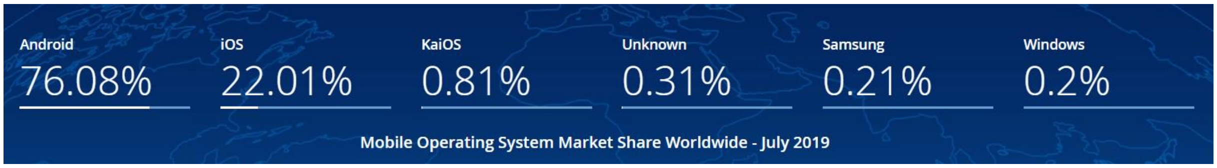


Figure 1.5-2: Global Mobile platform market shares

Figure 1.5-3: Namibian Mobile platform market shares

1.6. Research Outcomes

The expected outcome for this study was to design, implement and evaluate the usability of a cross-platform interactive museum guide in forms of a mobile and web application. A database server supports the application for information retrieval. The mobile application, together with a web application (website) makes out a computerised museum exhibition and guidance system. The web application serves two primary purposes, namely an information-sharing portal and a content management platform for the mobile application.

The aim of the mobile application if to enhance museum visitors' interactions with the artefact by providing more detailed information in forms of text and audio-visuals. The mobile application accomplishes these by using wireless technologies to detect artefacts nearby and then query the database for corresponding information. The interactions will further provide the museum management with information to be used to improve museum setting and exhibitions.

1.7. Research Benefits

The impact of such an interactive system to the museums is an increased awareness of historical artefacts to visitors through easy access of information for the respective museums, which could trigger an estimated increase in the number of visitors and museums’ exposure to the general public. The decisions about how the museum operates can be guided using statistics of the visitors looking at certain artefacts. These include things such as which artefacts’ display or information access needs to be improved and what new artefacts to be included in their exhibitions. Visitors will also benefit in that they then get a personalised view of the artefacts and they can decide which other parts of the museums is of interest to them hence, they build upon their knowledge at different paces and directions. Depending on the type of device used during the visit, the visitors can record and later retrieve information of what they explored

The nation’s cultural heritage and historical artefacts as supported by Chivarov et al., (2013) can be best preserved and widely disseminated using technology, in the long run, this means the artefacts or museums do not become obsolete but rather are adapted to fit in a continuous growth of public education in culture and identity building.

This cross-platform approach to the presentation of museum exhibits will improve communication between museum staff, visitors (mainly students and young researchers as indicated by Smith, (2011)), enabling them to be part of this exciting multimedia tour of the cultural and historical heritage, by sharing their opinions and reviews. These reviews could be used by the museum management and staff to improve the exhibitions as indicated earlier. In addition from our observations and as supported by Chivarov et al., (2013), this could enhance the experience and satisfaction of visitors as the interactive system will bring back life into the exhibits, allowing communication between the visitors and museums, plus offer new individual learning at all levels.

1.8. Thesis Outline

The final thesis write-up is divided into eight (8) chapters as follows:

Chapter One: Introduction – In this chapter, we provide a background of the problem under study, provide a detailed explanation of the problem and our proposed research goals. The researcher also provides the scope of the research and in the end provide a summary of the whole write-up.

Chapter Two: Literature Review – This chapter takes a deep look at the preliminary literature and expands on our theoretical underpinning. Here we look at systems in place and understand the impacts of integrating our proposed technology in museums. We also explore similar research projects as a form of benchmarking and pick up on issues that could be improved, with more bearing on state-of-the-art theories, techniques and practices. It is in this chapter that we pick up on what might or not be possible and hence have a clear path to follow.

Chapter Three: Methodology – This chapter presents an overview of the methodology adopted when conducting this research project. We explain the constructive design structure and explore tools associated with such an approach. We hence select tools to be used for data collection and evaluations that are further discussed in the next chapters.

Chapter Four: Baseline Study – This chapter is crucial to the progress of the whole research as it indicates what needs more attention. It is in here that we start interactions with museum visitors and staff, which in turn informs the design and development requirements of the proposed system and evaluation techniques to be employed later.

Chapter Five: Design - Following the previous chapter, by now we should have an informed decision on designing the proposed system. Here a proposed design for the system is created and rationale is given as to why this is considered suitable for the study.

Chapter Six: Implementation – Following the system design, by now we should have an informed decision on implementing the proposed system. This chapters hence explores the implementation in detail following cross-platform tools and practices discovered in chapter two following the system designs. The focus is on justifying choices followed during the implementation and the actual development process.

Chapter Seven: System Testing, Evaluation of findings and discussion– This chapter focuses on evaluating the implemented system's usability and implications. The produced system or prototype is tested against user requirements to evaluate its usability and extent to which it satisfies the required functionality. We explore user inputs in detail and also try to benchmark with the baseline study and decision made thereof.

Chapter Eight: Conclusion and Future Work– The final chapter gives a detailed summary and discussion of the whole research conducted. We revisit the goals and objectives set at the beginning of the project to compare with what has occurred. . As a form of conclusion, we give our final thoughts of the research project and proposed future work.

2. LITERATURE REVIEW

2.1. Overview

Museum exhibitions are the main attractions to the public and in most cases are the only visible benefit to the museum visitors, and it is widely agreed by scholars (Brassil, 2014; Ahmad et al., 2014; Sheng & Chen, 2012), that museums' core operations are centred on the exhibitions. Brassil (2014) and Dawson (2006, as cited by Ahmad et al., 2014) both acknowledge museum exhibitions as a medium of communication to the public that has a significant impact in transforming and expanding the visitors' experience, awareness, interest and valuation of many aspects of themselves and their world. Museums are cultural institutions with the main aim of collecting, documenting and preserving the cultural and historical objects, artefacts or specimens as assets (Ahmad et al., 2014). These activities are mainly for research, personal interpretation and entertainment.

2.2. Museum Guide Challenges

The traditional way of museum exhibition requires efforts from both museum staff and patience from the visitors. It involves a human guide leading a group of visitors into a room or a corner to explain more details about any given artefact. Such a process is not only tedious and exhausting, but it is limited to exhibition space, suitable venue and schedules (Li, et al., 2012). The total number of visitors with direct sight and interaction is also limited, and by taking turns which is even more time-consuming, it can improve. The total number of visitors that acquire relevant knowledge during museums visits is further challenged by the ratio of visitors to human guides or museum staff on duty. Li, et al., (2012) also argued that the human factor has further implications to the museum should they attempt to increase their human resources as the benefit of such approach does not out weight the implications such as cost to the museum's budget.

Another form of museum guide that dates back to the inception of the museum exhibition is summary notes attached to each artefact. This method offers visitors' no interactions nor content engagement. Backer, et al.,(2015) in an article that explores issues faced by adult museum visitors state that most visitors end-up wandering without interest and knowledge about the artefacts which leads them to end their visits precipitately. The overall impact of such experiences is the main reason most museums end up in what is termed by Li, et al., (2012) as an "antiquity warehouse" because the numbers of visitors drops drastically defeating the overall purpose of its existence and further depriving the people from acquiring knowledge as the museums become detached from society.

Ahmad et al., (2014) clearly states that museums have become progressively more popular, and hence adapting many techniques of technology such as audio-visual shows, multimedia programs, simulation and other experiences which have a significant impact on the entertainment aspect of the museums. These interactive experiences according to Lord (2001, as cited by Ahmad et al., 2014) are most likely to motivate visitors' interest in their environment or act as a cognisance factor affecting their enthusiasm. Numerous efforts are made in Namibia, to advance the technology used in museums, but in most cases, the efforts have little impact on the overall visitors' interest and eagerness (G. Guarirab, Personal communication, October 14, 2015). Guarirab (2015) further stated that in the case of the Independence Memorial Museum, it installed iPads and LCD screens, however, lack of security and care led to damages and losses of these equipment. The other concern is the fact that this kind of setup had no interactivity as static content is loaded on these devices and the visitors have to play or stop in response to their interests.

A common challenge faced by electronic or implementations of mobile museum guides is the issue of localisation and indoor navigation. It is evident that the use of Global Positioning System (GPS) is the most popular approach used for outdoor navigation. The

GPS chips in mobile phones and other smart devices are used to pinpoint the location and for directions, which is what mobile services like Google maps use to direct mobile users (Köhne, Sieck, 2015). The use of GPS has been in the past heavily challenge by indoor localisation and it was only around March 2011 (Chang, 2018) that Google added indoor localisation to their map services. In Africa, especially in Namibia, such services have limited to none recorded use. This study just like that of (Köhne, Sieck, 2015) opted for the utilisation of Bluetooth Low Energy- BLE (iBeacons) due to its capability to calculate the visitor's relative distance from the artefact and the relatively affordable prices of the iBeacon tags.

2.3. Museum Visitors Expectations and Experiences

In the study of experience expectations of museum visitors (Sheng, Chen, 2012) explores and acknowledges that human behaviour such as museum-going is a complex subject and that measurements of demographic categories alone cannot offer any insights into understanding visitors and particularly non-visitors. A study on visitor and operational development of museums by Liu (2008, as cited in Sheng & Chen, 2012) articulates that in order to offer exhibitions and services suitable for visitors, museums have to conduct studies and systematically acquire knowledge related to visitors' expectations, and apply it to planning and decision making. Most museums in the world often overlook this critical point, yet it holds the key to unlocking the museums' true potential and simultaneously impact visitors' interests and satisfaction.

A workshop paper by Chivarov et al. (2013), concludes that the benefits and potential of mobile digital technologies in museums are exponential as it tackles the core aim of museums: knowledge transfer. It further emphasises that this would stimulate the protection of rich culture and history. These technologies are easily usable and accessible to all and hence would provoke an increased interest in cultural heritage. The paper by Chivarov et al. (2013), also classifies the usage of mobile technologies as an innovative way to display the exhibits in the museum and will attract a new range of visitors, mostly young people, who are the main enthusiastic users of mobile devices.

2.4. Interactive Systems for Museums

The use of technology in museums has been getting much attention, and so many studies are being done in different directions in hopes of improving user experience. Some of these emerging technologies at the heart of museum community are Virtual Reality (VR), Augmented Reality (AR) and Web3D as indicated by (Styliani, Fotis, Kostas & Petros, 2009; Sommerauer & Müller, 2014). Due to the diverse contextual environment found in cultural institutions, there is a huge range of possibilities in addressing user experience.

There are comprehensive range studies conducted on ways to innovate best and modernise museum exhibits. Such studies include a study by Ferrara and Sapia (2013) which focuses on the use of technology by means of digital museums to create new learning environments in educating the community and its visitors, especially the youth as this knowledge gained can still be used by youth in their schools' subjects. Ferrara and Sapia (2013), strongly believe that children born towards the end of the 20th century all the way into 21st century perceive knowledge transfer and learning differently hence for the museums and other cultural institutions to remain relevant, digitalisation and adoption of innovative ways need to be critical to their daily operations.

Most museums' systems are utilising wireless technologies on mobile phones; these include Bluetooth, WLAN, RFID and NFC. Karahoca & Karahoc, 2012; Broll, Vodicka, & Boring, 2013, conducted studies using the above-listed technologies because of the features that they provide with regards to indoor navigations, video streaming and rapid data transfers. Another popular technology is the use of QR codes as indicated by Smith(2011) and Schultz(2013); this technology dates back as far as 1994, where it was used by Toyota company to track and identify parts, but it only gained momentum and popularities in museums around 2011, due to its ease of use and low cost.

Mutual location of visitor and artefact of interest is the key to any museum system that aims to be both interactive and relevant throughout the visit; this study considers the use of Bluetooth technologies called iBeacons in combination with Wi-Fi as an optimum solution considering the resources available to both the visitors and museum. Cultural digital data for exchange may include text, image, graphics, video and sound. Despite a recent interest increase in indoor positioning technologies, the rate of successfully deployed systems has been unimposing when compared to the rapid adoption of outdoor positioning technologies and applications, and this is mainly due to high system cost (Brassil, 2014).

Brassil (2014) further acknowledges that the surging interest in Bluetooth Low Energy (BLE) beacons (e.g., Apple iBeacons, Estimotes) is motivating enough to consider their use in improving indoor localisation. Though primarily intended to serve as proximity sensors, these low-cost devices hold great promise as an unmanaged beacon overlay infrastructure in cultural institutions and any enterprises. This, together with increasing intensity in similar location-aware applications using BLE in recent years has hence motivated our choice of iBeacons for this study.

2.5. Mobile Phones and Handheld devices as Interactive Systems

The exponential increase in mobile phone penetration worldwide and the rapid advancement in the technology offers an opportunity for greater sophistication in the integration of mobile phone interactive systems with cultural institutions and the innovations of exhibition methods (Chivarov et al., 2013). Namibia is no exception to this penetration growth, a newspaper article by The Namibian (2012) on the 11th of September and ITU Statistics (2015) on Mobile-cellular telephone subscriptions, indicate that the mobile phone penetration has exceeded 110%; this means there are more mobile usage then the actual population and it could easily be attributed to the broad market of mobile phone retailers countrywide.

The high market penetration of mobile phones however, still leaves us with two common categories of mobile phones; feature phones and smartphones. Feature phones, according (Lee, 2010) on CNET, are defined as being on a midway point between smartphones and basic phones. They usually have a limited proprietary operating system, and not all feature phones support third-party software; i.e. feature phones may offer internet access, video and audio playback, but they generally cannot download apps from an online marketplace. Smartphones, as defined by CNET.com (Lee, 2010), can run a third-party operating system and or the manufacturers' operating systems (as is the case for iPhones and Blackberry). In addition, all smartphones can run third-party software, also referred to as applications or "Apps" that are easily accessible on different online apps stores. The proprietary operating system introduces a new issue with feature phones as we are not able to upload and run third-party software on such phones.

2.6. Cross-Platforms Development Challenges and Benefits

Smartphones in their category also come in different operating systems that give varieties of user interactions and experiences; hence a large domain of visitors are more likely to have a range of all these operating systems. Several cross-platform development tools and frameworks are already widely used in both research and industry. Such tools include but not limited to Phonegap, Appcelerator, Xamarin, Codename One and Ionic ("Top 10 Cross-Platform", 2017 & Griffith, 2017). These tools and frameworks have pros and cons, but selection depends on the desired project type and requirements. In order to support a large number of visitors, we have opted to explore cross-platform mobile development, with major benefits such as those stated by El-Kassas, Abdullah, Yousef, and Wahba, (2014):

a) Development is done once and distributed for use on different platforms
b) Reduction of development time and hence resources plus efforts
c) Allows code reusability and easy development, since code is written once but deployed multiple times.

These could shorten our development time, and with access to native functionality, we would be able to explore those functionalities on all different platforms. This option, however, is only limited to platforms with Bluetooth Low Energy (BLE) compatibility as that is the core aspect of the system that we aim to achieve in this study.

2.7. Benefits of mobile interactive systems

Mobile phones today have evolved from mere communication devices to one of the powerful computers in the palm of our hands, leading to people being more reliant on these devices for almost all aspects of their daily lives such as organising their work, entertainment, research, socialising and even banking. The list of key features or functionality in people’s lives is endless, and within this range of features are the opportunities and benefits to be explored for the betterment of the human race.

In the museum definition, two concepts stand out, one being social, and the second is education. These are the same concepts that are included within the core features of mobile phones. According to Li, et al., (2012), people realise the social aspect and cultural heritage through sharing ideas, opinions and knowledge; these further feeds into this study’s focus of enhancing user experience. Li, et al., (2012) go on to indicate that digitalisation of museums should concentrate on visitors’ experience more than on the technology itself, one can sense the importance of visitors’ experience in the overall approach of museum digitalisation, however, this is not to belittle the technology in use and its advancement as without technology the whole process could be rendered void.
Education and research form part of the key reasons for museum visits and these can only be attained by providing substantial details about any given artefact or exhibits, museums the world over have always invested in ways to provide visitors with more information about their artefacts efficiently. Ahmad et al., (2014) highlighted that museums are not restricted to information sharing, they should also consider aspects such as enjoyment which further means as museums adopt digital tools in their settings they should consider how the new systems aim to enhance the element of enjoyment.

Mobile phones offer us the benefit of being able to combine all features in one, as it can provide a substantial amount of information at lightning speed, provide a link to extra resources and allow us to interact with the artefact, plus give us a platform to socialise, preserve and share knowledge. It is therefore coherent for any museums attempting to digitalise their operations to consider the use of mobile phones.
A couple of key aspects stand out in the use of mobile applications and museum digitalisation, these are visualisation, personalisation and interaction plus as of late augmentation. Since visitors’ experience is considered imperative in museum

digitalisation it is only rightful to pay attention to what is deemed captivating for the visitors, which most scholars such as (Beer, V. (1987) and Pousman, et al.,(2007)) would agree that enhancing knowledge, immerse interactivity and personalisation sit right at the top of that list. Furthermore, these three form part of the fundamental components of a digital museum because they are targeted at the museum's main clients which are the visitors.

2.8. Impacts on overall museum operations.

An initial look at the impacts needs to be inclusive of both beneficial and detrimental facts, even though going into this study, the main focus is on the benefits of the digitalisation of museums. Digitalisation dates back to the beginning of the 21st century and it was around the same time that the term "digital curation" was first heard off at an academic seminar in London (Li, et al., 2012). It is however clear that the exponential advancement in information technology and shift in social living around the world has transformed digitalisation into a complex, continuous and extended process.

Complexity in the process has led to a change in overall museum implementations since the introduction of new technologies in museums settings such as Virtual Reality (VR), Augmented Reality (AR) and Web3D as indicated by (Styliani, Fotis, Kostas & Petros, 2009; Sommerauer & Müller, 2014). It can further be acknowledged that virtualisation and augmentation allow for museums to connect with people outside the normal museum setting, some museum management fears this connection as an attempt to render the physical museum settings obsolete. In Namibia, this issue seems inevitable due to the lack of plans (G. Guarirab, Personal communication, October 14, 2015) in place to transform our current museum settings to structures adopted by museums in other parts of the planet, however when glanced from another angle one could deem these issues as a false alarm. It is deemed as a false alarm because in implementing digital systems two things happen, the current staff member will get training to use such system which is an overall plus in capacity building and new experts in the field of computer science need to be hired to maintain or advance the system with time which is one the country's key goals in terms of reducing unemployment rates.

Museum digitalisation may also be seen as isolating the physical museum from visitors' interaction, as visitors now interact virtually and not directly with the artefacts (Li, et al., 2012). Li, et al., (2012) further states that the visitor's opinion is that digitalisation should be an add-on to complement the current setting, not replace or hinder the museum's operations. Carol, as quoted by (Li, et al., 2012) strongly, believes that museum digitalisation has in the process eroded the traditional values of a museum unintentionally, as she believes that the main objective of digitalisation is to occupy the gap left by the physical museum setup.

2.9. Related work

Museum visitors' experience just as outlined in the previous sub-topic has been receiving relatively close attention with most studies exploring solutions and options in the computer science field, with heavy involvement of application and or software development. At the core of museum definition and purpose (ICOM), it is said to be an institution that promotes learning and cultural identity, hence any approach to enhance museum experience should consider providing sufficient information to allow for learning to take place (Ahmad et al., 2014). Additionally enjoyment has been outlined by ICOM as one of the motivating factors for museum visitors. This further means information needs to be provided by the museum to the visitor in forms of amusement and learning should be informal and subconsciously.

According to Ahmad et al., (2014), their study not only indicates the importance of learning but further explores the difference in learning styles and the impacts of different exhibition methods to the visitors learning. This study, however, focuses on museums visitors experience and interaction via mobile application as a follow up on the researcher's previous study (Kandjimi, 2015) about interactive mobile guide for Namibia museum visitors, hence in attempt to keep visitors' active and learning our proposed system provides information and entertainment over a broad range of mobile devices available and commonly used in Namibia.

A number of studies have previously explored virtual museum guides and visitors' interactivity within the museums, such as one by Zhao (2012) which explored the use of Web3D as virtual museum to allow for interaction, visitors' immersion in the museum artefacts and consequently allow for individual imagination for the visitors, such approach, however, extracts the visitors from the traditional museum setting. Yatani, Onuma, Sugimoto, & Kusunoki, (2004) on the other hand, explored a more portable approach by using Personal Digital Assistants (PDAs) to support young audience in they corroborative learning within the museums. They clearly understood the importance and impact that mobile devices have on societal learning and integration from a very young age (Yatani, Onuma, Sugimoto, & Kusunoki, 2004). The emphasis on mobile devices has more weight on this study as mobile devices are progressively becoming powerful yet personalised hence easily identified with their users.

A modern approach to museum virtual guide system with AR by Chang, et al., (2014), in this paper Chang, et al., (2014) clarifies and illustrates how they designed a mobile AR-guide system that focuses on behavioural patterns to influence the visitor's learning and overall appreciation of museum artworks. Their system evaluation revealed that visitors' effective learning enhances their individual experiences and additionally prolonged the amount of time spent by the visitors focusing on artworks of interest. Chang, et al., (2014) further stated that visitors using the AR museum guide reacted positively and had an accepting attitude towards the overall system.

Independent companies have implemented some mobile museum guides such as the British Museum Guide and, Berlin Guides in an attempt to provide interactivity for museum visitors and entertainment. Even though a great number of applications exist for museum guides, none has been done for any Namibia museum let alone does any of the museums have a fully-fledged computerised systems to manage and exhibits their artefacts, this alone is enough motivating factor for this study to explore an implementation of a museum mobile guide for Namibian museums and based on the context and expectations of museum visitors in Namibia.

3. RESEARCH METHODOLOGY

3.1. Introduction

This chapter describes the methods, techniques and frameworks adopted by this study, it clarifies the overall data collection process and provides the rationale behind choices made and envisioned benefits in the overall approach. In research, the term methodology is used to describe the overall research framework or design, these include standard method and tools used by the particular study while exploring its respective research problems and question for the ultimate goal of creating or discovering new knowledge (Williamson & Johanson, 2018).

This study used the mixed methods approach, in that preliminary data collection was mainly quantitative using surveys and the outcome was further used to generalize and inform the prototype design. The study used qualitative methods, mainly interviews with experienced software developers to explore trends and techniques applied in modern development processes. The usability evaluation also adopted a mixed-method approach, since a focused group ran through the test cases that were provided, then answered an open-ended survey but most important follow-up interviews were used to discuss the individual participant's thoughts further.

This study further couples a constructive design structure to the mixed research methods for on the application design and implementation with the use of users' requirement elicitation followed by incremental prototypes design and software development with usability testing.

3.2. Mixed Research

Mixed research also referred to as mixed methods have been gain momentum and popularity as more researchers are embracing and adopting this approach in their studies. This popularity has placed it as the third major research approach after the traditional qualitative and quantitative approaches (Johnson, Onwuegbuzie, & Turner, 2007). In attempt to personalize and familiarize with mixed research, researchers have nicknamed the approach a handful of names such as "blended research (Thomas, 2003), integrative research (Johnson & Onwuegbuzie, 2004), multimethod research (e.g., Hunter & Brewer, 2003; Morse, 2003), multiple methods (Smith, in press), triangulated studies (cf. Sandelowski, 2003), ethnographic residual analysis (Fry,
Chantavanich, & Chantavanich, 1981), and mixed research (Johnson, 2006; Johnson & Christensen, 2004)" as cited by Johnson, Onwuegbuzie, & Turner, 2007. These authors collectively explore the benefits of the mixed research approach, compelling new and upcoming researchers to rip from these benefits.

Just as a large number of researchers have nicknamed and adopted the use of mixed research, there exists a wide range of definition provided from a different viewpoint by numerous research leaders as cited by (Johnson, Onwuegbuzie, & Turner, 2007):

a) Pat Bazeley – Defines mixed methods research as including the use of more than one approach or method of design, data collection or data analysis within a single scope of the study, with the integration of the different approaches or methods occurring during the scope of the study, but not just at its ending point. Bazeley clearly states that mixed research is not limited to combining qualitative and quantitative methods by rather any combinations of methods/approaches/data collection and analysis.
b) Jennifer Greene - Says mixed-method enquiry is an approach to investigate the social world that ideally involves more than one methodological tradition and hence more than one way of knowing, along with more than one kind of technique for gathering,

analysing, and representing human phenomena, all for the purpose of better understanding.

c) Burke Johnson and Anthony Onwuegbuzie – Openly indicates that mixed methods research is the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study or set of related studies.

d) Steven Miller – Sums up by defining mixed methods as a form of evolving methodological inquiry, primarily directed to the human sciences, which attempts to combine in some logical order the differing techniques and procedures of quantitative, qualitative and historical approaches. At present, mixed-methods must devote itself to resolving a set of issues, both epistemological and ontological. The first must devote itself to what Miller and Gatta (2006) call the "epistemological link," that is the rules and rationales which "permit" one to proceed mixed methodologically. The second must adhere to some form of "minimal realist" ontology, where either social reality is "One" but can be accessed by different methods separately or working in conjunction, or social reality is multiple in nature and can ONLY be accessed through mixed methods. Present-day attempts to couch mixed methods within some broad notion of pragmatism are not satisfactory.

Mixed research hence takes the creams of both worlds and combines it into one functional, sophisticated yet easily adoptable methods in research. It is further clear that almost all the researchers that use mixed-method must involve the use of multiple approaches and or paradigm in the research design, execution and conclusion. It is widely acknowledged that change is imminent and hence embracing change is what sets the winners apart from the backbenchers. Thus a research method that is considered as evolving will always lead to state of the art studies and ultimately new inversions and knowledge discovery.

3.3. Constructive Research

Constructive research is referred to by Crnkovic (2010) as the construction based on the existing knowledge used in novel ways, with the possibility of adding a few missing links. The construction proceeds through design thinking that makes projections into the future envisaged solution (theory, artefacts), and fills conceptual or other knowledge gaps by purposefully tailored building blocks to support the whole construction.

In this study, a suitable design was introduced and agreed upon by the researchers and museum stakeholders based on observation of museum visitors and benchmarking to existing museum mobile guides added to the initial user requirement process. The development of the first prototype begun by validating the building blocks of software development against the initial system's requirements. The initial prototype was based on limited artefacts in the Independence Memorial Museum, however, the overall system design gives room to extend the artefact content easily and hence covering the whole museum plus an option to have the same system working in other museums. The main aim of this study is to enhance user experience in the museum with the use of mobile devices and hence the decision to build a cross-platform interactive system was to meet the key objective of this study; of not restricting visitors to a certain mobile phone platform, such as Android or iOS only. An improved system will then include more artefacts, identified as major exhibits in the Independence Memorial Museum. The section that follows outline the methods adopted in the system implementation and usability test to ensure study objectives.

3.4. System Implementation and Usability Tests

The study employed agile development methodology to create iterative and incremental system implementation; this study was further specifically be based on extreme programming(XP) since the system's versions were meant to enhance its quality following the users' responses or the continuous change in users' requirements ("Extreme programming- Wikipedia", 2017). Software development in the 21st Century has been challenged by factors such as the rapid change in requirements from different sources [Including from the customers, technology and social factors], unrealistic schedules and obsolete features to name a few due technology advancements or other unforeseen changes (Meso & Jain, 2006). The agile development approach also offers an opportunity for development teams/individuals to rapidly change with the requirements and technology advancements, thus increasing the overall responsiveness and progress of the development process.

The above-stated benefits are the main reason why this study adopted the use of iterative and incremental system implementation, which can be categorized as XP methodology. This study further emphasises this methodology as it boosts confidence during development due to the constant interaction and inputs from the stakeholders. There are four main areas that are tackled by the use of XP, which are: professional communication, systems complexity (simplified), comprehensive feedback and solid courage.

The iterative nature of this approach allows for production/deployment of early prototypes that are later improved by the next iteration, hence the reference to incremental implementation.

Figure 3.4 illustrates the overall steps followed by this study in the adoption of the iterative and incremental system implementations. This figure further emphasises the use of incremental builds in terms of cumulative outcomes as the result of every development sprint.

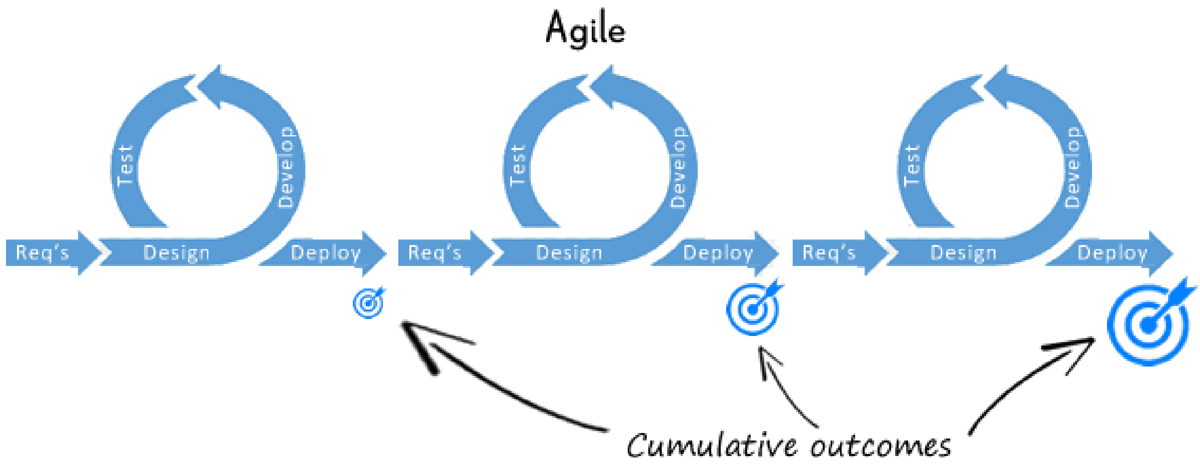


Figure 3.4-1: Iterative and Incremental Development, retrieved from http://www.crmsearch.com/agile-versus-waterfall-crm.php

Requirement Elicitation - This study used three methods to collect the system requirements, which are interviews, observations and an online survey to inform the system's design and implementation. The interviews were carried out with the museum staff members to get a comprehensive list of expected features for our virtual museum guide system, including types of content that would be provided to the public and others that are for internal usage. A few of the museum visitors were also interviewed to get their viewpoint and what the expected. The observations were randomly carried out as people were touring the museum be it with the guide or alone. This helped us understand user expectation more. The online survey was carried using google forms and the link was shared to the general public to broaden our understanding of user experience in the museums and how they expected this experience to be enhanced. The survey questions were based on what was previously observed and what some of the interviewed people said. It is in the survey were the study explored common operating systems used by both desktop/laptop computers and mobile/smart devices.

System Design - This step is focussed on the design of the overall system's architecture, functional modules and visual components, it also explores the different interfaces of those components and the data flows of the system. In this study, during this phase we employed a top-down approach by starting off with the visual components in forms of wireframes, followed by the functional modules attached to each component and its data flow, then finally explore the combined system architecture. This step also requires one to transform ideas indicated in the requirement elicitation process and turn them into tangible system prototype design and implementable process flow. This study made use of Creately (from Creately.com) to model the system's use cases and flowcharts using Unified Modelling Language (UML), it is here were we specified all the possible actors/users of the system and functionalities that are available to them.

The uses cases were then transformed into visual components with the help of wireframe drawings using mockFlow (from mockflow.com). A combined look at the uses cases and the visual components provided this study with the system architecture.

System Development – Development is the process of transforming the design into an actual program(s) or application informed by system requirements as guidance. It is in this phase where the implementation of the system takes places. In this study, the system implemented contains 2 main parts: a web application and a cross-platform mobile application. The web application was implemented using the Angular (formerly known as AngularJS) Framework, which is an open-source web application development framework initially developed by Google. The cross-platform mobile application was developed using the Ionic Framework, which also an open-source mobile and web application development framework based on Angular, but with a rich mobile UI toolkit for developing high-quality cross-platform applications. Visual Studio Code (VS Code) was used as the main development environment or IDE (Integrated Development Environment). The backend of the overall system was backed by google's Firebase server as both a data store and data integration API between the web application and the mobile applications. This study employed the agile software development approach and hence the development was incremental and based on the relevant sprint.

System Testing and user evaluation – This stage is crucial to the agile approach as it acts as a validation and recommendation point for the overall development. In this study, testing was repetitive and the outcomes fed into the next sprint's requirements and overall refined system requirements and design. The cumulative outcomes of each sprint further meant the different tests were also incremental and ticked off errors encountered in the previous tests.

In this study, since there was a focus on usability, extensive testing and usability evaluation was carried out to conclude the research, as part of the larger cumulative outcome, the researcher together with the testers and evaluators explored the system usability as individual and as focussed groups and discussed issues and recommendations for the system.

System Deployment – This stage usually marks the end of application development, however in agile, this step takes place at the end of the sprint and to allow for remote testing it is in most cases interchanged with system testing, whereby a developmental prototype is deployed and respective remote users get to test the system live on a development server. Deployment was mainly done before testing as it allowed for the researcher and testers to explore the system as a single system combined and constantly interacting with the Firebase server. The web applications developmental prototype was deployed using firebase as a web server and for the mobile application, sample production builds were created and locally deployed on the testers mobile devices.

3.5. Data Collection

Data collection plays a crucial role in research and in the overall process of knowledge discovery or construction. In research, data collection refers to the assembling and testing of measurable content information from all relevant yet reputable sources based on specific variables of interest in purposeful pursuit of answers to research questions, hypothesis and the evaluation of the produced outcomes (Kabir, 2016). Every researcher must understand this importance regardless of their field of study, in order to be at a position to validate and replicate the study's findings for future projects. Kabir (2016) in his book clearly outlines the importance of collecting accurate data as the consequences of inaccurate data collection leads to an inability to articulate the answers to the research questions, distorted findings and overall misuse of resources hence leading to compromise in policy and decision making.

In this study, the system specifications were derived from requirement elicitation through interactions with both prospect users (museum visitors) and museum management using qualitative research method in which interviews and participants observation were the main data collection tools. The participants' observations were mainly meant to inform our interviews and mixed questionnaires. The use of mixed questionnaires offers flexibility and hence easily adaptable in variable research types. In addition, it allows for the collection of more comprehensive data than would normally be collected by either open or close-ended questionnaires alone (Creswell & Plano Clark, 2011). Myers (1997) states that in many disciplines, interviews and participants' observation are common tools to explore social phenomena, which in this study include museum visit and client management by museum staff. The user requirement elicitation provided the study with a preliminary understanding of the current situation and the way forward after the result had been presented to the museum management.

The data required for the development of the overall museum system was provided by the Independence memorial museum curator –Mr G. Guarirab from archives and backup of the museum. However, these data were not sufficient nor of the correct quality for digital consumption and modification. The first prototype of the mobile was hence reduced and tested on data from six museum artefacts, with the data provided by the curator being insufficient the researchers resorted to alternative sources to retrieve more data especially media data from sources such as YouTube and the Museums Associations of Namibia (MAN) website.

With the help of museum staff members, the mixed questionnaires were designed and distributed to 50 visitors and staff of the museum for the collection of statistical data to broaden the understanding and reduce the margin of error ("Sample Size: How Many Survey Participants Do I Need?",2017) and (Dattalo, 2008). Descriptive statistical data analysis was used to inform the system design and development of the incremental prototypes and implementation of the final product after prototyping.

This study further relied on the literature review for benchmarking and to explore trends in software development. This is mainly due to the fact that software development and the overall software engineering field is ever-growing and for a researcher to create an updated system, he/she needs to explore the literature of relatively recent studies and projects done in the field. Saunders et al.,(2009) in their study on research methods outline that literature review provides a thorough understanding of emerging trends and constructive research findings in the respective field, thus informing the researcher of what is relevant and how to go about applying these concepts. This study has been fortunate enough to explore a substantial amount of journals in cross-platform mobile development and software trends at large, these include (El-Kassas, Abdullah, Yousef, & Wahba, 2017) and (Perchat, Desertot, & Lecomte, 2013) who separately did studies on frameworks and approaches for cross-platform mobile development, they both clearly outlined the benefits of cross-platform development as shortening the development time and simplifying the developers tasks. These studies subsequently acknowledged that cross-platform development is an emerging approach in software development and most frameworks and approaches being used are results of ongoing research projects and recent findings thereof.

3.6. Population Sampling

In an attempt to answer any research question guided by the research objectives, researchers often look at a subset of the target population as this provides them with an overall understanding of the group in question. While conducting any study it is almost impossible for any researcher to collect and analyse data from all available members of a selected group due to the research timeline, resources limitations and sometimes access restrictions (Saunders et al., 2009). However population sampling needs to be well planned and follow the right procedures to acquire the desired outcomes, population sampling can thus be categorized in the following steps as:

A) Clear definition of the target population
B) Selection of sampling frame
C) Choosing sampling techniques
D) Determination of exact sample size
E) Collecting actual data and analysing the outcomes.

These stages best fit in the probability or representative sampling techniques, and our study even though adopts mixed research, our sampling techniques for the preliminary data collection was purely representative.

This study's target population was all museums visitors and staff members, irrespective of their age, gender or economic status. The study aimed to be inclusive by considering all types of museum visitors and the data collected from museum visitors were mainly used to inform the initial system design. The difference in age and tech-savviness also helped the study to be more inclusive in the design and implementation of the system. the younger visitors were more experimental and playful hence would discover most features should they be given any system to use however the older visitors are more reserved and would require more assistance and understanding of why certain features are the and the overall procedures. The second part of the museum system was intentionally meant for the museum staff members hence interactions via interviews and surveys strictly targeted the current museum staff members to provide what they deemed necessary for the administration of the overall system requirements.

Data collected during application and overall system testing had two categories of focused groups. The first target group that tested the cross-platform mobile application were mainly university students from different fields of studies and the second target group was the museum staff members that tested the web application of the system. The first target group was mainly comprised of voluntary participants and a few with interest in mobile development. The study further had professional developers test both parts of the system to give their inputs and recommendation, this third group had few participants and were highly technical in responding to the questions posted, in the end, provided very constructive comments about the system overall.

3.7. Ethical considerations

Ethics is “Moral principles that govern a person's behaviour or the conducting of an activity.”("Ethics", n.d., para. 1). This study took the responsibility and drafted a letter that was forwarded to the Independence Memorial’s management requesting for ethical clearance and permission for data collection to be carried out, during the testing phasing another communication was sent out seeking assistance and go-ahead from the museum management. A copy of the letter is included in Appendix A.

The main purpose of this letter and communication was to seek permission and clarify how the collected data will be used plus the overall aim of the study. It indicated that participation was on a voluntary basis and participants are welcome to pull off the exercise at any time. As for the interviews, participants were asked for consent prior to any interactions and clearly explained to the purpose of the exercise and emphasised that participation was voluntary and the respondents could withdraw anytime they wished to.

4. REQUIREMENT ELICITATION

Requirements elicitation and analysis is the process involved in the searching and collecting of information that defines a systems functions and constraints of system's operations coupled with the overall evaluation of this collected information to deduce the systems functional and non-functional requirements (Wazlawick, 2014, pp. 29-57). It can further be noted that requirement elicitation is a crucial phase in the development lifecycle and that it can only be successful through effective collaboration by all stakeholders, as it further requires intense communication and mature approach from both the developers and prospective clients or system users.

As outlined in the previous chapter, Interviews, user observations and an online survey were used as the main data collection tool for the system requirements. Following the agile development approach, the requirements just like all other aspects of the systems were continuously revised and for this study. Two main methods proved fruitful in this regard, which is continuous interviews that in turn informed the systems use case for the respective users and rapid testing of the prototype of the system.

The interview conducted helped this study to understand the overall user expectation and crucial features required for the system. Consequently, not all stakeholders are involved but a sample based on expertise and credibility is used to represent the overall population. In this study, we followed an open-ended approach blended with a few structured questions that were prepared beforehand, but there was no fixed agenda in most interactions as that allowed the research to collect more accurate information from the users. The user observations helped the researcher to understand types of users for the system and also explore their behaviours and expectations during the visits. It is here where the researcher observed the visitors activities through the museum and what they would do when they encountered artefacts of interest. The online survey was informed by both the interviews and observation, hence aimed to clarify the users' expectations further with more detailed explanations. The research further explored aspects of the functional requirements by asking the visitors, prospective users and staff what specific features and behaviour would be required in the systems and how it would enhance the museum experience. The survey responses also informed the researcher on what could be the expected non-functional requirements such as look and feel of the application plus the performance of the overall system.

4.1. System Overview

The main objective of this study was to design and implement a location-aware interactive and content delivery virtual guide that is both easy to use and stable across multiple mobile platforms. After exploring the research sub-objectives and analysis of users' expectations and requirement, the system structure was based on two main components: Web Application and Cross-platform mobile application. This study further adopts a uniform approach for both components using the 3-Tier/Layer software architecture, consisting of the Presentation, Application and Data tier. The 3-Tier architecture is one of the most commonly used architecture in software development and sometimes referred to as the n-Tier architecture since the number of layers is not restricted to three (Frith, 2015).

The Presentation Tier(Frith, 2015) – represents the frontend also referred to as the User Interface (UI), this layer presents information to the user in a friendly and easy to use manner, and it additionally offers an interface to interact or manipulate data used by the system. In this study this layer had two components, the web part was implemented using the Angular framework mainly using HTML5, Bootstrap and Material Design,while the cross-platform/mobile component was implemented by using the Ionic framework which also makes use of HTML5 and adds rich UI toolkits for different mobile platforms including Material design for android platform.

The Application Tier- represents the functional business logic that provides the implementation for the system's fundamental features and functionalities. For this study this layer was unified and developed using Typescript, this was an advantage and allowed for code reusability on both components since the frameworks used are similar. It is here were service logic was defined that talks to the Data layer through the respective API gateways.

The Data Tier – represents the data storage and manipulation layer, this layer contains the actual database system used and the respective access layers through the API calls. In this study Google Firebase was used and further leveraging its scalability yet relinquishing maintenance responsibility for the database, this allowed the researcher to concentrate on the two layers for the system developed. Figure 4.1-1 below illustrates an overview of the 3-Tier software architecture.

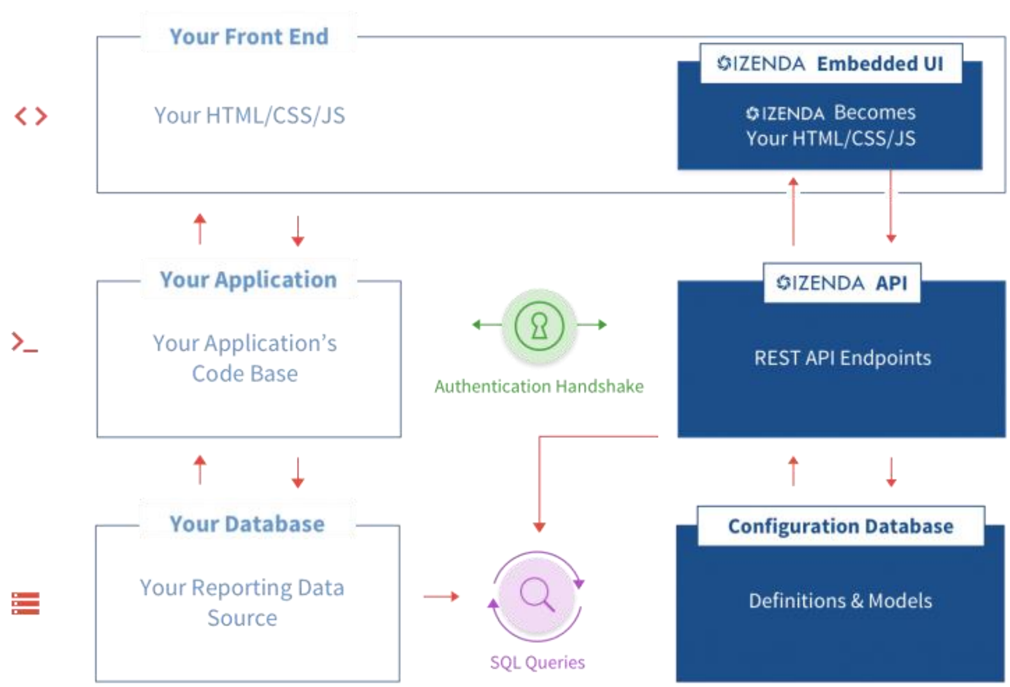


Figure 4.1: Sample 3-Tier Software Architecture overview retrieved from https://www.izenda.com/5-benefits-3-tier-architecture/

This study adopted the 3-Tier architecture for its advantages in performance and scalability. These would allow for the envisaged non-functional requirements and further, allow the software to be up scaled for bigger institutions or general use without restructuring and redesign of the system. This architecture also allows for different technologies to be adopted and updated at different layers without an effect on the system’s operations.

4.2. Functional requirements

The functional requirements are focused on two main aspects of the system, which are the system's functionalities and behaviour. The functionalities refer to what activities/ tasks the system can perform and the behavioural aspect is concerned with how the system behaves when provided with certain inputs, hence exploring the system's functions in terms of input, processing and subsequently the output. The figures 4.2-1 and 4.2-2 illustrates the functionalities in forms of use cases for the web application and the cross-platform mobile applications respectively.

The sections that follow below each figure explains each use case explicitly.

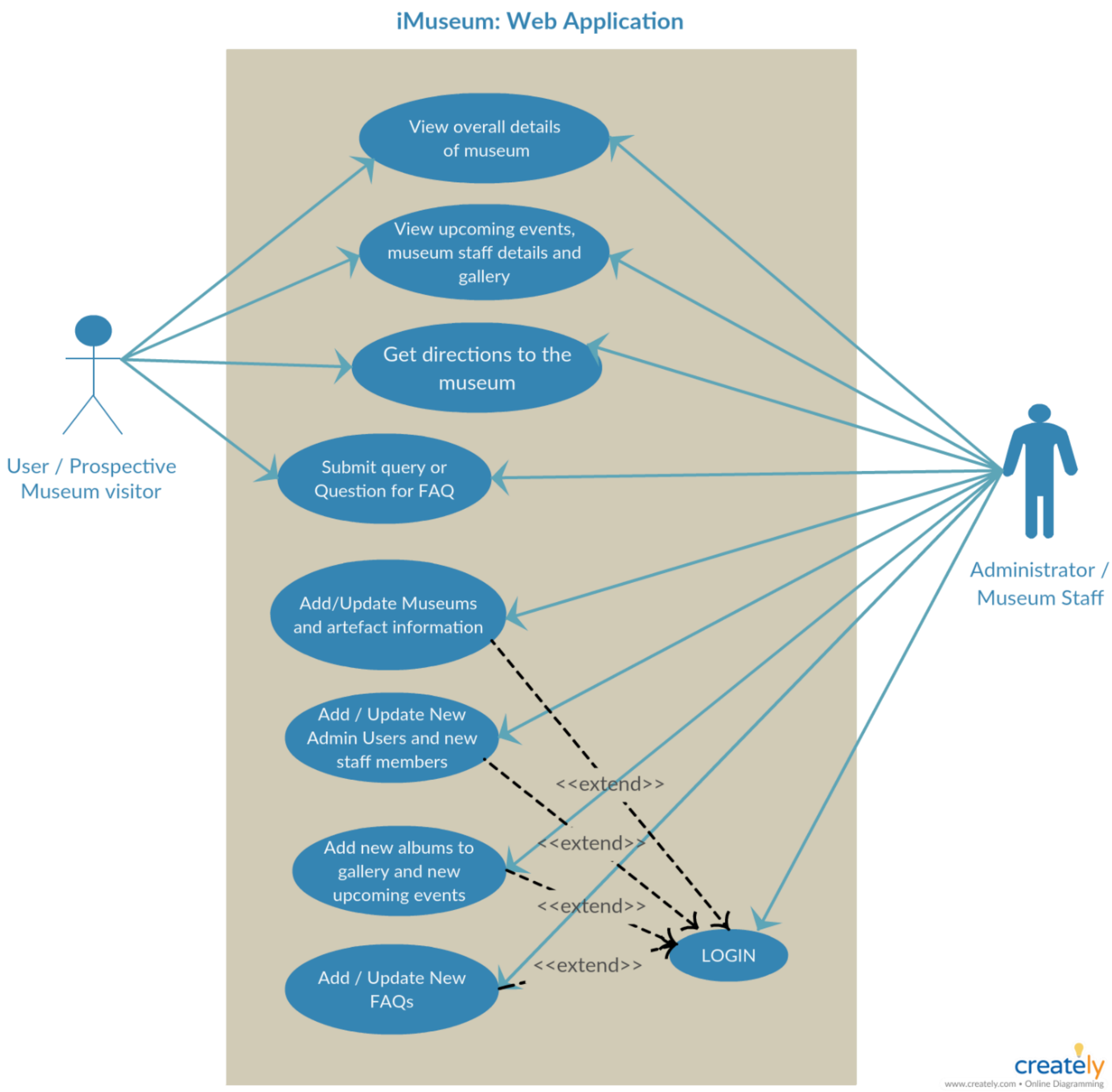


Figure 4.2-1: Use cases for Museum web application

All Users

The use cases below are accessible to all system users, which includes the museum staff and prospective museum visitors, these functionalities mainly focus on information dissemination.

View overall details of museum – The web application being specific to the independence memorial museum, offers the user a detailed explanation about the museum, such as its structure and how the museum exhibition is distributed within the museum.

View upcoming events – these allow the users to view events scheduled to take place at the museum and there are sorted according to dates, consequently when the event is passed it will be removed from the list.

View museum staff details – Here the user gets a glimpse of the staff members in the form of user profile cards that display staff pictures, job description, office contact and career aspiration note.

Gallery – These offers various albums from within the museum exhibition and recorded events

Directions to museum – One interesting feature embedded in the web application is the ability to pinpoint the user's current location and based on this location offer the user directions on how to get to the museum.

Submit FAQs – The system allows the users to submit Frequently Asked Questions, that is mainly based on issues faced using both the mobile and Web application. The administrator also has access to this feature but in addition, they could do further manipulation as indicated under updating of FAQs

Administrator / Museum Staff

The use cases below are accessible to any a privileged group of system users, which are responsible for data management of the whole system and these includes data to be accessed by the mobile application.

Login – All the privileged users need an account to login into the system. Once the account has been success authenticated the user the gets access to the administrative tasks outlined below. These administrative tasks are the main purpose of the web application to act as a management platform for all information in the system.

Add new/Update museums– These allow the user to add details of a newly built museum or update details of an existing museum. This information is mainly viewed in the mobile application.

Add new/update artefacts – When new artefacts are introduced in the museum, the staff members are able to add its details, most specifically the information about the iBeacon tag attached to the artefact.

Add new/update admin users and staff members – This feature allows for an admin to add new administrators and staff members, additionally allows for them to make an alteration to already existing users.

Add new/update gallery albums – The system through both the mobile and web application offers a gallery to the users. The administrator through this feature is able to add new albums and update or ultimately delete existing albums

Add new/update events – Events displayed on the web and mobile application are added and updated through this feature, but deleting is left for the system to handle once an event overdue by 6 months it is removed from the database.

Add new/update FAQs – FAQ questions submitted by the users are answered and details updated on the database.

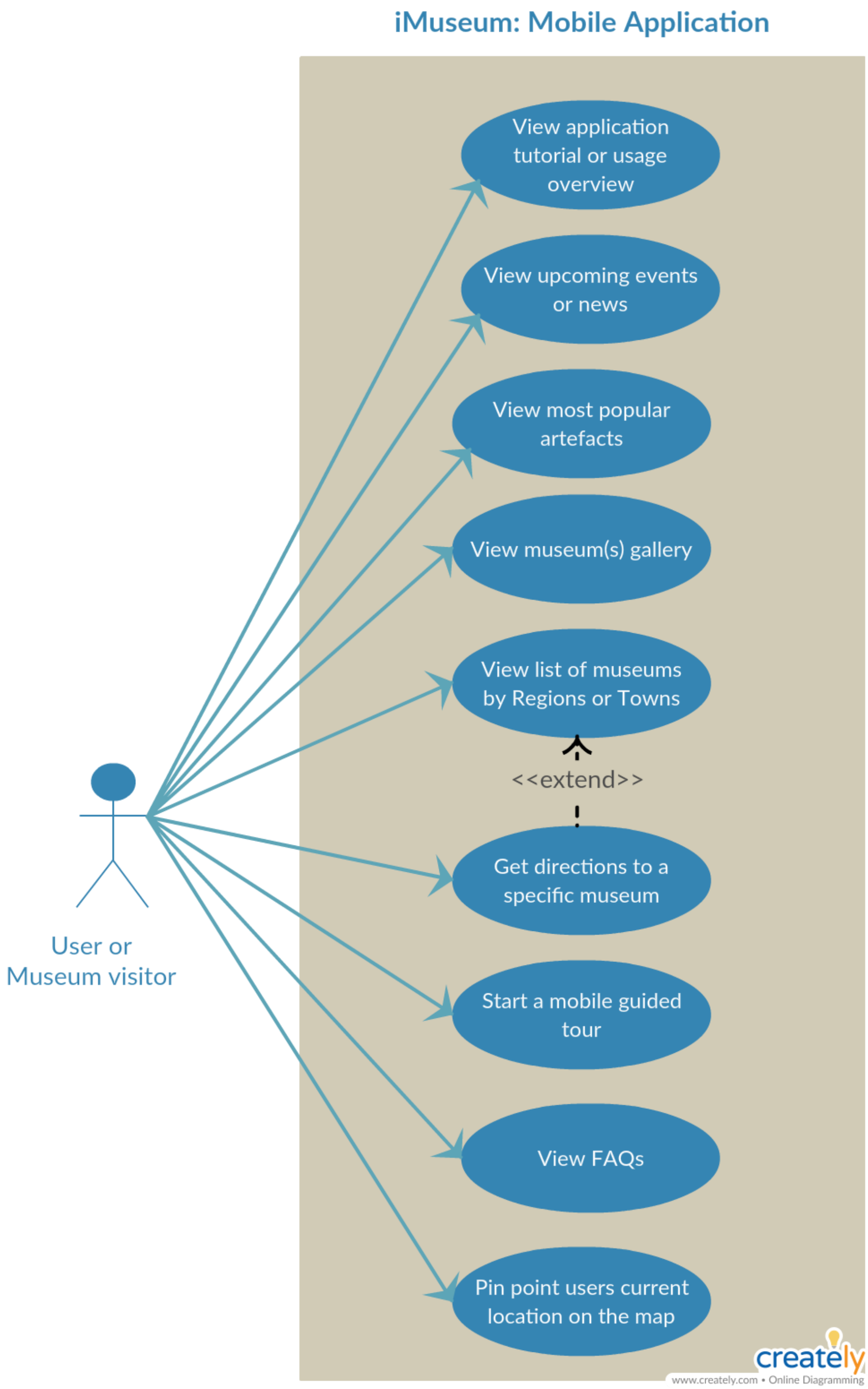


Figure 4.2-2: Use cases for Museum Mobile application

Mobile User / Museum Visitor

The use cases below are accessible to all user using the mobile application on the respective mobile platform. The main purpose of the mobile application is to expose the museum visitors to relevant information about an artefact in front of them with the help of iBeacons to filter and display artefacts in the visitor's close proximity. The mobile application does not require authentication and hence all users of the application have the same rights and privileges.

View application tutorial – The very first time the application is launched after installation the user is directed to an introduction page that provides an overview about the key features available and a mini-tutorial on how to use the application.

View upcoming events/news – Just like the web application, Users on mobile platforms are able to view a list of upcoming events but here it is improved with the option to display the latest news at the museum.

View most popular artefact – The mobile application through the self-guided tour allows users to like artefacts that they find fascinating and hence through this option users can view a sorted listed of popular artefacts starting with the most liked on top.

View museum(s) gallery – Numerous albums uploaded about museums and events around museums in the country can be accessed through this feature.

View museums by Towns/Regions – Museums all around the country are accessible to the user but in addition, the users can categorize the list by town or region and this could come in handy for people visiting the country for the first time, since they might not know the regions but rather the town. The application hence shows a list of museums surrounding the selected town or within the regions. Once clicked on the museum, a card with a museum summary is displayed with information such as opening times and allows for the users to make a voice call from the application.

These five described use cases are all available to the user through the side menu option available on the top left side of the application and hence these are considered as sub-features of the application. The features outlined in the use cases below are the core functions of the application and overall system purpose.

Start mobile/self-guided tour – This is the fundamental feature of the application, once started the application acts as a museum guide for the visitor detecting and notify the visitor of artefacts close by and giving clues to related artefacts. Upon receiving a notification the user has an option to view more information about the given artefact and when the click to view the application offers the user media files inform of images, videos and even audio whichever is available for the artefact. Below the section of media files is a division with a summarized description about the artefact with the option to read all about the artefact. The video and audio files streaming has an auto-mute option if no headsets have been connected to the mobile device to avoid noise within the museum.

Get directions to a specific museum – This option extends the viewing of the museums, once a user clicks on a museum the get an option to get turn by turn directions from their current location to the museum, hence allowing the application to be helpful to users before they get to the museum.

Pinpoint users location – While on the main page of the application and additionally to finding direction the application allows for the user to find or pinpoint their current location on the map. The main idea behind the pinpointing is to discover all museum within a radius of about 100km and display them as well hence letting the user know which museums are nearby.

View and add FAQs – When faced with issues with the mobile application the users have access to FAQs and if not satisfied have an option to submit their issues and allow the staff members to answer or attend to their query. This option could also be used to track errors when testing.

4.3. Non-Functional requirements

The non-functional requirements are concerned with the assessment criteria and or the actual assessment of how the system operates rather than the specific system's functionalities or behaviour. These include a set of standard employed to assess the specific operations of the system and further determines the quality of the system.

The non-functional requirement also separates the concepts of functionality from attributes concerned with quality and is more focused on productivity, time and cost constraints on the system (Chung, Nixon, Yu & Mylopoulos, 2000). Even though not compulsory to a system, non-functional requirements are just as crucial to every system since the quality of the system defines its usefulness and hence allow the users to explore the features as described by the functional requirements. Taking into consideration all aspects of software quality, the possibilities of exploring and satisfying all non-functional requirements are close to impossible, however, every system must pay attention to key concepts that are fit into its context and considered crucial to harness maximum functionalities of its key features. This study has selected and paid more attention to the attributes below:

Usability – Which is concerned with the simplicity and ease of use of the system. Usability further includes the user's comprehension and adaptation to the system's features such that they are able to provide correct inputs and ultimately understand plus interpret systems outcomes. This attribute is more aligned with the presentation layer, hence the system's user interface design and implementation should be sensitive and considerate of all types of users. Part of this study's objective is to enhance user experience and inclusivity through an interactive system that's is both stable and user-friendly, hence usability is at the core of this study. The inclusivity is addressed by offering the system on multiple platforms and the personalised experience would mean provide a familiar look-n-feel for all the respective platforms consider in this study.

Performance – This attribute refers to the rate at which a system achieves its key features under provided constraints such as, speed, resource usage and its overall accuracy in executing expected tasks. It is further related to terms such as the system's response time, throughput, utilization and others. Performance plays a crucial role in a system as it closely ties in with the system's functionality, it would be trivial to have a friendly and easy to use system that spends time processing operations. This attribute hence explores ways in which the system effectively operates during a varied work load and in cases of system overload.

Adaptability – This refers to the degree of the system's or its components overall flexibility or easiness to be modified and adjusted to fit a different requirement or operational environment altogether. A highly adaptable system can further be scaled to any size as it gives room for major modifications to be done to the system. This study paid more attention to this attribute to allow the system to be adapted to different requirements seeing that an incremental approach was adopted.

Maintainability – Refers to how easily faults or defaults can be modified and corrected to fit the envisaged logic for the system. This attribute furthers allows for the system to improve its performance, usability and adaptation to the new environment. In a fast-changing world, systems must provide room for change be it to fix errors or just to make amendments to its operations due to a change in requirements.

Understandability – This attribute just like usability is aligned with how easy it is for the user to comprehend and make out the means of the system's components, such as what certain sections are meant to do or what some icons represent. A well-understood system allows the user to explore all its features and provide constructive feedback that could further be used to improve the system. This study is about inclusivity hence places emphasis on this attribute to allow all users to easily understand the system and use their time to experience the museum as the main focus.

Testability – This attribute is concerned with the validation, verification and evaluation of the systems key feature. A system that can be easily tested not only validates the features but helps in uncovering potential or hidden features that can be used to enhance the performance of the system further. Testers spend more time focusing on the actual test specification of the system and hence recommending changes that are crucial as specified by the functional requirements.

Security – This attribute is concerned with data access and modification, seeing that the system requires data to be served across the respective platforms it is imperative that the data is secure. The attribute is aligned with how the logical layer controls access to the data layer through roles and user privileges. In this study, the system implemented is secured from all data modification using firebase authentication framework.

5. SYSTEM DESIGN

System design is the stage in which an outline of the system architecture, components, interfaces and data are created, then following the requirements these aspects are all verified and documented. System design informs the developer of the overall approach to be used during the implementation and clarifies the rationale behind the adoption of certain development approaches. In this study, the design took both the web components and cross-platform components into consideration, with the idea that the logic and the data to be used is shared across all platforms. Operational differences between platforms were closely considered and an optimal approach was included in designing the proposed prototype. The section below further outlines the different aspects of the system that was considered in this study.

5.1. Design Tools and platforms

The design process of this study was solely based on free to use tools both online or offline, this seemed like a drawback in the beginning but later proved beneficial to the researcher. There were three main tools used to design the system architecture and model the system's data structure and their relationships.

Creately (from creately.com) is an online tool that offers a platform for modelling of functional requirements as shown in the respective use case figures found in chapter 4. This tool goes further to offer data modelling structures that are perfect and commonly used in systems that are object-oriented and more often used by relational database for creating Entity-Relationship Diagram (ERD). Creately has a commercial version, but for the scope of this study, the free version worked like a charm.

The next tool is MockFlow (from mockflow.com), another powerful online platform used to create impressive and realistic wireframes mock-ups of the user interface designs. The study used MockFlow for all the visual components of the systems and due to its realistic design outcomes (see figures 5.2.1-1 to 5.2.2-13 for reference), implementation time was reduced.

The last design tool was Moon Modeler, we used this to create data models of the NoSQL database structure used by the system and as highlighted earlier Creately is best suited for a relational database with the traditional ERD structure and could not be used in this regards. This study used the trial version of the Moon Modeler and the results were outstanding, this tool was created specifically for document-based databases. The models created are easy to implement and it further allows for the addition of validation rules for collections and documents within the database, this is very crucial as it gets the developer thinking about implementation at an early stage. Figure 5.3-1 shows a sample model of the systems database structure created with Moon Modeler.

5.2. System Architecture

System architecture refers to the overall organization of a system and or its components structures, these includes the interconnection of components, principles and recommendations that direct the changes in the system design over time. The architecture, therefore, provides a skeleton for the operations of the system, interactions between components and overall data flow within the system. The sections that follow provide an overview of the key components of the iMuseum system and its operations.

The main aim of the system developed as a result of this study is to identify artefacts closest to the visitor's mobile device and provide the visitor with a personalised view of the artefact’s textual information and associated media data. The system relies on Bluetooth low energy for its detection and ranging of artefacts within close range of the visitors. For this process to be successful we tagged each artefact with a unique iBeacon tag that continuously transmits a signal over Bluetooth low energy with information used to identify the artefact. The information from the iBeacon tag contains a unique id that is used by the application to query for further information about the artefact from the database. The communication between the application and the database needs internet connectivity and this can be attained over WIFI connection or via mobile data. Almost all new mobile devices are embedded with GPS sensors, the system leverages this feature to detect the current location of the user and additionally use the database to plot nearby museums on the user's mobile map allowing them to get direction and detailed navigation instructions to any museum. The figure below provides an overview of the system architecture and the section below outlines a few of the key components in details.

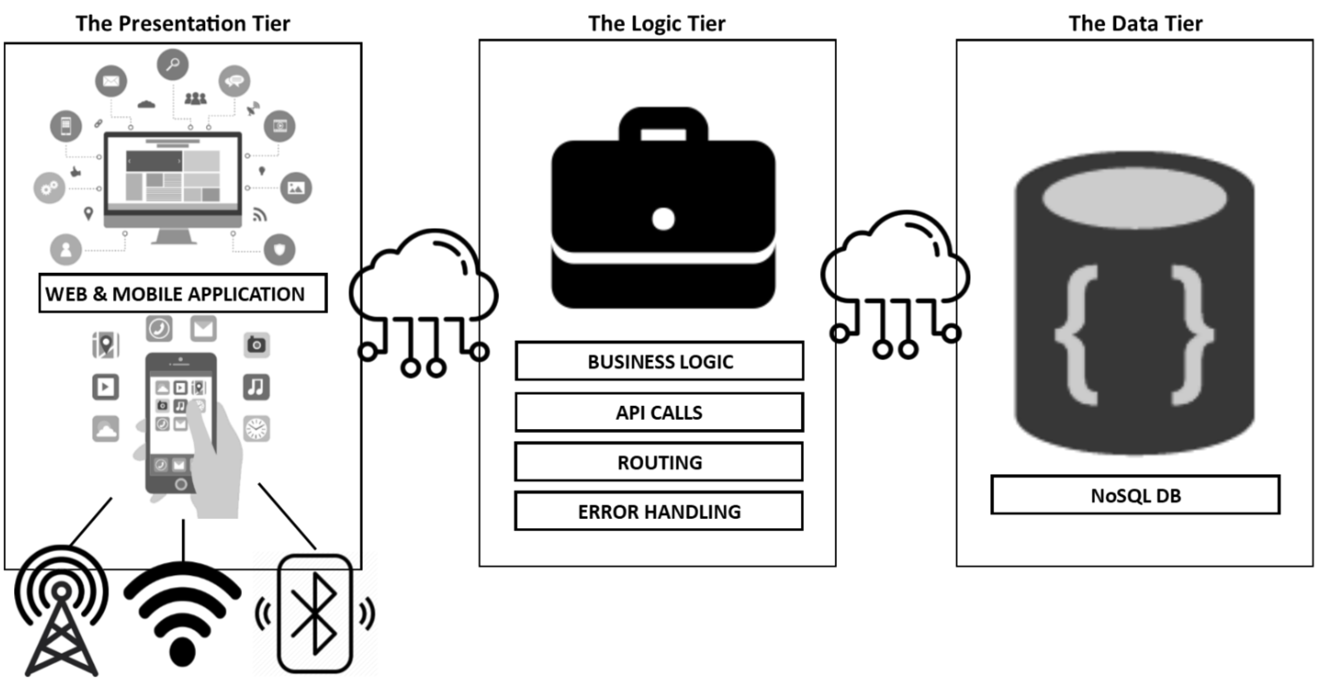


Figure 5.2-1: Overview of System architecture

5.2.1. Web Application

The web application acts as marketing, information sharing platform and most importantly used by the museum staff and management to populate data about museums, events and artefacts or current exhibition in the museum. This application was designed in such a way that it's self-reliant, i.e. within its components it allows the administrators to control data that is exposed to the user and hence the main purpose of the web application is to act as a Content Management System (CMS) for mobile application.

A detailed explanation of key features has been covered by the functional requirements and possible use cases as outlined in Chapter 4. The figures that follow are wireframe mock-up design of a few components for the web application.

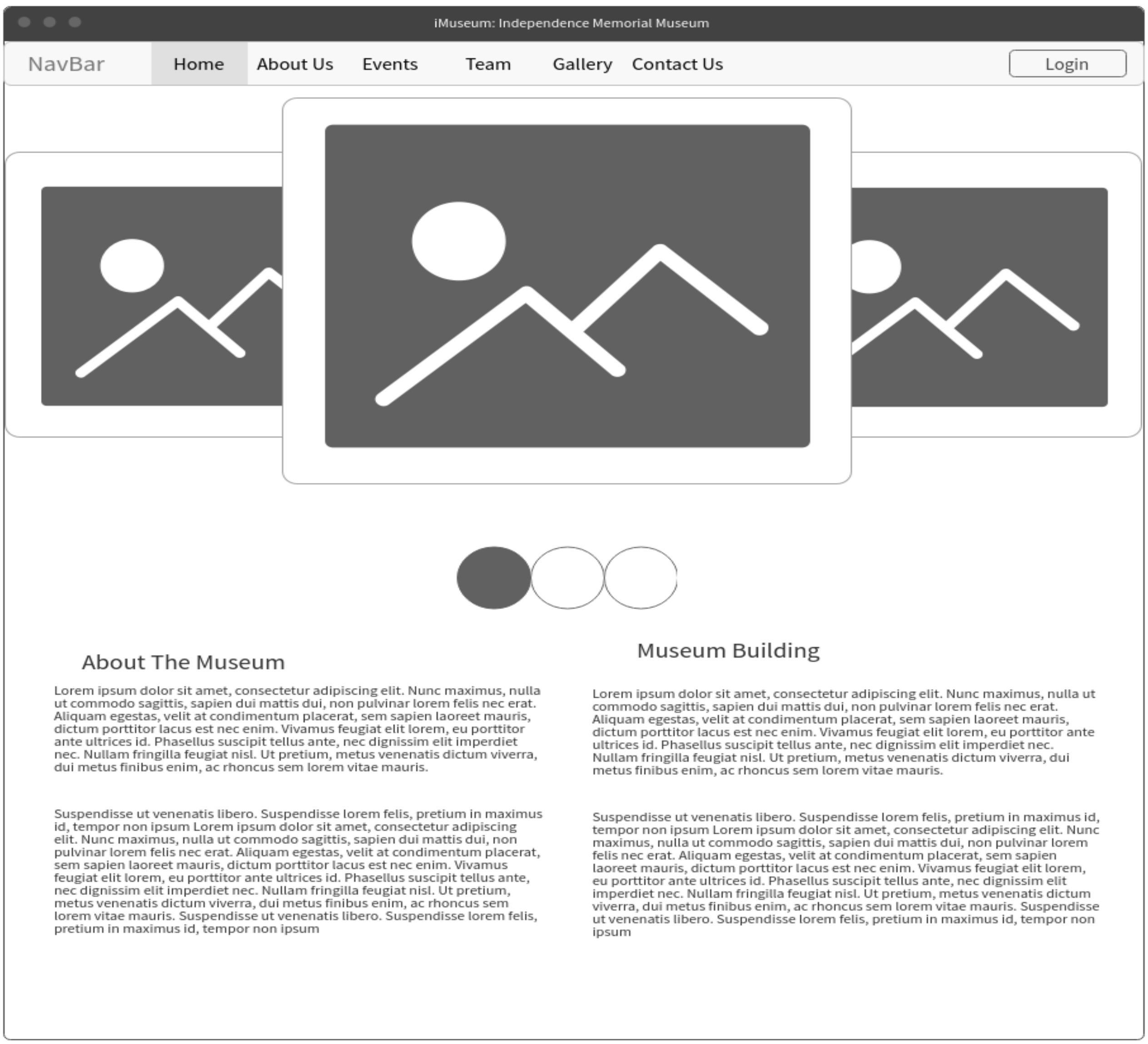


Figure 5.2-2 : Web Application Landing Page

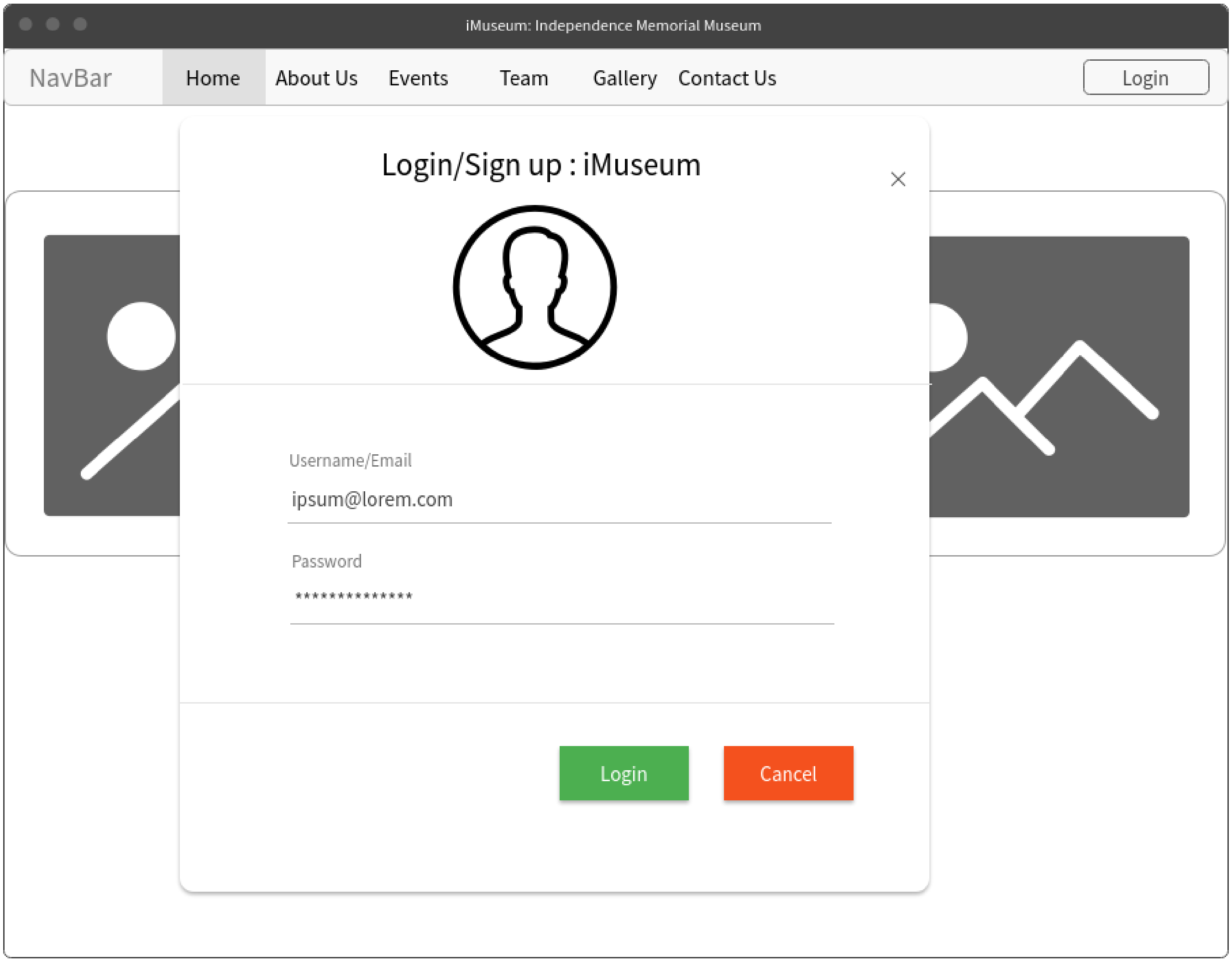


Figure 5.2-3: Web Application Login Page

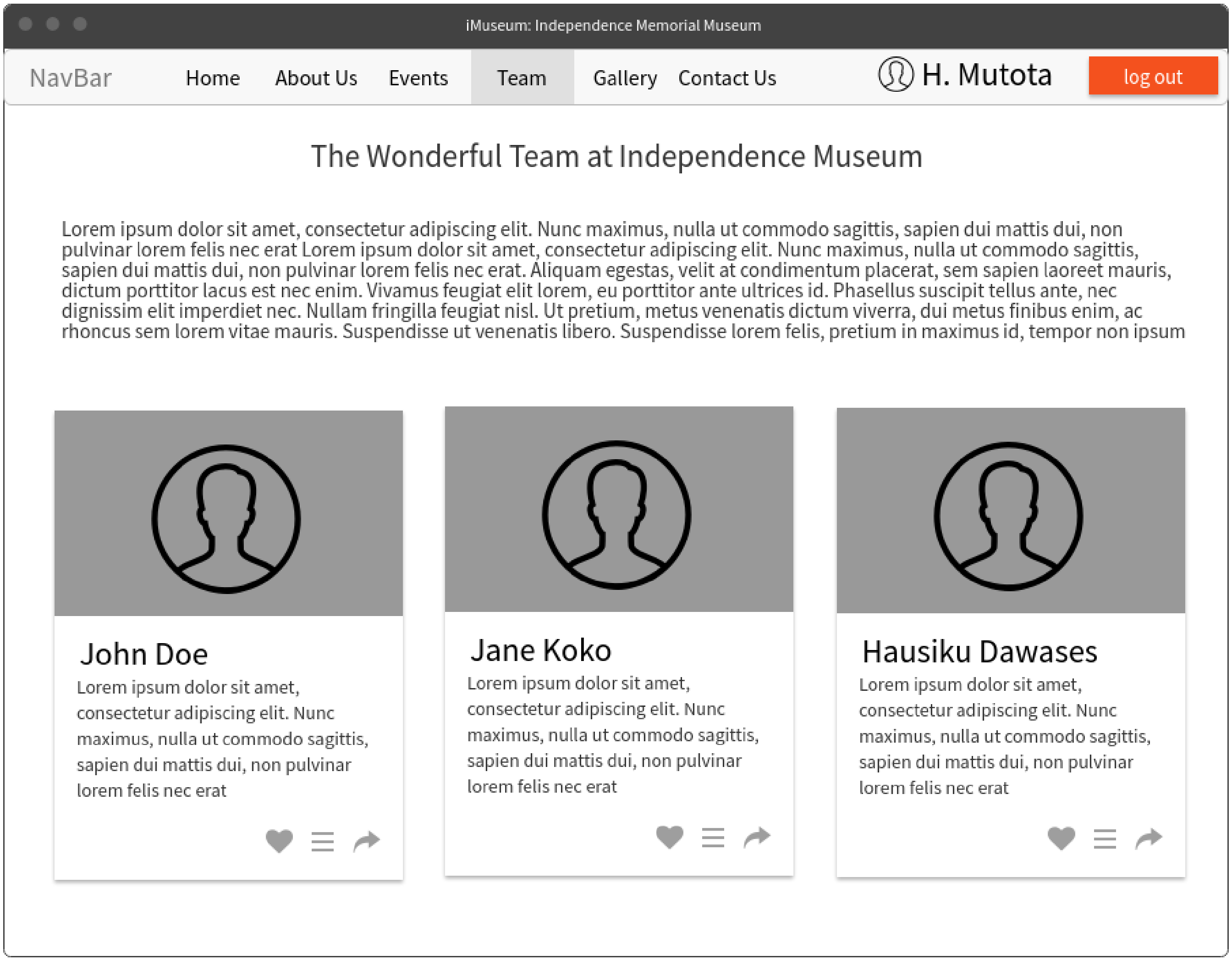


Figure 5.2-4: Web Application Staff Members Page

5.2.2. Cross-Platform Mobile Application

The cross-platform mobile application was designed to broaden the user base of the museum system, and this is anchored towards the objectives of this study which is to enhance museum visitors' (users) experience by providing them with a personalised view of the content in a more user-friendly way and ultimately encourage potential museum visitors to come and explore the full museum experience. The application running on multiple platforms means the visitors (user) pay more attention to the actual tour and the auto guide acts as an add-on to their experience and since they are already familiar with their own device, operating the application is quite easy.

Below are a few wireframe mock-up designs for the mobile application components on both supported platforms. The wireframe designs to a unified approach with close considerations of the differences in the mobile platforms, this is what allowed the researcher to concentrate on the logical implementations that consider and leverages different features available on each platform.

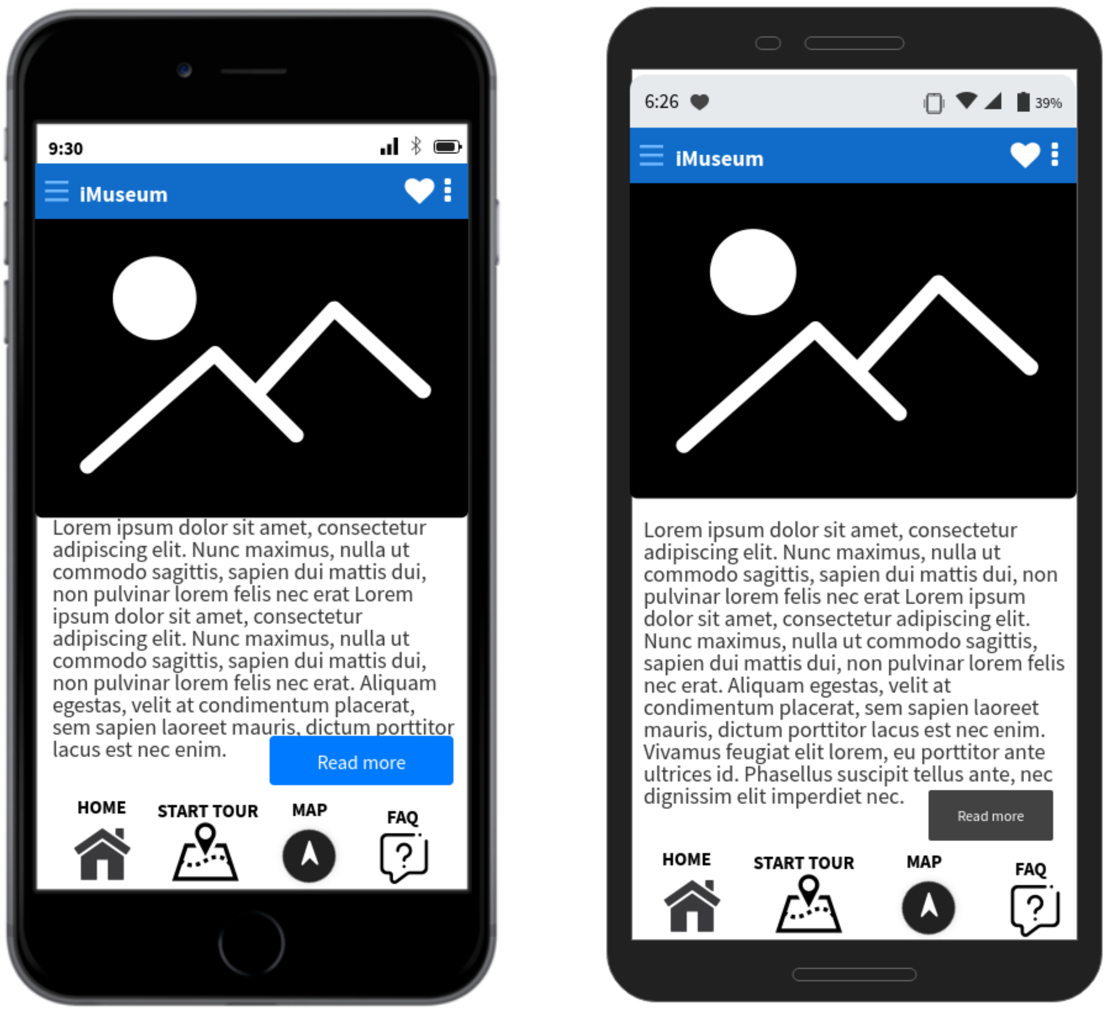


Figure 5.2-5: Mobile Application Landing Page

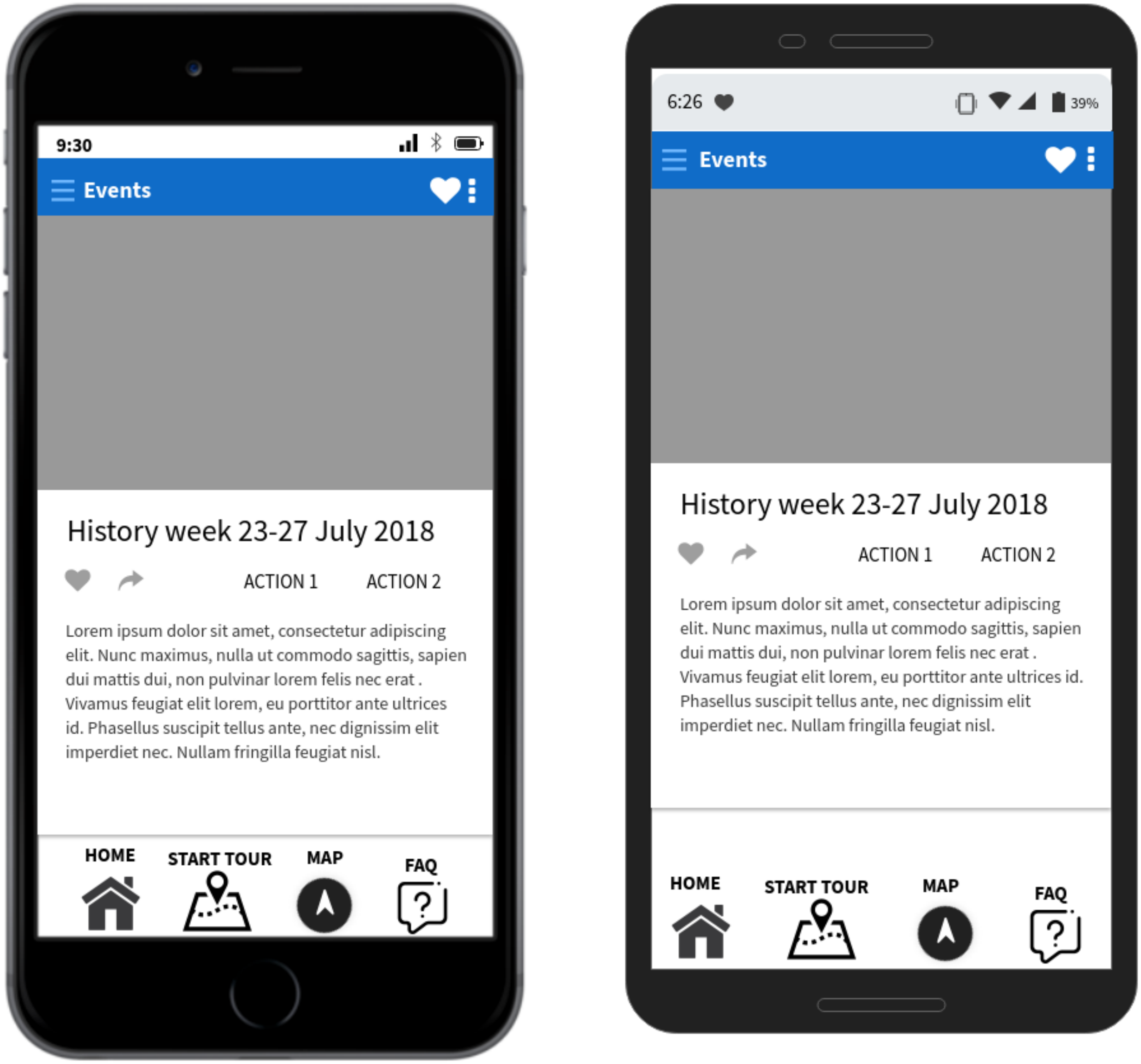


Figure 5.2-6: Mobile Application Events page

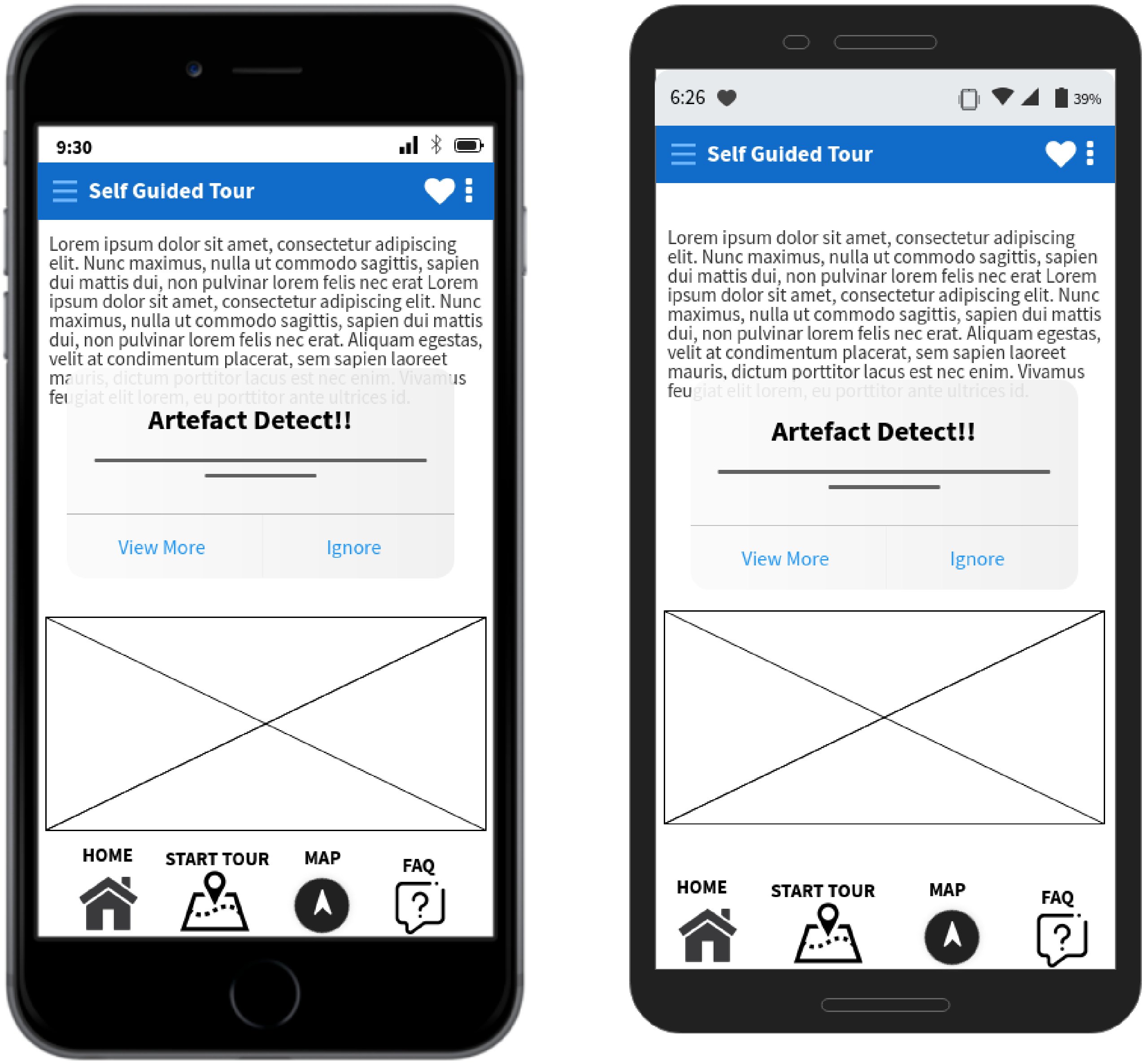


Figure 5.2-7: Mobile application Self-guided tour detecting artefacts close by

5.2.3. Bluetooth Low Energy

The system heavily relies on Bluetooth low energy to detect artefact using the iBeacon tags attached to each artefact. The motive behind using Bluetooth low energy just as the name suggest is its efficiency in energy consumption and the considered low cost of the tags plus their maintenance. The system upon detecting close by artefacts puts up an alert to notify the visitor of the closest artefact to where they are standing, additionally, a list of all artefact with the visitors proximity is displayed in the background so if the user dismissed the alert they still have a list ordered by distance and they can select which artefacts they would like to learn more about.

5.2.4. WIFI and Mobile Data

The system upon detecting artefacts close by need correct information associated to the given artefact, the metadata and most especially the textual data is synced with the database and an offline version is cached with the local data for the application. However, to be more interactive the application offers the user media data informs of images, videos and audios files that are streamed from the data store using reference links stored on the database, the system, therefore, requires a fast internet access for media streaming and that is why this study adopted the use of WIFI as a recommended internet access mode or Mobile data under the assumption that most museums are in areas with 3G/4G network coverage. The study recommends WIFI with assumption and further recommendations to the respective museums to have WIFI set up on their premises, as this takes the responsibility away from the visitors' having to worry about internet connection for an application or system adopted by the museum without full considerations of resources needed to operate the system.

5.2.5. APIs

The system is heavily dependent on data flow between its respective clients and numerous data servers and service, it is hence crucial for the design and implementation to include the use of one or more Application Program Interfaces (API). The main objective of any API is to coordinate how different components of the system interact. The following are the key APIs used in this system:

Firebase API: Google offers any developer a powerful tool - Firebase, which offers an API, database and file storage plus many more services. This study takes advantage this features and hence uses the Firebase API to coordinate communication between user interfaces/presentation layer and the data layer which also makes use of the Firebase real-time database for storing metadata and the google storage for storing of large media files and saving their links in the database. The system also makes use of the authentication services offered by firebase for management and validation of user-profiles on login.

Google Maps API: Google maps offers accurate and relatively up to date information on maps, roads, routes and locations. This API allowed the researcher to obtain precise location information of the users, provide recommended routes and estimated times for the user to get to the museum. With the Google Maps API, the researcher was able to embed a map component within both the web and mobile application, to extend is further the API is able to transform the users request for directions to be used on any native mapping application of most mobile platforms in cases where google maps is not installed.

5.2.6. Geocoding and Reverse Geocoding

Whenever dealing with localisation one is either expected to transform, easily readable/street locations into geographic locations in forms of latitudes and longitudes or vice versa. Geocoding refers to the process of converting readable addresses into latitudes and longitude whereas Reverse Geocoding does the opposite. This system uses Geocoding to transform museum information into geographic locations that are stored in the database for adding markers on the map viewed by the mobile application and additionally, to calculate the distance in between the user and the museum. The users' coordinates are retrieved as geographic locations and for filtering of museums within the same town or region the system needs to reverse them into street addresses.

5.2.7. Database (NoSQL DB)

This study opted to use a NoSQL database due to its ability to handle large volumes of either structured or unstructured data and the overall flexibility of the database structure. The main purpose for the database is to store metadata in textual format, hence as support the media files were store using google drive storage and then the links were store in the database together with other information. The metadata stored was for the museums, events, galleries, staff members and Artefacts, with the objective of feeding into both the mobile and web application respectively.

5.3. Data Model

NoSQL databases are meant for big-data storage and manipulation, and due to the constant change in the data structure most of the NoSQL databases do not have a fixed schema to start with, this is because the database does not require documents from the same collection to have the same schema. This flexibility allows documents from one collection to have different fields and data types, however, one can enforce the structure if need be using validation rules. With these in mind, designing the data model of a NoSQL database looks at the whole modelling process from a different angle which explores the question of "What queries will be made to the database?" hence the model should be guided by application-specific access patterns which are based on main queries to be fulfilled by the database.

This does not, however, imply that NoSQL databases have no models or schema, on the contrary, they need the model even more than other approaches. In a NoSQL database design, the model follows an agile approach, starting with the basic schema for the respective collections and documents, as the application evolves does the schema. The basic schema is closely aligned to the queries about the questions meant to be answered by the database. The agile approach further allows for both the schema to evolve over time and also make provision for new queries that may arise due to the changes. In this study, the researcher made use of Moon Modeler (which is a data modelling tool for document-based databases) to model the conceptual database schema as outlined by the figure below:

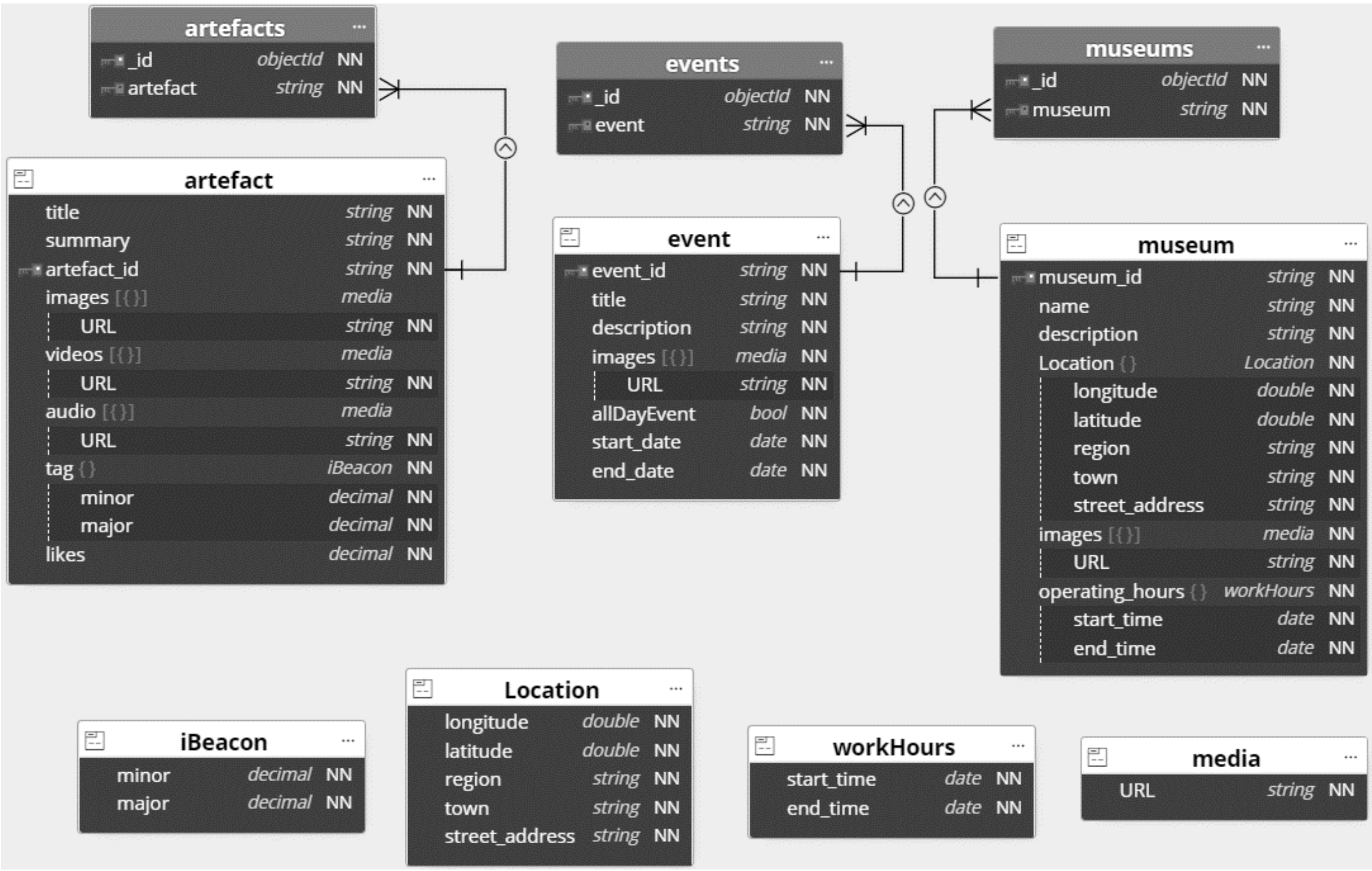


Figure 5.3-1: Conceptual data model for the museum system

Figure 5.3-1 above provides a snapshot of the overall data model for the system and as indicated earlier, we adopted a NoSQL database with agile design approach, in so doing, the data model is mainly focused on the collections and documents to be stored in the database as these directly speak to the expected queries for the system.

NoSQL databases are often document centred and just as illustrated in the figure above one cannot make out relationships between documents, however, in a NoSQL database relationships are mainly represented by the embedding of documents within one another. The sentence below explains this concept with the use of the museums' collection.

The museums' collection stores a list of selected museums for testing the system, these details are then used in the web or mobile application to clarify museums by region, towns and even calculate museums that are closest to the users. The museum document contains about three more embedded documents which are: location to get the exact coordinates of the museum, the operation hours which is when the museum opens and closes plus an array of images that is in actual sense a list of URL links to where images about the museum are stored. The system has more collections and the figure above is just a snapshot of the collections and possible relations that exist in the systems. The use of embedded documents allows most NoSQL database to upscale and downscale data hence allow the systems to access and manipulate related data in one single operation.

5.4. Summary

The above sub-topics have concentrated on a design that clearly outlined the system architecture, its main components, their interaction and data flow plus the manipulation of these data by the system. This architecture has been intentionally adopted to fulfil user requirements that were in chapter 4. The researcher has taken into consideration trends in development concerning the system integration of external tools and room for change in technology hence the adoption of agile approach even on the database design and modelling. In the chapters that follow we explain how this design and models were implemented plus what the results were.

6. SYSTEM DEVELOPMENT

This chapter describes the overall development process, frameworks and tools used, rationale behind using them and highlights challenges faced in the implementation process. We clarify how we followed the design and to come up with a practical working system that is relatively easy to use and conforms to the normal behaviours of most applications in the market.

6.1. System Development Environment

The two frameworks (Angular and Ionic) selected for the system implementation offered the researcher the flexibility of tools for designing and development. This in itself provides room to explore various tools and evaluate them for the desired outcomes, thus contributing positively to the system. However due to familiarity, a few tools were adopted across all stages of this study and seeing as the study's focus was not on graphical design, most of the components that required designs such as icons and any other graphics were obtained from free online sources.

The study adopted an agile software development approach hence the process was iterative and incremental, lead up to multiple versions that were tested and recommendations from these tests used to improve the later prototypes/versions. The development environment and all tools for this study were run on a Macintosh Computer running macOS Mojave operating system, this was mainly done to allow for building and deployments of iOS incremental prototypes. The computer was further installed with nodeJS to act as a local server for testing the web application.

Visual Studio Code was used as the overall Integrated Development Environment (IDE) for this study, this is due to its compact design and ability to expand depending on the required plugins. The power in the frameworks adopted lies in the open integration to almost any tools or features available and the fact that they are open-source meant that they are both rapidly growing with new updates and hence this study's approach of incremental builds fits perfectly in these frameworks. The overall system design was made easy by the outlined open integration of the frameworks used. A combination of Bootstrap and Material design was used in the design of the web application and for the Cross-platform mobile application Ionic comes preloaded with default toolkits for all supported platforms, additionally, it allows for the developer to import external UI toolkits into their projects.

6.2. Front-end and Visual components

The system' front-end is composed of two main visual components, one for the web and the other for mobile. This distinction was made at an early stage to prevent confusion in the development process and to clarify the difference in behaviour between the web and native mobile application. The subsection below explores the distinction further.

6.2.1. Web Application

The web application is mainly meant for the museum's staff members as a content management platform, but it also serves as a marketing and information sharing platform for the independence memorial museum and other museums county-wide. The development was done using Visual Studio code, which is an IDE created by Microsoft for development of web, mobile, desktop and cloud applications, it is rich in tools optimised for modern application development and has a flexible architecture that easily allows for integrations of new tools.

Angular (previously called AngularJS) was the main framework used for the development of the web application. Angular is a typescript-based web development framework that leverages the power of JavaScript for its logic and the flexibility of HTML5 for visual components. Typescript is merely a superset of JavaScript, hence trans-compiles to JavaScript for enhanced performances but expands the language with optional static typing and supports extra modules such as JQuery and NodeJS for more functionality. The styling and arrangement of components were based on Bootstrap and Material Design, this meant that the researcher spent less time on the implementation of components in terms of visual arrangement because both bootstrap and material design have predefined styling, one just needs to know how to use it in their components. Angular allows for code reusability in that different components of the web application are considered distinctively with controllers and logic through services that integrate it into the overall system. The researcher adopted the single-page application (SPA), by dividing the web application into sections but loading all components at once and avoid delays between consecutive page loads. Below are a few screenshots of the web application.

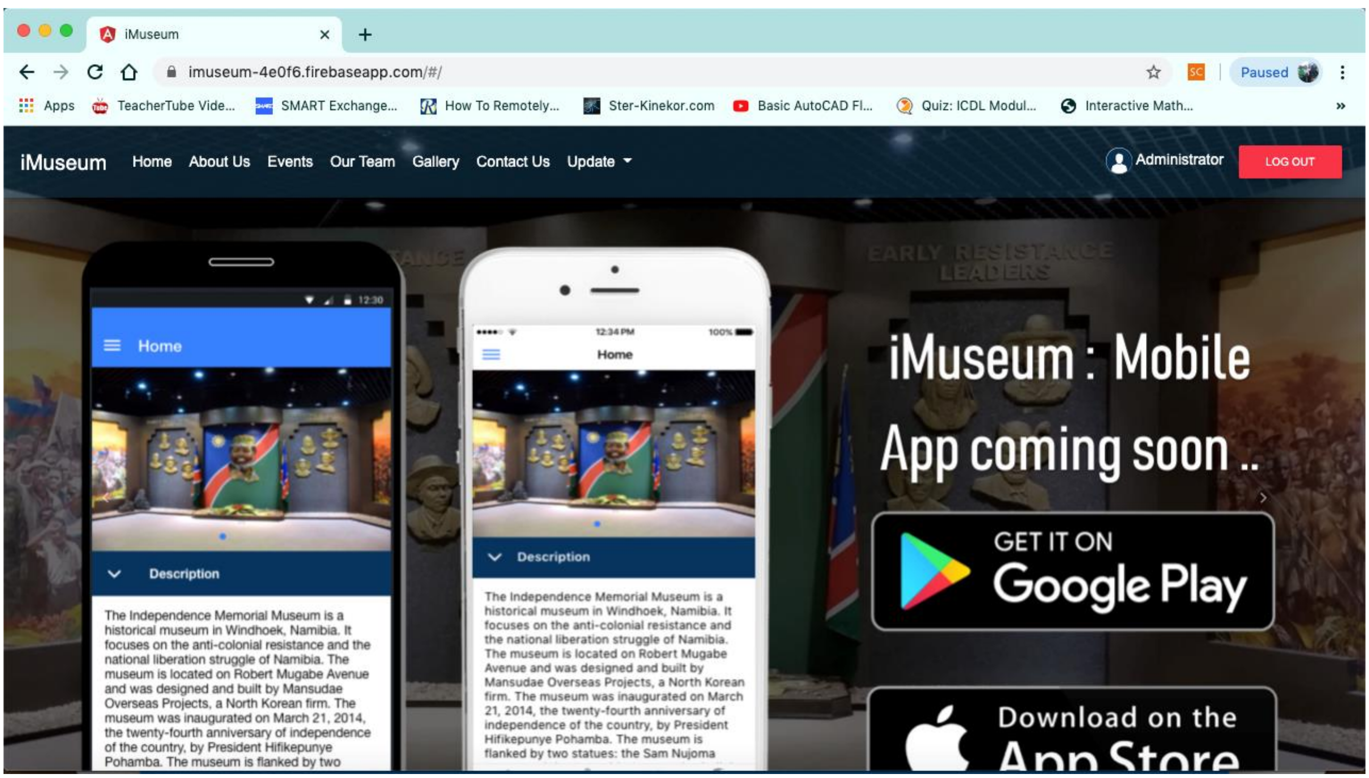


Figure 6.2-1: Web Application Landing Page

The landing page is the first page that the user sees opening the web application and since it was designed as a SPA, the user is able to scroll through from the Home page until the contact us section which has a live map plus contact details of the museum.

The landing page has two options, when the user is not logged in and when logged in. The logged-in option allows for content management and if not logged in, the page behaves like a normal site without additional options.

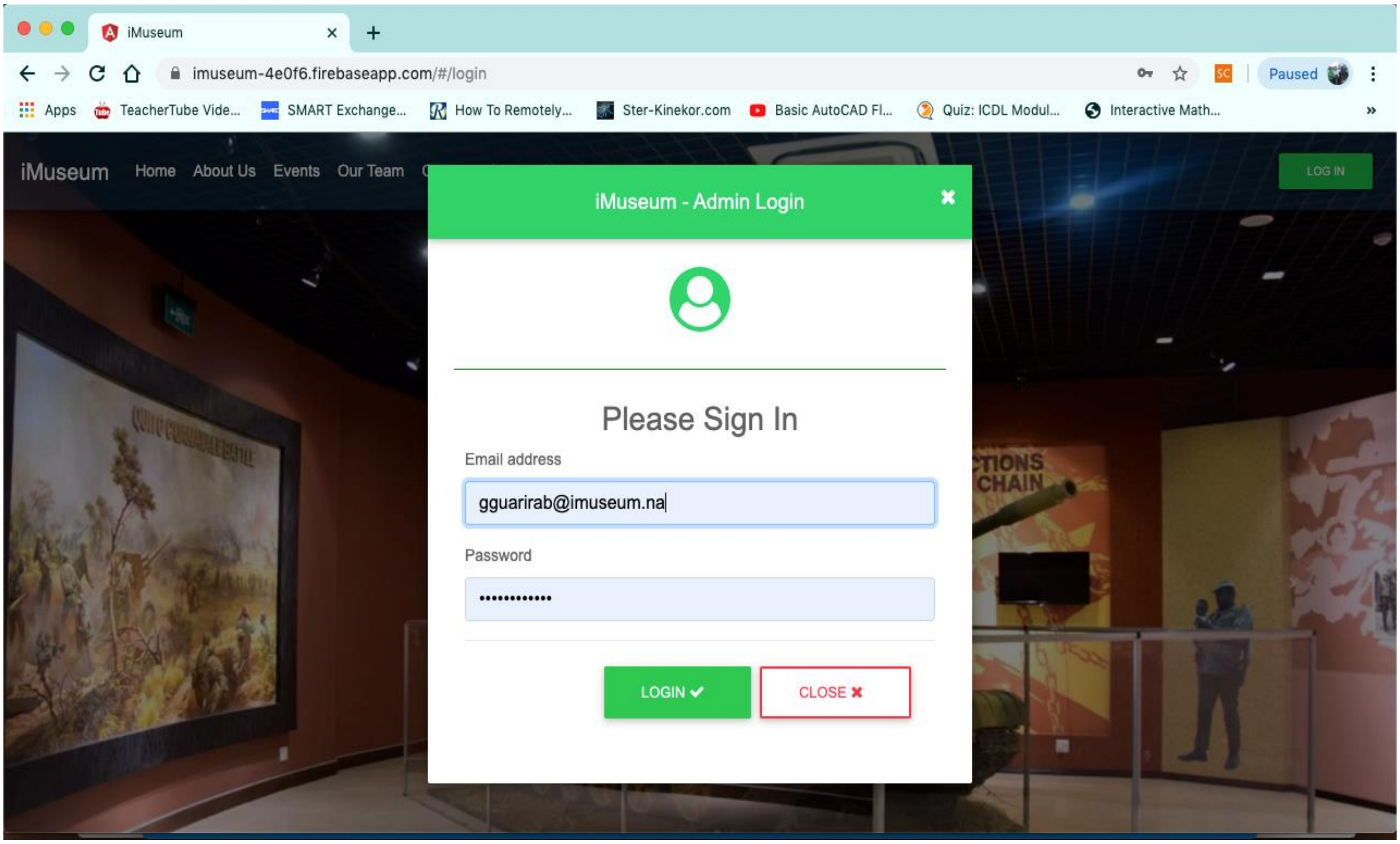


Figure 6.2-2: Web Application Login page

The login page (as shown above) is in actual sense a modal or a popup screen that allows the user to provide the login details and authenticate before proceeding to administration options. Once successfully logged in the navigation bar gets an extra link called Update and it allows for all the content management options to be carried out. The page also recognises the user by displaying the profile picture and names on the top left corner (see figure 6.2.1-1).

Figure 6.2.1-3 below provides a snapshot of how the application displays a list of events, it further has to be noted that the system automatically filters events by their start date and end date, this only shows events are currently happening or are yet to come.

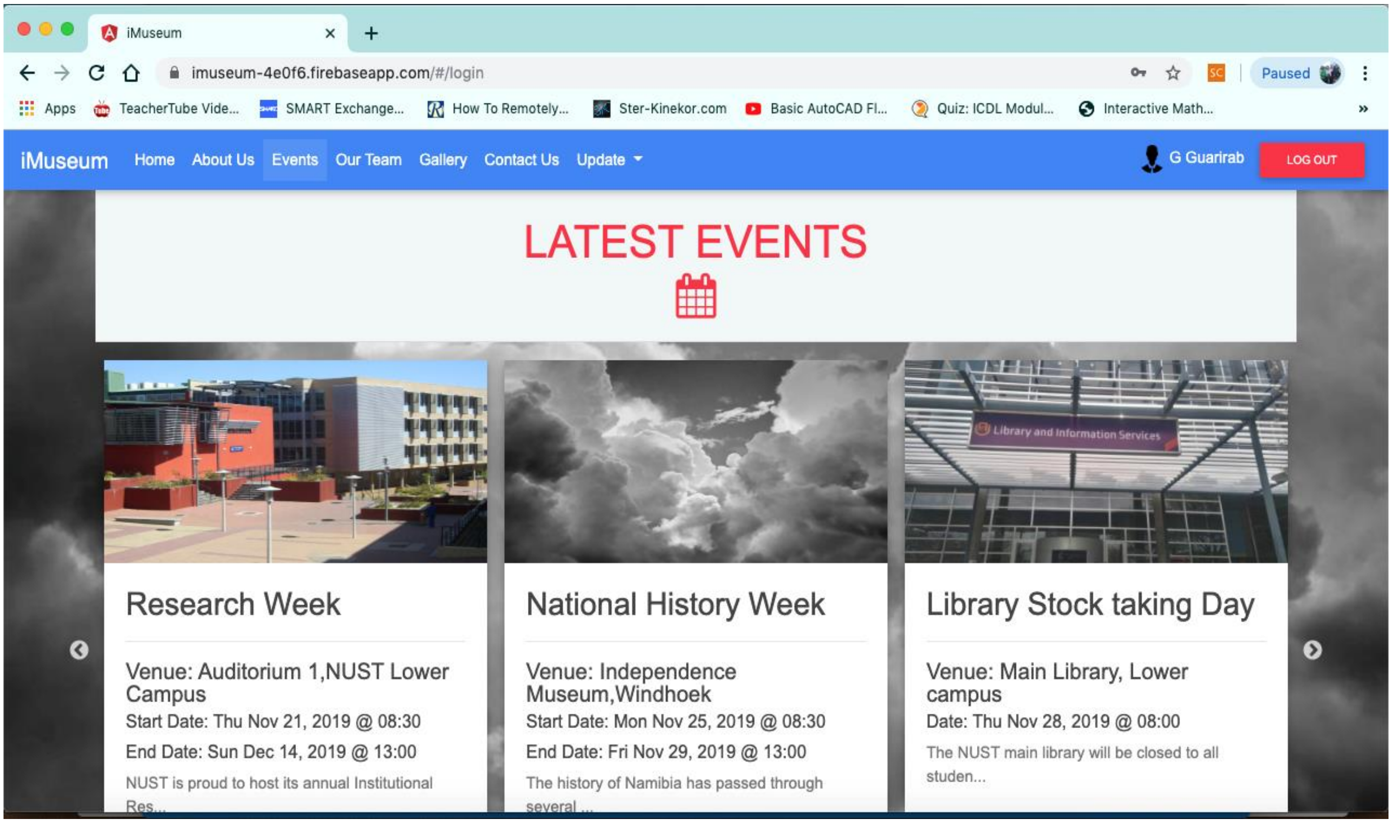


Figure 6.2-3: List of recent events

The system functionality is quite extensive hence going through all the pages and views could take up space in this dissertation, however below is an overall site-map of the web application.

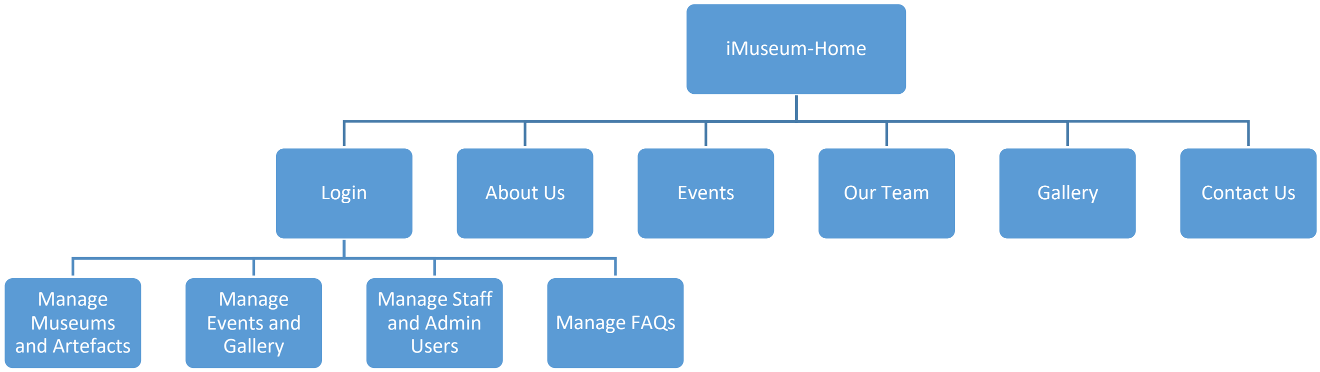


Figure 6.2-4: Complete web application site map

6.2.2. Cross-Platform Mobile Application

The mobile application took up the biggest chuck in this study be it during design or development. The researcher paid close attention to the components because they are the main front-end interface for the user or visitors and all users that are prospective visitors. The study adopted the development of a cross-platform application targeted at Android and iOS as per the initial findings prior to this study, however, this meant that the design and implementation should be unified with consideration of differences in features of the mobile operating systems.

Ionic was the optimal framework selected for this study, due to the fact that it is based on angular and allows the application logic to access the native features of the respective mobile devices. This further meant that a common application logic was shared for both the web and mobile application, or when necessary a few services were modified to fit the platform. The Ionic framework makes use of web technologies, leading to an effortless process of designing and developing high-performance mobile and Progressive Web Apps (or PWAs) that embrace the original look and feel on any platform or device, and further has a rich and flexible library of front-end components and UI-toolkits making it easy to design beautiful visual components (Ionicframework, 2019).

One of the core aims of this study is to provide a personalised view to the museum visitors and hence the choice to implement a cross-platform mobile application because this has an impact on the look and feel of the end product. The UI-toolkits used by Ionic plays a crucial role in attaining the expected look and feel for every mobile platform and hence during development the visual components take up the normal application behaviour on the respective platforms allowing the researcher to further leverage on the native features of the mobile devices and hence making the application to function seeming less like an ordinary native application. The visual components subsequently conform to the different platforms by making use of default icons found on each platform and this allows for a reduced learning curve and easy adaptation of users to the application.

The native access provided by Ionic further allows for the cross-platform application to have the same input options and gestures responses from the users as offered by native applications. User to application communication is a crucial aspect in developing mobile guide application that aims to tackle visitor's experience as it is closely related to the over interaction of the user with the application and objects around the museum in forms of artefacts, this further aligns to the modern approach of museums by being visitor-centric (Kassim, M. H., Eshaq, A. R., & Woods, C. P., 2019). With this in close consideration, the researcher in developing the system allowed for normal touch inputs and swipe gestures for controlling things such as the side menu or navigation through the respective galleries.

Below are a few screenshots for the mobile application based on the use cases outline earlier. All the modelled use cases as is shown below has two options, one to illustrate the look and feel on iOS and another for Android devices.

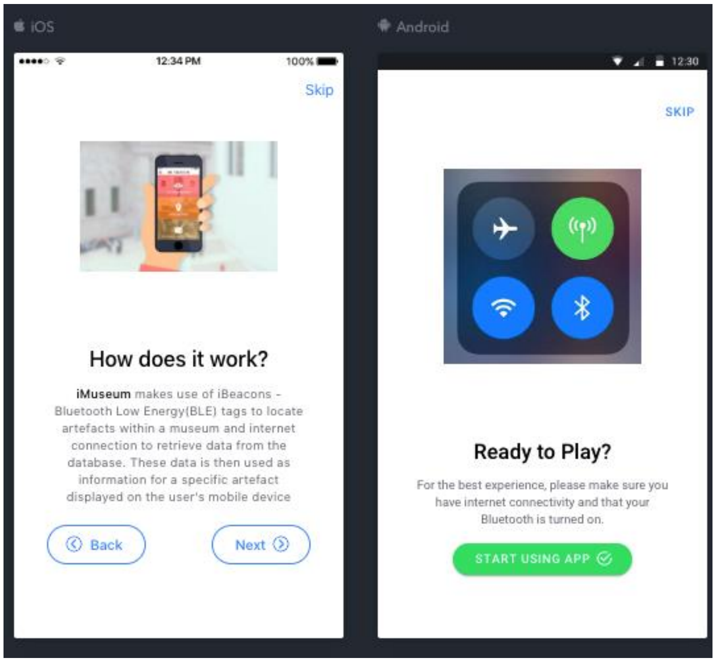


Figure 6.2-5: First Start Tutorial

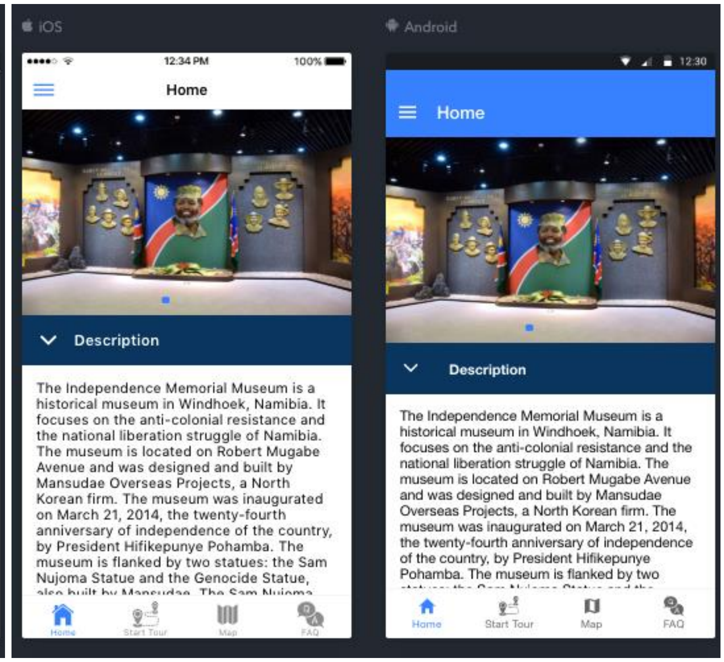
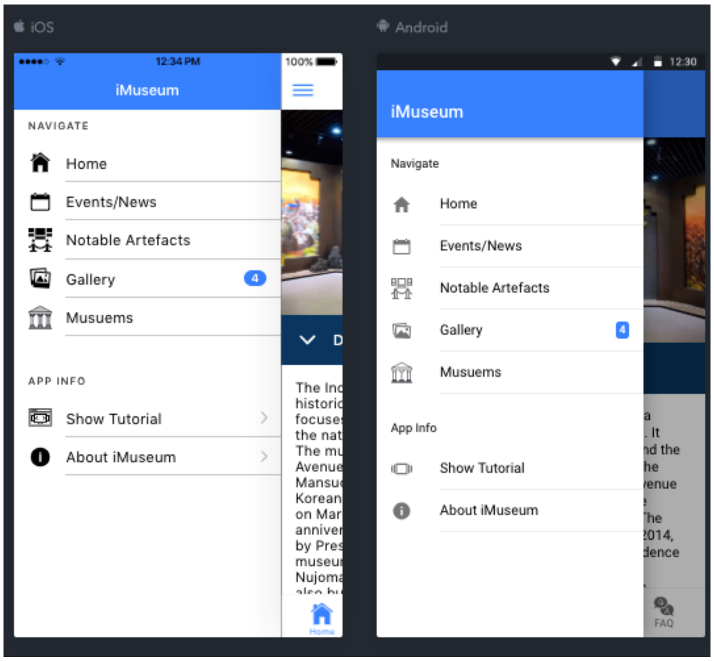


Figure 6.2-6: Landing Page

The application has an in-build first time start-up tutorial (Figure 6.2.2-1) that provides the user with an overview about the application and what features to expect, this only runs the first time after installing the application or if the user wants to re-open it from the side menu options. The landing page (Figure 6.2.2-2) is the next page that comes and is the normal start-up page for the application. In addition, the application also supports a common trend in mobile application development which preserves and restores the previous application state every time an application is normally closed and opened.

Figure 6.2.2-3 below illustrates the applications side menu, which is a very useful option and the user can access it by sliding their finger from left to right or just clicking on the bars that denote menu options. The icons for the side menu just like most options in the application adopts default icons from each platform. The next figure (Figure 6.2.2-4) illustrates the most crucial feature of the mobile application- searching for artefact near to the visitors, this option is key to the application because it is at the heart of the self-guided mobile tour which was explored by this study in an attempt to enhance the museum visitors experience. Once the visitors start the guided tour the application services for searching artefacts using Bluetooth low energy runs in the background looking for artefacts and will only stop if the application is closed.



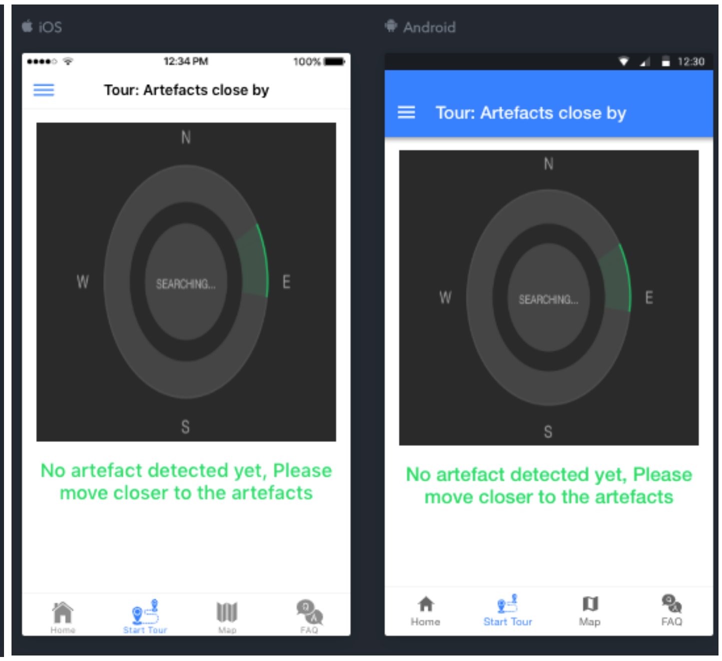


Figure 6.2-7 : Side Menu

Figure 6.2-8: Searching for Artefact

Figure 6.2-9 below shows the alert or pop-up that is displayed once the application detects an artefact close to the visitors and additionally provide a list of other artefacts around the visitor. From the alert, the visitors can either view to see more information (Figure 6.2.2-10) illustrates as well as look at videos or listen to audios about the artefact if they exist. The artefact view also allows the visitors to like the current artefact and hence making it popular such that when other visitors view the application suggests to them which artefact or most view or most liked.

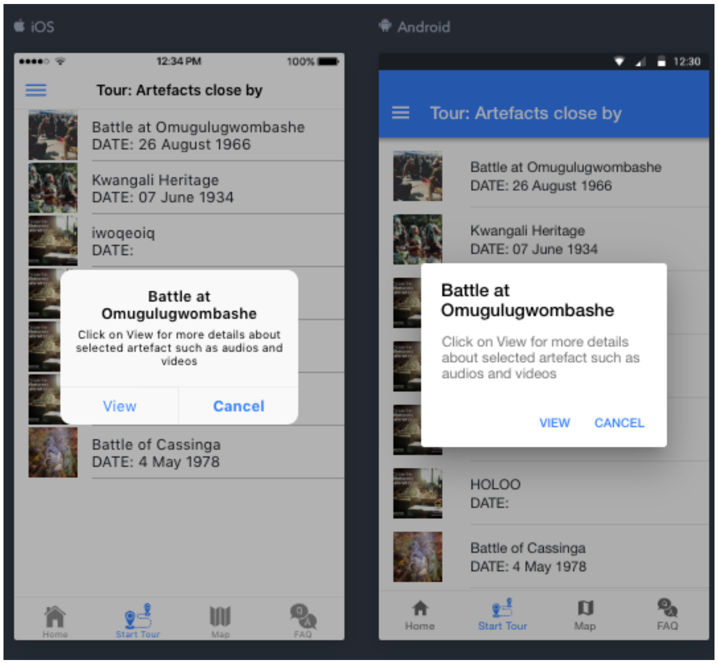


Figure 6.2-9: Artefact Found Alert

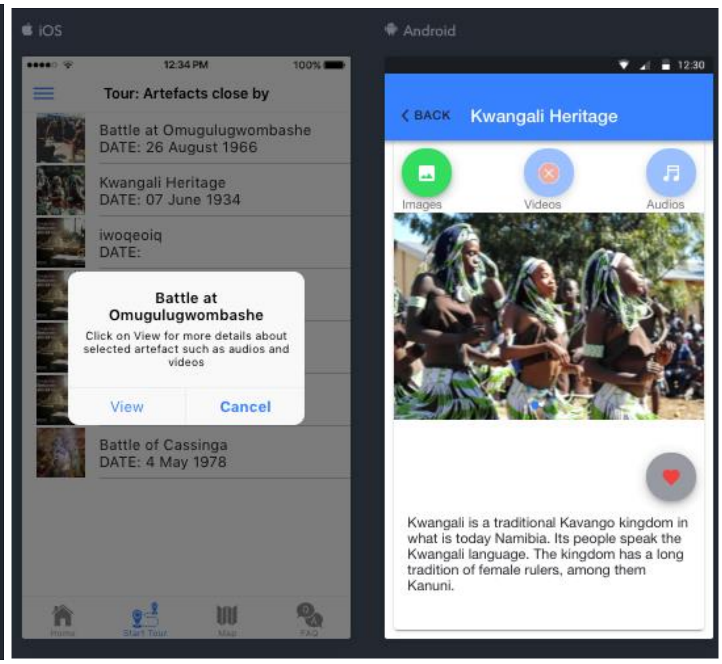


Figure 6.2-10: Viewing Artefact info

Figure 6.2-11 and -12 below are screenshots for the listing of ongoing/upcoming events and views of museum lists by either regions or towns respectively. The events list helps keep users informed about latest happening at the museums and the museums list is very helpful for visitors to find out museums within their regions and as for the international visitors, it becomes more helpful for them to pick out the town in which they are and be able to get directions or further information by calling the museum.

Figure 6.2.2-13 shows the page that opens when the user clicks on the option to view the museum information as a follow-through after the museum list. The last figure (Figure 6.2.2-14) shows a view listing the most popular artefacts viewed and liked by visitors, the list is sorted in descending order with the most popular artefact on top of the list.

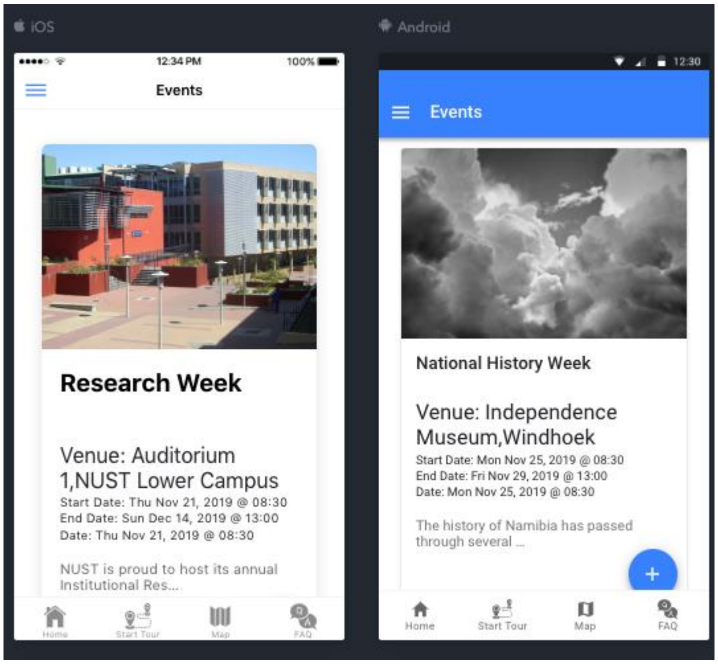


Figure 6.2-11: List of Events

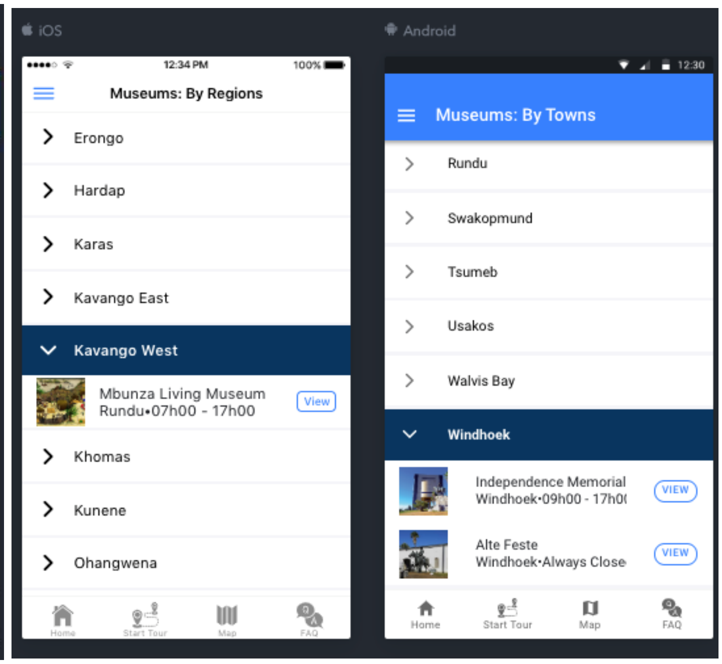


Figure 6.2-12: List of Museums (By Regions /Town)

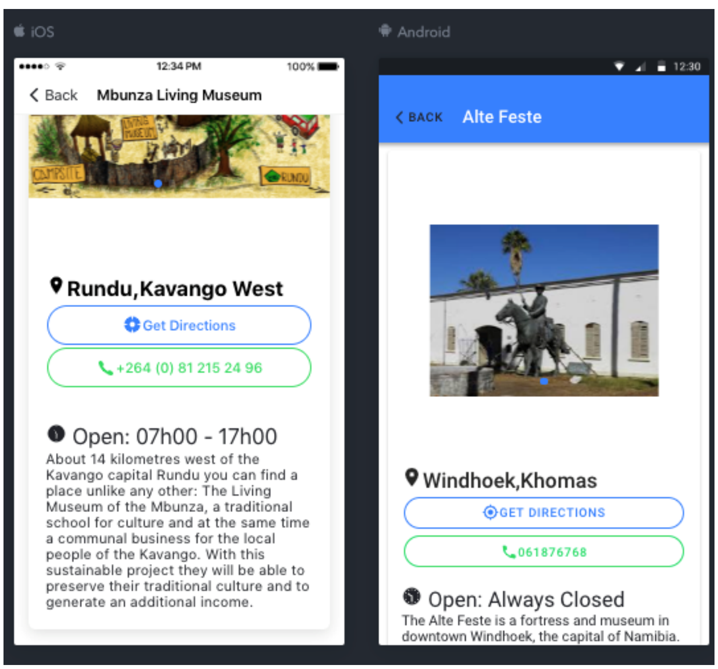


Figure 6.2-13: Viewing Museum details

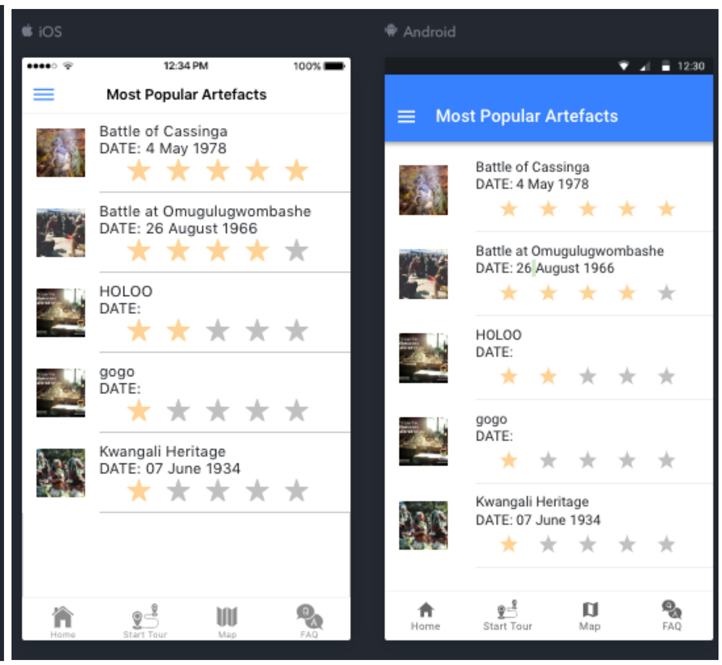


Figure 6.2-14: List of popular artefacts

6.3. Business logic

The business logic as indicated in chapter 4, acts as an intermediate between the visual/presentation layer and the data layer. In this study, the researcher made use of Typescript to handle the business logic and due to the similarity in the frameworks used, this logic was shared for both the web and mobile application. To simplify the process much further the system relies on services to do most of the functionality, one common service was used for checking and monitoring internet connection. Both applications need data from the Firebase backend but have options to use local data either stored in the system cache or the offline firebase files. Below is a code snippet for the network service.

```
export class NetworkService {
  //internet status observer
  private online$: Observable < boolean > = Observable.create(observer => {
    observer.next(false);
  }).pipe(mapTo(false));

  constructor(private network: Network, private platform: Platform,
    public toastController: ToastController) {
    //set observer to false by default
    this.online$ = Observable.create(observer => {
      observer.next(false);
    }).pipe(mapTo(false));

    //detect network disconnection and change observer status to FALSE
    this.network.onDisconnect().subscribe(()=>{
      console.log("DISCONNECTED")
      this.online$ = Observable.create(observer => {
        observer.next(false)}).pipe(mapTo(false));
    });
    //detect network connection and change observer status to TRUE
    this.network.onConnect().subscribe(()=>{
      console.log("CONNECTED")
      this.online$ = Observable.create(observer => {
        observer.next(true)}).pipe(mapTo(true));
    });
  }
```

Figure 6.3-1: Network service operations

Another crucial service required in the system's logic is the one that pulls the data from firebase, the researcher has a combined service to handle all firebase API calls and it is in this service were data is filtered if needed, below is a code snippet from the firebase-data service.

```
//get all artefacts in database
getArtefacts() {
  return this.firebase.list('/artefact');
}
//get the 5 most popular artefacts
getPopularArtefacts() {
  return this.firebase.list('/artefact',{
    query: {
      orderByChild:'likes',
      limitToLast:5
    }
  });
}
```

Figure 6.3-2: Firebase-data service

The systems main objective is to be able to detect artefacts close by, this function is dependent on the system searching for beacons close to the device and using its identity to query information about the artefact. The beacon service was hence one of the complex to implement as it requires timing and continuous usage of resources, below is a code snippet used to detect artefacts close by and display the popup alert.

```
    /**Detecting of artefacts close by and making sure it doesn't display the artefact
     * that is currently being viewed*/
    if (this.beacons.length != 0 && this.beacons[0].major != this.currentID) {
      console.log("Detected");
      this.currentID = this.beacons[0].major;
      this.currentArtefact = this.artefactList.find(x => x.major_id === this.currentID)
      this.presentAlert(this.currentArtefact.title);
    }
   }else {
    //search for new artefact every 15 seconds
    setTimeout(() =>{this.updateBeacons = true;}, 15000);
     this.currentTime = new Date();
  }
```

Figure 6.3-3: Beacons detection and monitoring service

6.4. API

The system adopts a RESTful API approach, REST stands for Representational State Transfer and two main components are considered crucial in this approach that is the resources and the client. The resources are stored and served by the server or data store, these in our case are the media files and Metadata or supporting information usually in text format. The client refers to the systems that use the API to access the resources, for this system the services explained in sub-section 6.3 acts as the clients and they transfer and transform the resources ready for the system's visual components to represent the data easily.

One key feature of any RESTful API is that offers the client a clear representation of the current state for the requested resource, this representational state can be in any format and for this system JSON was used for its compact nature hence allowing for speedy transfer of data. The researcher made use of two main API from Google namely the Firebase RESTful API for the firebase database and the Google maps API for handling all the map request, hence there was no need to design and develop a new API.

6.5. Database implementation

Following the data models as discussed in chapter 5, sub-section 5.3: database implementation was straight forward because now the researcher was guided and with the use of a NoSQL database concentration is mostly on the actual data. Most NoSQL databases are highly scalable and support real-time synchronization, these were the main reasons for using Firebase plus the fact that with this approach the system implementation does not require extensive database management skills.

The key data components as illustrated by the data models were to model artefact information, museum information, gallery details and events information. During Implementation, however, some of the models had to be modified to suit visual components and planned API calls. The web application is more internet-dependent hence most of the information is only retrieved on request and always offered real-time data, this becomes an advantage in that the ordinary users get to see information being updated. However, as a normal approach, the meta-data is stored in the local cache preventing the application from making repetitive calls to the database. The mobile application, however, has a different yet interesting approach to the data usage. The application comes pre-installed with offline data enabling it to operate without internet connectivity and this was the motivation behind having a network monitoring service which allows the mobile application to be aware of the current device's network status. The offline data also means the system does not need to be fully dependent on data query from the real-time database but rather keeps track of update time or timestamps when the database was last updated. The application then keeps using the local data if the timestamps are the same whereas if the database was updated later then it uses online data and synchronize with the offline data on closing the application. Below are a few figures illustrating some of the few data models and structures stored in our Firebase database.

Figure 6.5-1 below show a sample document from the artefact collection will all the details and just like indicated in our data model, every artefact has a title, summary, date and media URLs for images, audio and videos whenever available. The iBeacon tag information has been modified to store only the major and minor id, the ideal behind the id is to categorize related artefact with the minor id and use the major id as the unique identifier for each artefact. The likes field is used to measure the most popular artefact and hence used to encourage other visitors to see the artefact.

Figure 6.5-1 : Artefact list and details

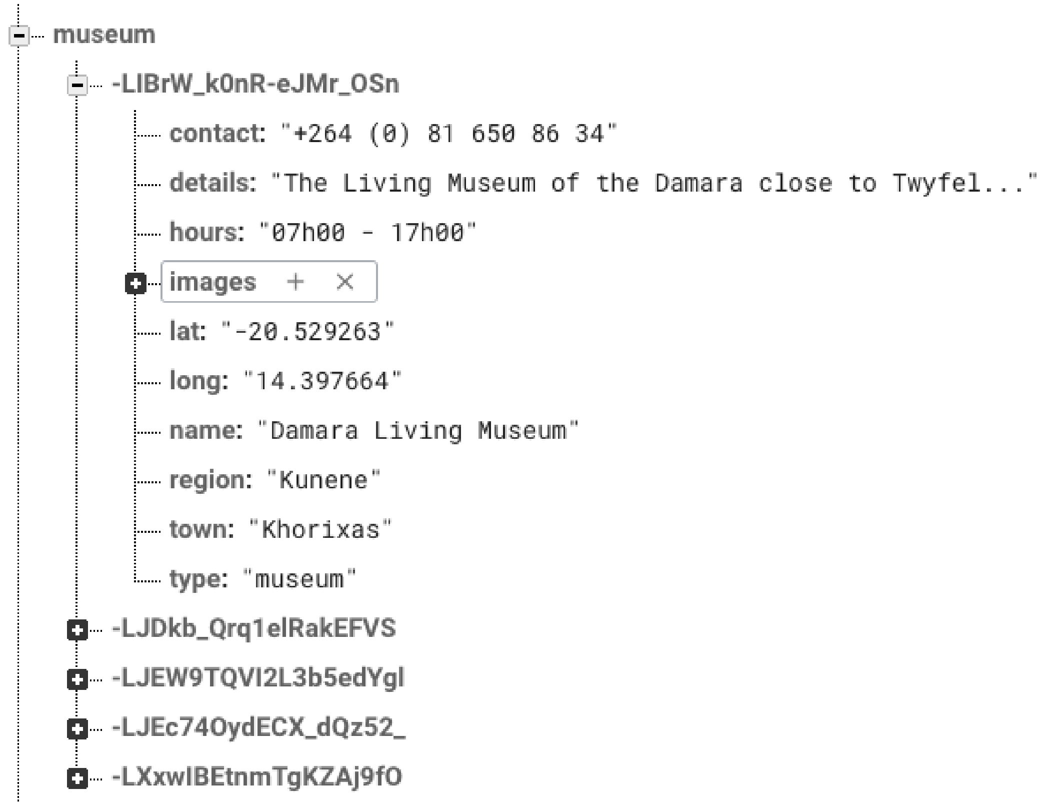


Figure 6.5-2: Museum list and details

Figure 6.5-2 above is a snapshot of the museum list, the structure is similar to the artefact model in 6.5-1 with modifications to the location object by breaking it up and using the field such as the latitude and longitude for geo-locations, then using the region and town for further categorizing as is shown in the mobile application when listing the museums.

Database access and manipulation are usually governed by access rules and Firebase offers these access rules for any developer to customize it as suited for their application. In this system we opted for a simplistic and minimal rules setup, however a strong emphasis was made to make sure not everyone could make changes to the data. An important decision taken when implementing the database rules was to allow all users to be able to read or view data from the database. Writing new data and updating of existent data was strictly set for only authenticated users who are either museum staff members or the system's technical users or administrators. The Web Application is designed and build based on these rules and hence it restricts ordinary users from some of its visual components or options that are only available to admins.

Additionally, a special rule was implemented to allow every user to modify the likes field of each artefact, this then means when a user/visitor in the museum is enjoying the artefact they would click on the like icon and increase the popularity of the artefact.

```
{
  "rules": {
    ".read": true,
    ".write": "auth != null",
    "users": {
      "$uid": {
        ".write": "$uid == auth.uid"
      },
      "artefact":{
          "likes":{
            ".write":true
          }
      }
    }
  }
}
```

Figure 6.5-3: Database rules for Firebase

6.6. Development challenges

Every system development is most likely to be challenged throughout the process and the system was no exceptions. The first issue was encountered as early as the design of the database structure, the researcher was faced with a lack of data and content for museum artefacts and the museums themselves. This then meant that the system data model was started from scratch and constantly update when new ideas or information came to light, however, the agile approached helped to mitigate a few of the issues arising with time. The lack of content was mainly on digital data be it electronic format description or media files corresponding to the museums was nowhere to be found. The researcher, in the end, resorted to the use of information acquired directly from the internet.

The frameworks adopted also came with their own challenges, and one eminent issue was the constant updates of libraries used by the frameworks. Updates usually meant an improvement in functionality, however, the challenge was mainly due to backward compatibility issues hence most libraries once updated might not be compatible with previously compatible libraries, this meant that a few of the functionalities had to be modified to suit the changes. The biggest issue was usually raised when libraries auto-updated overnight and the next time system is run, it is totally broken.

The initial idea was to set up a local server and data store, this approach meant considering stable standby time and system security which could lead the researcher exploring database design and implementation extensively and ultimately this could require more time for the whole project. The adoption of Firebase drastically reduced this time hence staying on track and within the scope of the project.

Internet connection was both an issue during implementation and testing while adopting Firebase was a plus, it then meant the system must have a constant internet connection for data exchange. The testing site- independence memorial museum does not have a stable internet connection or any wireless internet access point, this then meant for testing the research had to provide a portable hotspot and in most cases do testing in a simulated environment.

During testing one aspect that the web application offers is the updating or adding of new information about artefact, museums, events and other details required. The system was designed to initially reverse geocode street addresses into geo coordinates (latitudes and longitudes), this was not successful for most museums as not all museum names or location could be resolved using the Google Maps API. The researched hence had to manually enter the geo-coordinates by physically looking through maps and pin-pointing the respective locations.

Cross-platform development is praised for having a common codebase, however, issues actually arise during development when reference is made to native features on the respective platforms. The researcher hence had to have some special condition when dealing with some features to make sure the applications behaves the same. One feature was the use of Bluetooth low energy where different access rights are used on iOS and android.

The list of minor challenges faced throughout the development could be much longer, but the take away from the overall process is that the researcher managed to provide a suitable implementation workaround and in the end learnt new concepts and approached in cross-platform implementations.

The systems prototype was later tested for usability, results and recommendations from this practice is discussed in the chapter that follows.

7. SYSTEM TESTING AND USABILITY EVALUATIONS

7.1. Introduction

System testing is a crucial process in the software development lifecycle, it is mainly used as a validation and verification step for the system or application developed. The process is based on the initial requirements against the actually implemented features, on one end we are looking at making sure the system developed meets the requirements and on the other end we evaluate the development process to ensure the system produced actually follows the requirements. This study's system testing was mainly used for validation and with the adoption of the agile development approach, testing was repeated several times and was the main informative step of every sprint.

This chapter is focused on the last system testing and user evaluation, which dealt with the largest system outcomes from all the cumulative deployment or incremental deployments of the system. This was done due to the fact that most features were only fully implemented towards the end of the development process, however, throughout the different sprint smaller units and functionalities were tested before being incorporated into the whole system.

The main objective of this study was to design and develop an interactive museum mobile guide aimed to enhance the visitors' individual experience in the museum. Two parts of the system were developed, one part is to be used as content management and the other as the main interface and interaction point between the visitors and artefacts. However a few aspects are required for complete testing of the whole system, this includes data related to artefacts, iBeacon tags and their relation to the artefacts and museum coordinates to locate plus direct visitors. Data collection as outlined earlier was a slight challenge during development, but for the sake of testing the system's usability this study made use of dummy supporting data for artefacts and as for locations made of google maps to gather coordinates and populate the database.

Below are a few sections on the system testing against the initial functionalities outlined earlier.

7.2. System overview demonstrations and testing

The overall system developed was meant to be used by both the museum staff members and visitors, however, the backbone of the system lies on the web application of the system as it is used for content management and without this, the system is incomplete. It was deemed necessary to demonstrate to the staff members the system's key features and expected behaviours, allowing the researcher to engage with the museum management and a few members to further clarify the studies objectives, what had been done and most importantly the staff members roles in the system.

After the demonstrations, the staff members were well informed about the system and were ready to do usability tests that were focussed on a few aspects of the system. The demonstration additionally allowed for further inputs or reformed ideas to be discussed between the researcher and the museum management.

The same approach was made on the cross-platform mobile application, a group of testers were first briefed about the application they were about to test. This briefing was given as a presentation starting off with the study's objective as well and key features for the mobile application. The researchers further outlined the initial functionalities as indicated by the functional requirements. Providing the objectives and application requirement allowed the testers to focus on how the mobile application intends to solve the research problem and hence more attention is paid to the key features of the application. Testing of the mobile application was simulated in a computer laboratory, using sample artefacts tag with iBeacons and placed around the lab, allowing the testers to move from one artefact to the next. The movements while testing allows for a more realistic setting for the testers and the application as well.

7.3. Testing Criteria

The sub-section that follow briefly explain how testing was carried out based on the initial requirements and outlined use cases, however more attention was paid to the overall usability of the mobile application than was given to the web application.

7.3.1. Functional Requirements

During the requirements elicitation process, key features of both the web and mobile application were identified and then represented as use cases. The use cases played an important role during the system design and implementation as it clearly outlines the users of each feature hence allowing the developer to be biased in implementation knowing who is the user and possibly their capabilities. A more informed development leads to a developed system that is more inclined and more usable for the target audience.

However, during testing, the system use cases are evaluated based on real-life scenarios to validate implemented features against requirements.

7.3.2. Non-Functional Requirements

Non-Functional requirement as indicated earlier play a crucial role in the usefulness of the system and with a key objective of this study being base on usability, it is even more imperative that the system's non-functional requirements are closely considered. Another crucial aspect is the system performance. Even though it is not easily measured, good performance in a system means the user is able to accomplish the main tasks with ease and without system interruptions. The system developed has other factors contributing to its overall performances such as internet speed when streaming media files and fetching or updating information on the database, nevertheless, the system has offline functionalities hence can perform normally once slow connectivity is detected.

7.3.3. Acceptance Test

At the heart of every system testing and development's lifecycle is acceptance test which looks amongst other to evaluate the conformity of the developed system against the requirements as set out in the beginning and most importantly to determine the system's acceptance for delivery. The system is evaluated using real-life scenarios to ensure that the system meets the needs of the prospective users and conform to the requirements. The following are the scenarios used:

A) The first scenario evaluates the system's ability to detect the user's current location and get directions to the preferred museum.
B) The second scenario demonstrated the main feature of the cross-platform mobile application, which the ability to detect iBeacon tags(artefacts) nearby
C) The Third scenario demonstrates the systems offline capability and hence was tested by listing all upcoming events while offline

All scenarios were carried out on real mobile devices with Bluetooth low energy compatibilities and using real data.

First Scenario: For this scenario, we assumed the user is new in Windhoek and hence was browsing through all museums within the city. This scenario was carried out with the user located at Safari Court Hotel, to make the scenario more real the user was in motion hence testing the accuracy of the system to locate the user and also offer directions and route options to get to the museum. The table below provides a summary of the outcomes of this scenario.

ID	TestCase_01
Title	Detect and directions from current location to the museum
Pre-Conditions	Location or GPS services enabled Internet connection
Steps to follow	1. Open the side menu and click on museums 2. Select by City category

	3. Select preferred museum under your City of choice 4. Click on get directions under museum information
Expected Results	The Museum information offers an option to either call or gets directions to the museum Clicking on get directions opens Google maps or opens a list pre-installed map apps When Google map opens it shows directions, distance and alternate routes plus travel options from the user's current location to the museum This offers native turn-by-turn directions and if the user's phone had an alternative map app installed, that app also attempts to offer native directions
Accept/Reject	Accepted
Comments	Procedure quite long and complex, consider an alternative

Table 1: Results of directions to museum test scenario

Second Scenario: In the second scenario we assumed the user is touring the museum and comes across an artefact of interest. This scenario is very crucial to this study focuses on the interactivity, responsiveness, ease to understand and accuracy of the system. This scenario is considered important because it involves a contributing factor to the museum visitor's experience. The user's interaction with the system and how the system responds plus how easily the overall operation is, can either be pleasant hence enhancing the users experience or unpleasant leading to the user being distracted and in the end reducing the user experience. This scenario further demonstrates how the automated museum mobile guide works including how close one needs to get for an artefact to be detected. Below is a summary of the result of this scenario.

ID	TestCase_02
Title	Detect artefact near
Pre-Conditions	The device is Bluetooth Low Energy compatibility Bluetooth enabled Internet connection
Steps to follow	1. Click on start tour 2. Move closer to an artefact 3. Click on view when an alert comes up
Expected Results	Once an artefact is detected an alert is shown, prompting the user if they want to view more details about the artefacts Clicking on view shows the artefact view, which shows more images about the artefact and offers options to see more media files. The user can click on the other media files and view them The artefact view also allows the user to like or love the artefact and hence making the artefact popular
Accept/Reject	Accepted
Comments	The procedure worked very smoothly

Table 2: Results of starting mobile tour test case

Third Scenario: This scenario simulates a user that has no internet access but would like to find out some information about the museum events and technically even tour through a given museum provided the Metadata of all artefacts have been uploaded prior. The user is hence able to do most of the operations on the system and the system will use place holders where internet connection is required such as display media files or streaming them from the server. This scenario in a way demonstrates consistency and performance as the system is able to discover that it is not online and then make provisions for working offline. The performance part is covered in that the system once it picks up a slow or no connection switches to the use of local data and seemingly do the same once the connection is restored.

ID	TestCase_03
Title	View list of upcoming events while offline
Pre-Conditions	No or low Internet connection
Steps to follow	1. Click on the side menu 2. Click on Events / News
Expected Results	Once the Events/News option is clicked, the event view shows a list of upcoming events Due to no or low internet connectivity, all images are replaced with placeholder
Accept/Reject	Accepted
Comments	Application loads smoothly and faster while online

Table 3: Result for offline test case

Tables 1 – 3 above outline test result of the cross-platform application, using three common scenarios that an ordinary user might be encountered and even though not all possible test cases were extensive covered, it gives a great impression about the interactivity and flexibility of the application for the user. The next section that follows outlines results from an extensive usability test with different user and hence offers distinctive ideas and recommendations about the application and the system.

7.3.4. Usability Test

The acceptance test cases even though carried out following real-life factors do not take all factors into consideration and hence it was deemed necessary to perform usability tests to evaluate the cross-platform mobile application further extensively and how it all ties together with the web application to create a complete museum management, information sharing and self-guiding system. The main factor considered when carrying out the usability tests is the human factor, this goes back to the objective of the study on enhancing user experience and hence the usability evaluation of the developed system. The second factor considered is the use of different mobile operating systems or platform hence exploring the behaviour of the application on both platforms even though the application was developed from a common code base.

Usability tests were carried out for both the web and cross-platform mobile application using google forms. The google form survey was divided into 3 sections, namely Demographics, Usability and Recommendations. The web application testing was restricted to museum staff members and due to time not extended to more users, this than meant a selected number of museum staff members after a brief meeting with the researcher had the privilege to use the system and provide feedback and recommendations. It was however noticed that the web application usability testing did not yield expected result as the users/museum staff members involved in the testing concentrated on the content rather than the actual operations of the system. The unexpected results could be attributed to a misunderstanding of the overall testing procedure and misinterpretation of the main objectives of the usability test. Below are the results and recommendations from the web application usability tests:

A) Usability Survey Results: Web Application

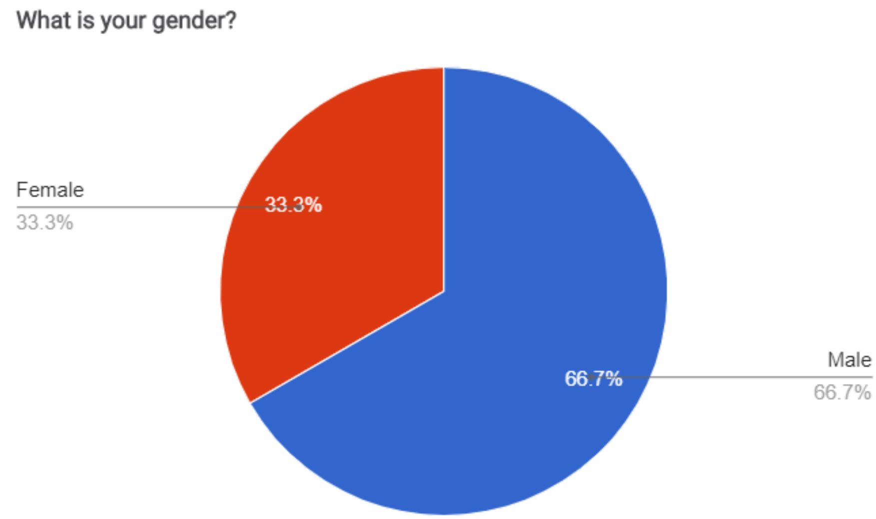


Figure 7.3-1: Gender count for Web application testers

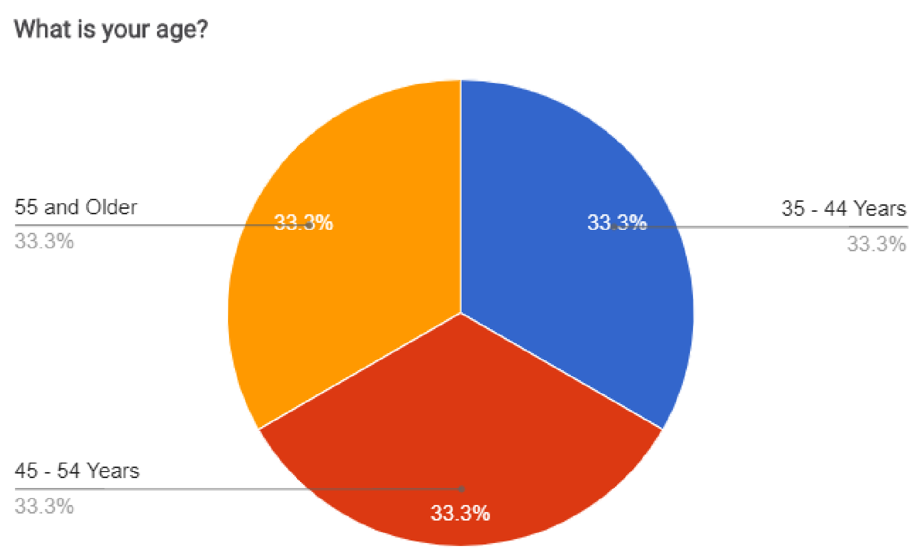


Figure 7.3-2: Age demographics of Web application testers

The demographics result do not show anything interesting and quite straight forward knowing the fact that only 3 staff members filled out the survey of which 2 are males and 1 female. The next section of the survey was the usability of the web application and it was further divided into subsections as shown by the outcome below.

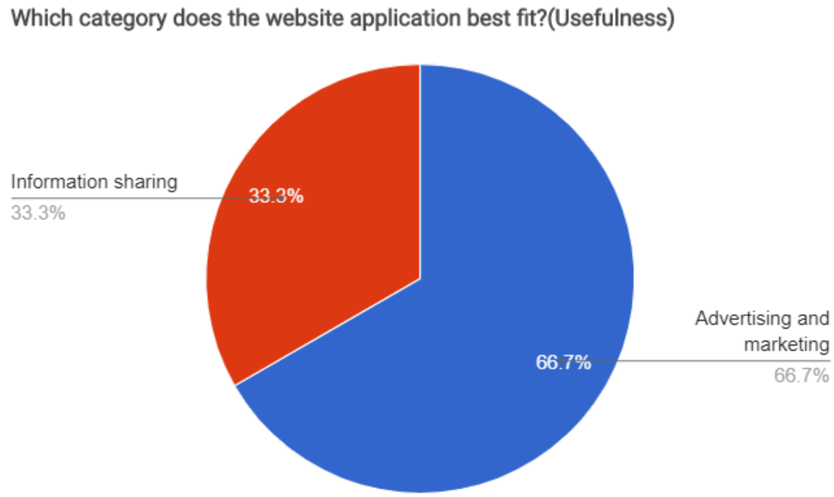


Figure 7.3-3: Web Application Usefulness

The first sub-section touches on the usefulness of the application, which further classifies the category of the application. The result shows that the majority of the response shows that the application is meant to be more for advertising and marketing hence it will help the museum's outside image. The smaller portion indicated that the application would also serve as an information-sharing platform.

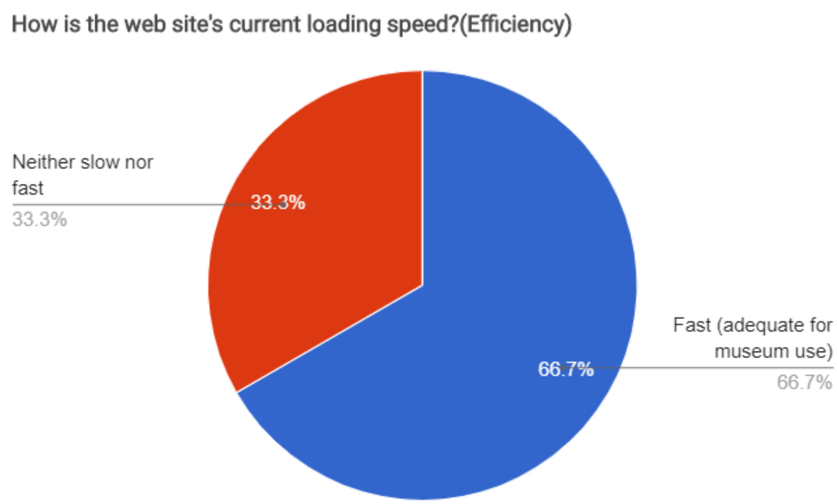


Figure 7.3-4: Web Application Efficiency

The next section covers efficiency and partly performance of which the users responded on the loading speed as being fast enough for museum usage.

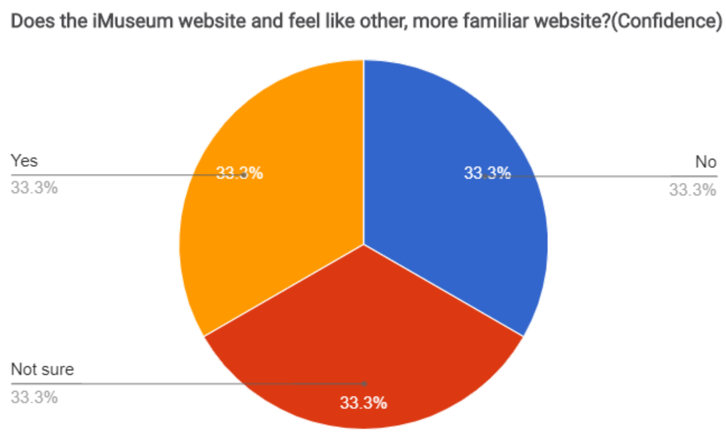


Figure 7.3-5: Confidence in Web Application

The section on user's confidence shows varied responses and no decisive stand, perhaps the result would have been more meaningful and decisive, if we had a large number of testers for the web application. The user's confidence in the application would further indicate how likely are the user's willing to recommend other prospective users and hence increasing the overall usage of the web application.

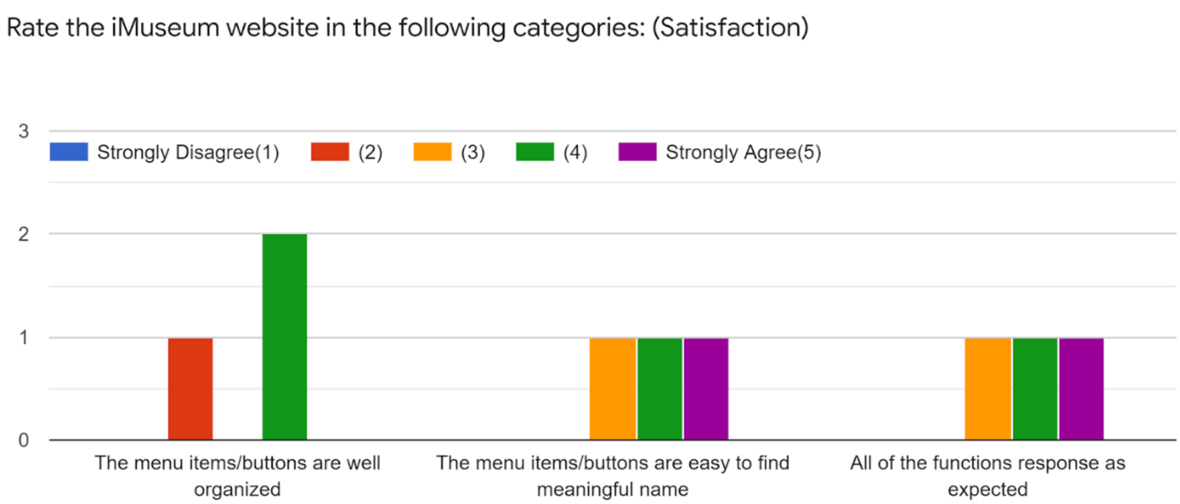


Figure 7.3-6: Web application Satisfaction

The next section then covered the user's satisfaction, which mainly looked at the organization of menu/buttons and overall function responsiveness. The results show a small concern on the way menu items and buttons are organized and hence require consideration for the next version. The results on the meaningfulness of naming and response of all functionality are adequate to excellent, which is a good start for the first prototype.

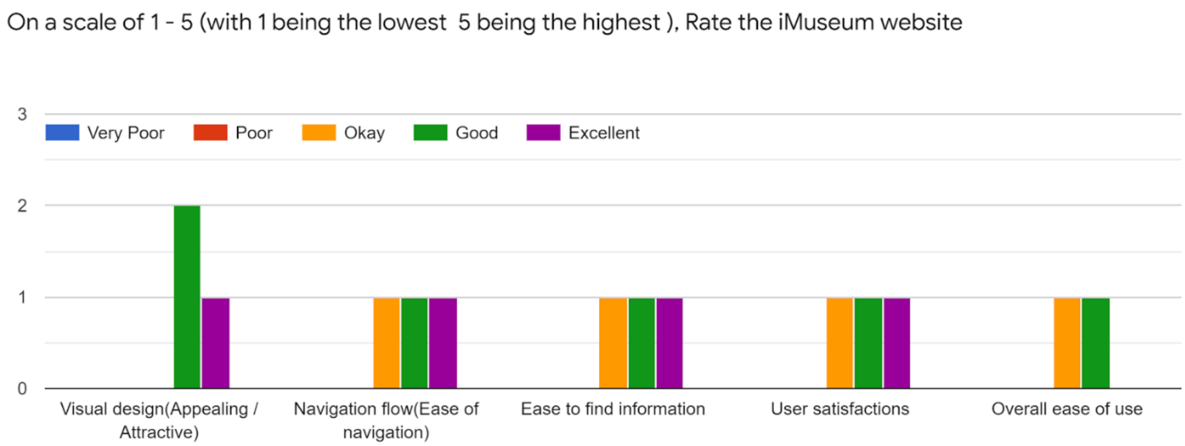


Figure 7.3-7: Overall web application rating

The last sub-section on the usability of the web application covers an overall usability rating, which ranges from the visual looks to the overall ease of use. The results show an impressive liking of the application's visual design, which at least means the application is appealing to the user. The other factors on navigation, ease to find information, user satisfaction and ease of use all show a moderate to the satisfactory response.

The recommendation section of the web application survey proved fruitless as indicated earlier, the users concentrated on the content of the web site rather than the operation and overall functionality of the web application. Below are the comments from the users.

Which one of the tasks, indicated on your task sheet was the most interesting? Why?

2 responses

Information on the web about the museum

All because they are all useful for the website.

Which one of the tasks, indicated on your task sheet was the least interesting? why?

2 responses

There is no information about owela and museum acre..

adding upcoming events. because it involve text layout and design.

Figure 7.3-8: Comments on tasks carried out

As noted earlier the comments were more content-based and not necessarily based on the tasks carried out and the overall objectives of the usability test.

How can we improve the iMuseum website?

3 responses

Add more information on the site

N/A

By acquiring more information on National Museum Sub-division.

Figure 7.3-9: Comments on how to improve web application

What is your final thoughts, recommendations, comments and inputs for the iMusuem website?

3 responses

It will advance museum visits.

N/A

Instruction on how to add, edit information on the website to be included.

Figure 7.3-10: Recommendations and inputs for web application

The final comments on how to improve the web application were also not as expected, however, the one of the recommendations kind of makes sense in that the user expects instructions on how to manage information on the web application. These comments and recommendation could have with no doubt been improved with an increase in the number of usability testers for the web application, however, the study's focus is on the usability of the cross-platform mobile application which is outlined below.

B) Usability Survey Results: Cross-Platform Mobile Application

The usability test of the cross-platform mobile application was quite extensive and the twelve (12) users involved in carrying out the tests understood the objectives of the exercise hence provided some interesting responses and recommendations. A focussed group approach was used for the cross-platform mobile application testing and this meant the user were gathered in one room for pre-test and post-test meeting plus user were free to interact with one another as they went around carrying out tasks outlined in the test cases. To simulate a museum setting a computer laboratory was set up with four sample artefacts that were placed at different places and users had to move around to artefacts and view information of the ones they desired. Below are the results and recommendations from the cross-platform mobile application usability tests:

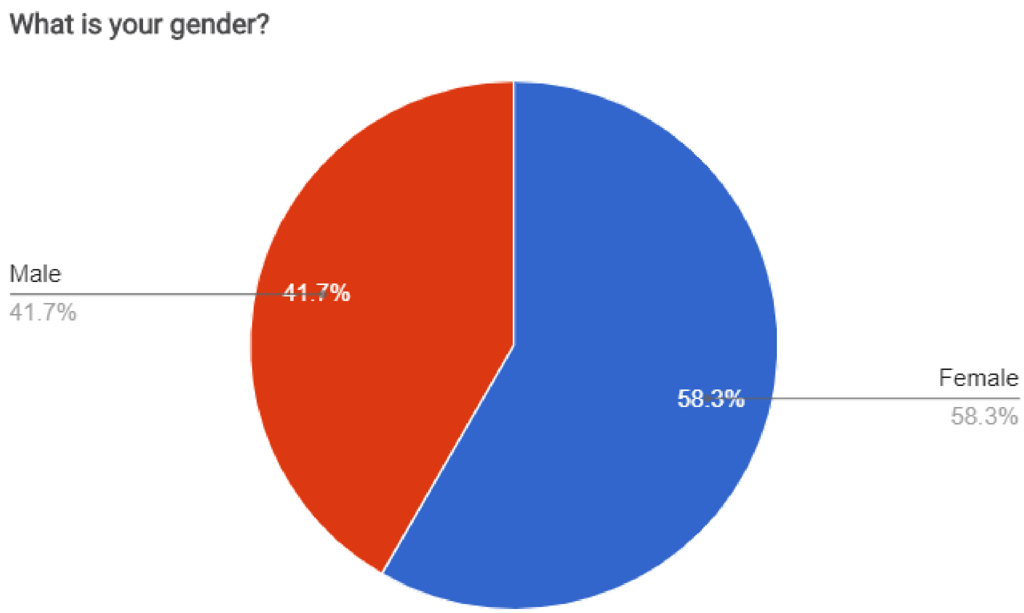


Figure 7.3-11: Gender demographics of testers

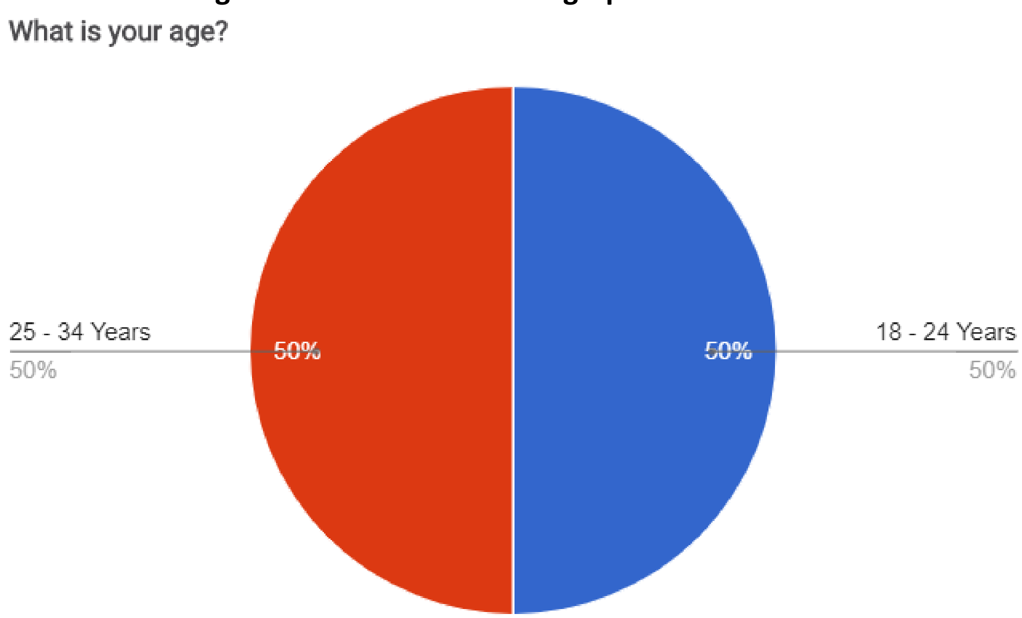


Figure 7.3-12: Age demographics of mobile application testers

The gender and age demographics of the cross-platform mobile application testers was almost balanced with Female testers being a little bit more than male, but the age groups we equally balanced having 50% between 18 to 24 years and another 50% between 25 to 34 years.

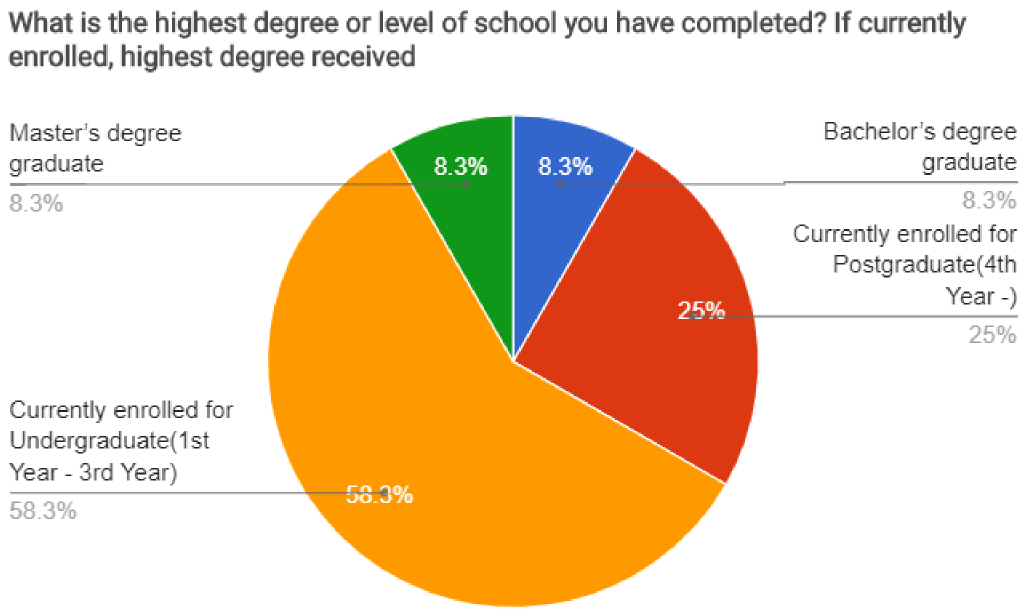


Figure 7.3-13: Demographics on the level of education for the testers

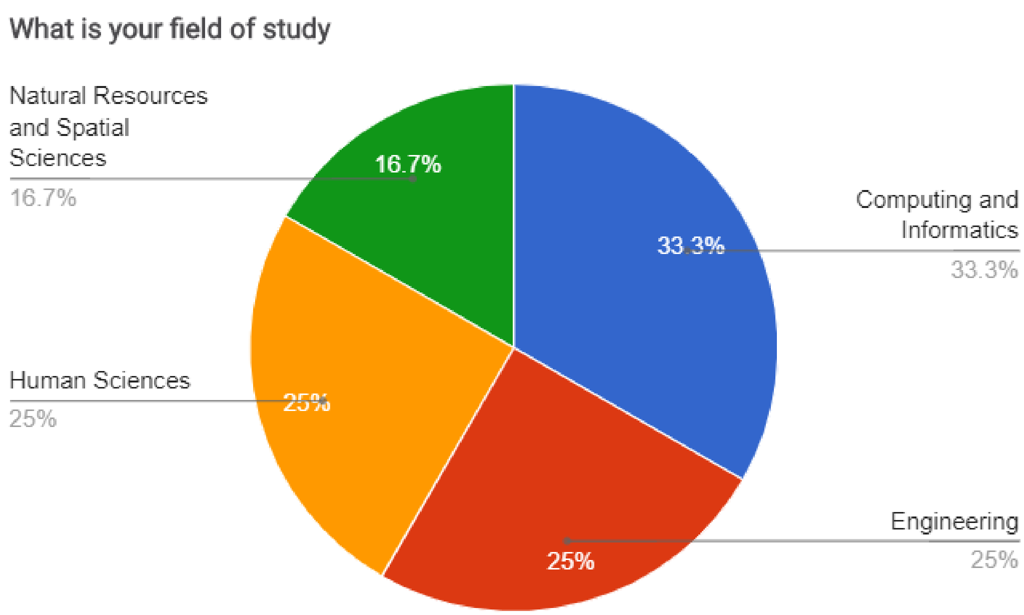


Figure 7.3-14: Demographics on Fields of study for the testers

The above 2 figures indicate demographics of education levels and fields of studies of all the 12 testers involved in the usability study. The level of education is widely spread from undergraduate all the way to postgraduate, however, the research had concerns on not including testers without formal tertiary education which could have also broadened the views on the application's usability. The fields of study have a wide range as well with computer science having a larger portion mainly to allow for critical view based on computing theories and practices towards application testing and overall usability testing.

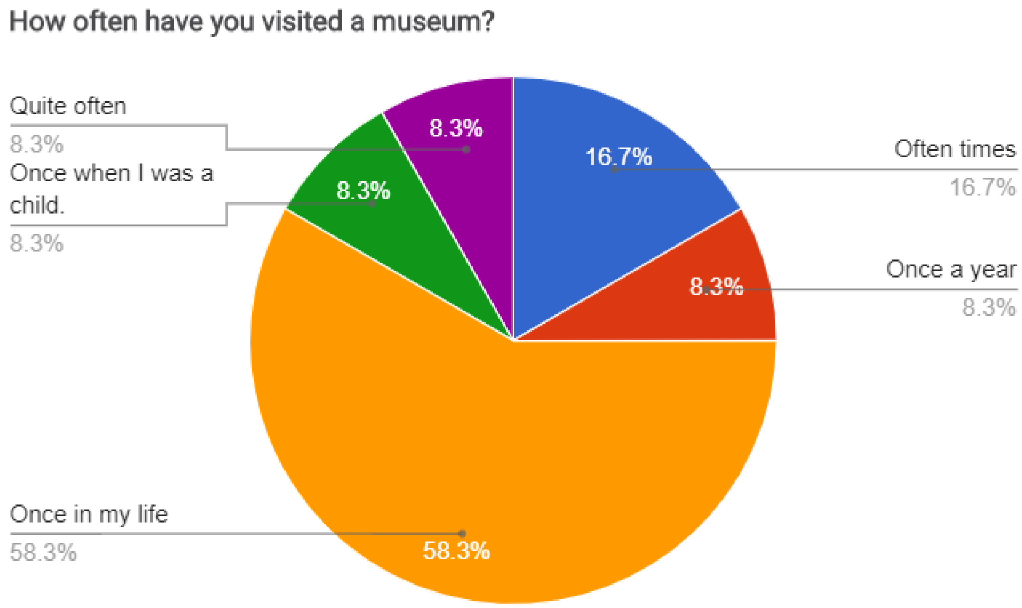


Figure 7.3-15: Demographics on museum visits

The last sub-section on demographics looked at how often the testers have been to a museum, this part is to inform the study on overall users interest of current museum set up and just as expected a large number have been to the museum only once and mostly when they were young, possibly on a school tour programme or with family trips.

The next section of the survey focused on the actual usability of the applications and the first subsection examined the demographics of users' mobile application development experienced, which showed a majority had not developed a web, not mobile applications before (see results in figure 7.3-16 below).

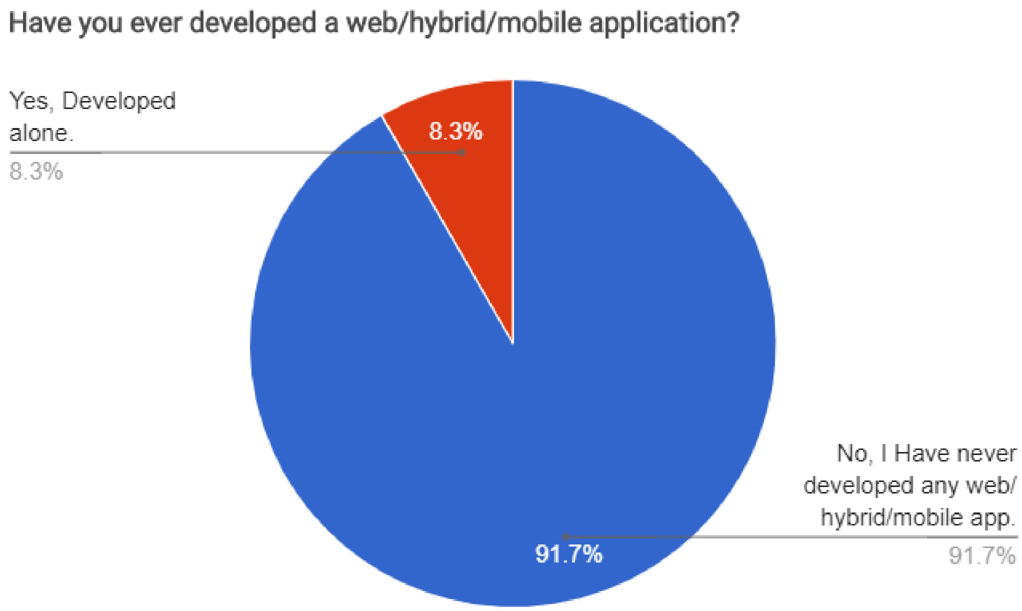


Figure 7.3-16: Development experience of testers

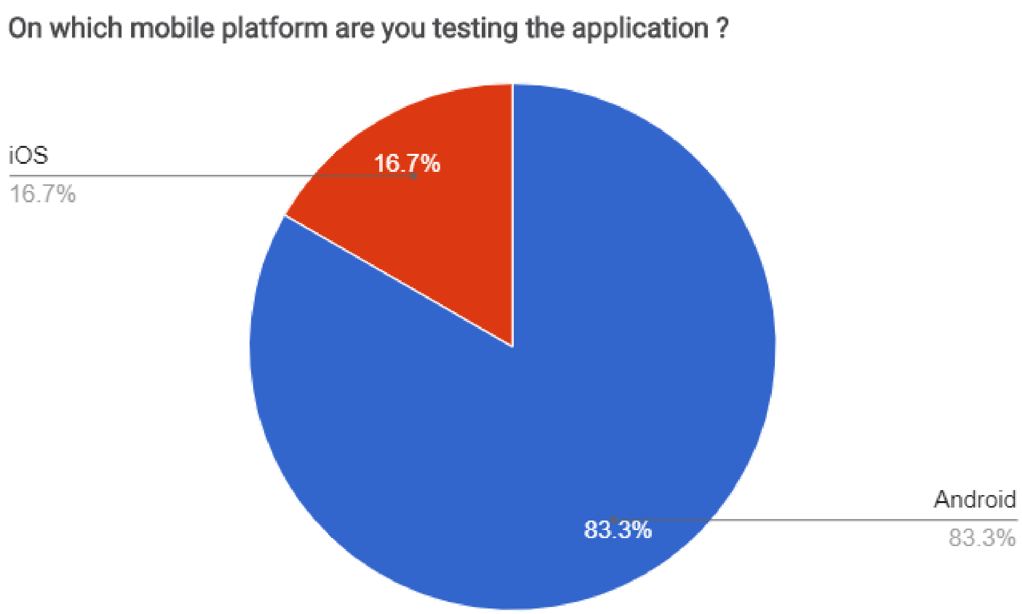


Figure 7.3-17: Statistics on mobile platforms used during testing

Figure 7.3-17 above shows statistics of mobile platforms used by the testers during the usability test exercise and the results show a majority of them used android devices, this will, in the end, help the researcher when making conclusions about the cross-platform application since the acceptance tests were carried out with an iOS device, hence positive feedback from these usability test cases could cement the acceptance test results. Another thing to be noted here is the devices were not tested for Bluetooth low energy compatibility, which meant some of the users had to figure it out later why they were not able to pick up artefacts or the iBeacon tags close to them.

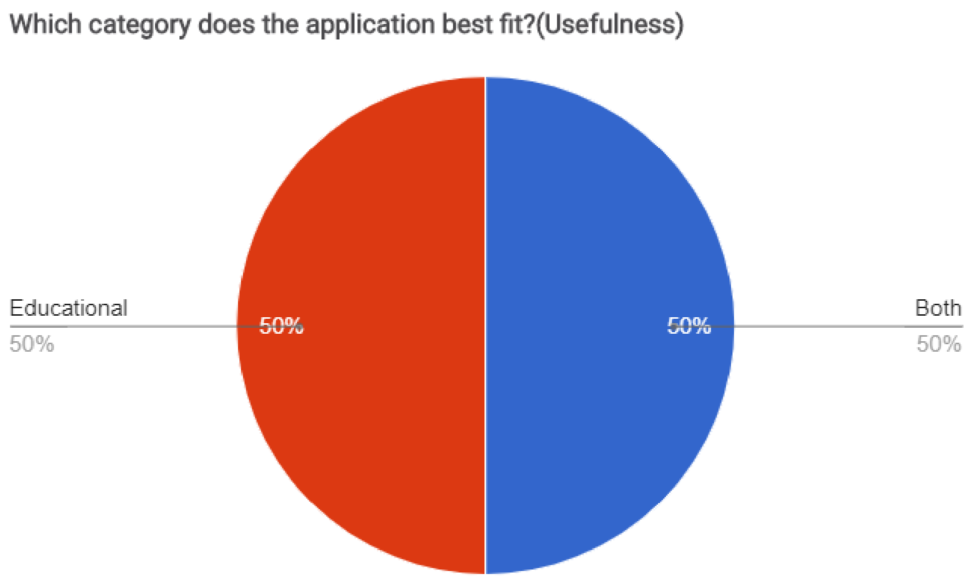


Figure 7.3-18: Mobile application purpose

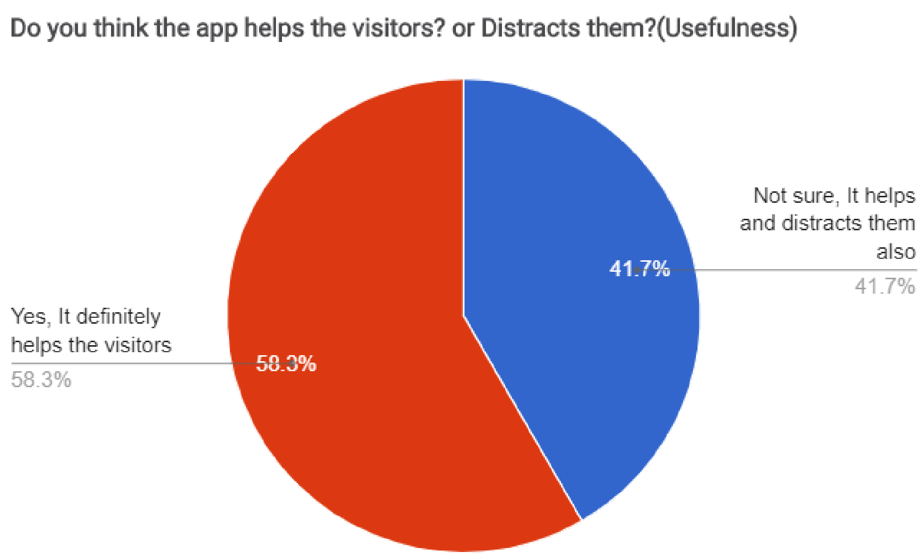


Figure 7.3-19: Mobile application usefulness

Two aspects of the mobile application's usefulness were examined, the first one was concerned with the category of the application – these being either educational, entertainment or both. The results as illustrated by figure 7.3-18, shows that half of the testers found it to be more educational and the remaining half thought it serves as both entertainment and education. These results further conform to the museum's purpose as outlined by ICOM (2007).

The second part looks at whether the application really helps or distracts the users (prospective museum visitors), the majority of the testers believed it definitely helps the users, however, an alarming number about 42% were unsure of they stand and hence thought it might both help and distract the users.

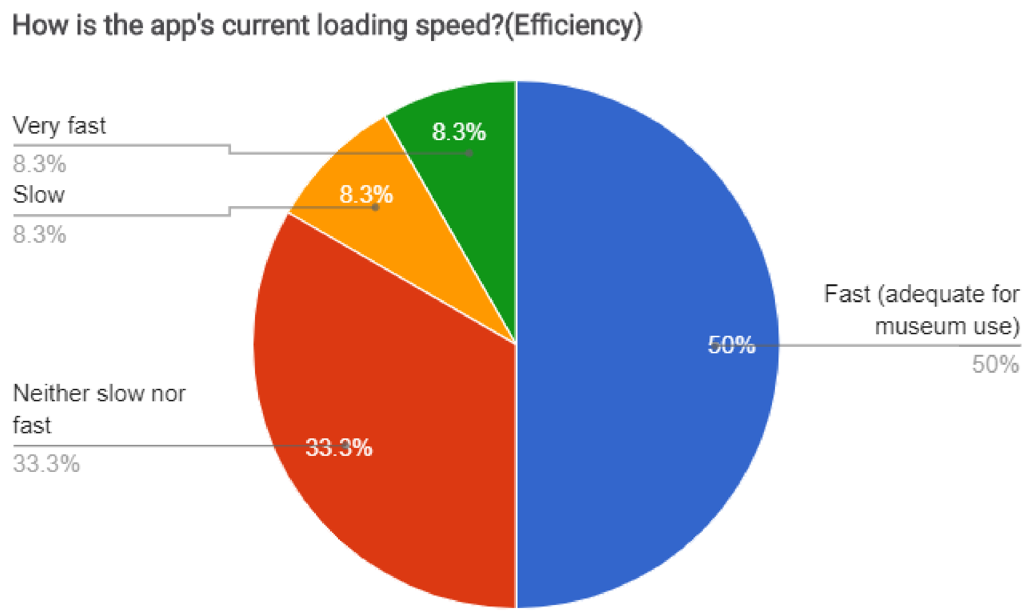


Figure 7.3-20: Mobile application loading speed (efficiency)

The next sub-section evaluated the loading speed of the application, of which majority notice it being fast to very fast and about 30% were undecided on the loading speed while about 8% indicated that it was slow. These varied results could be easily be attributed to the difference in mobile devices used and a more fair comparison could have been achieved with all users have the same devices.

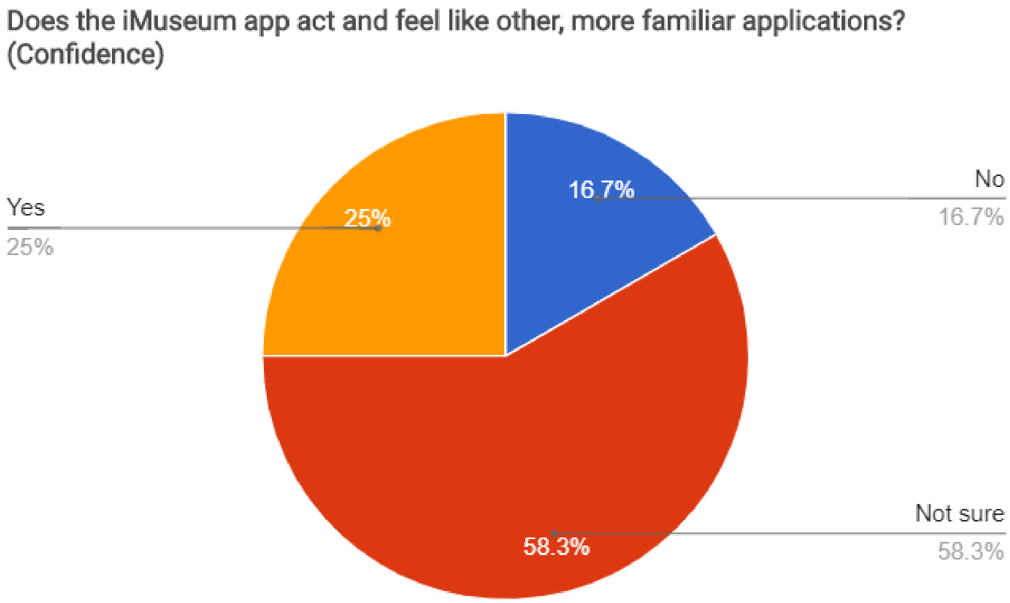


Figure 7.3-21: Mobile application look and feel

The results on whether the application acts and feels like other familiar applications are shown above, disappointingly the majority were undecided. Even though unexpected, it does make sense since the overall effort put into the user interface of the application was slightly less than that given to the application's functionality.

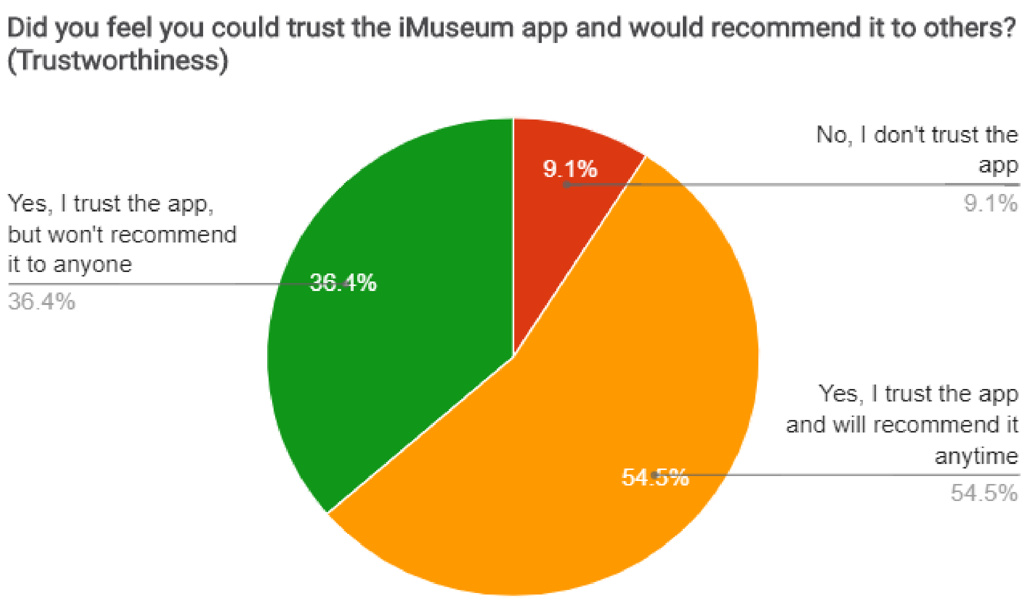


Figure 7.3-22: Mobile application's trustworthiness

Next, the tester we asked if they trusted the application enough to recommend it to someone else and more than half were comfortable with the application and would recommend it, see figure 7.3-22 above. A follow-up question on the trustworthiness was to find out why the testers felt that they could trust the application, of which more than half said it due to the usefulness, functionality and dependability of the application. These results are outlined in the figure below and it's a clear indication that the functionality of the application serves an important role in the user's perception hence targeting the main objective of the study.

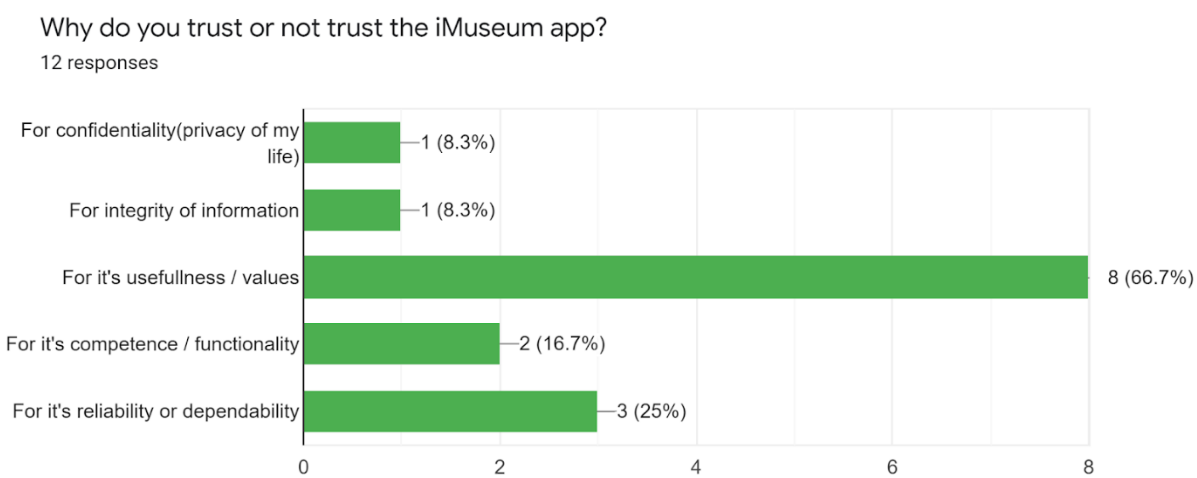


Figure 7.3-23: Rationale for trustworthiness

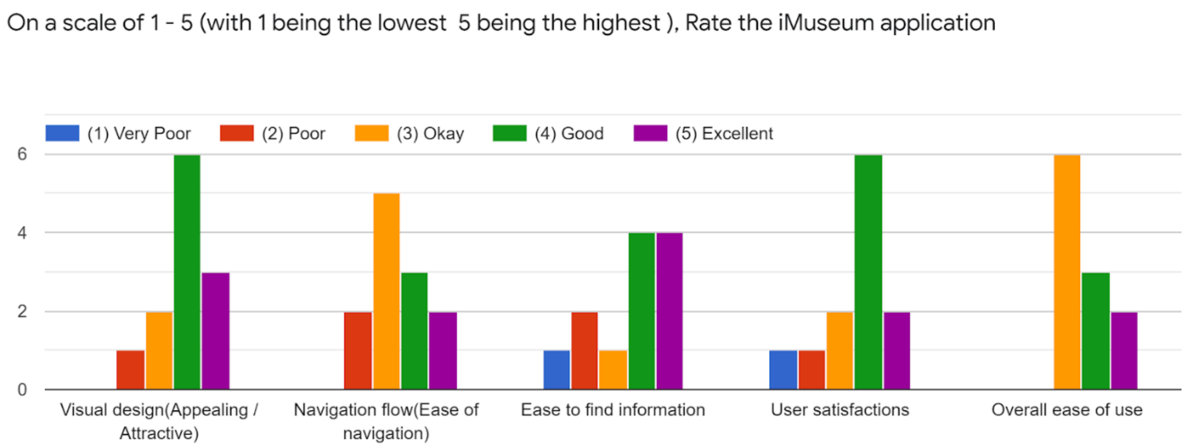


Figure 7.3-24: Overall application rating

Results on the overall ratings of the mobile application are outlined above and were categorized into five sections. The results show that the overall ease of use has the highest rating followed by user satisfaction, these outcomes could be used as supporting evidence that the application does indeed help the user or prospective museum visitors overall experience and satisfaction. The navigation and visual design even though not badly rated could use some improvement and hence assist the user with an easy flow to find and navigate the application

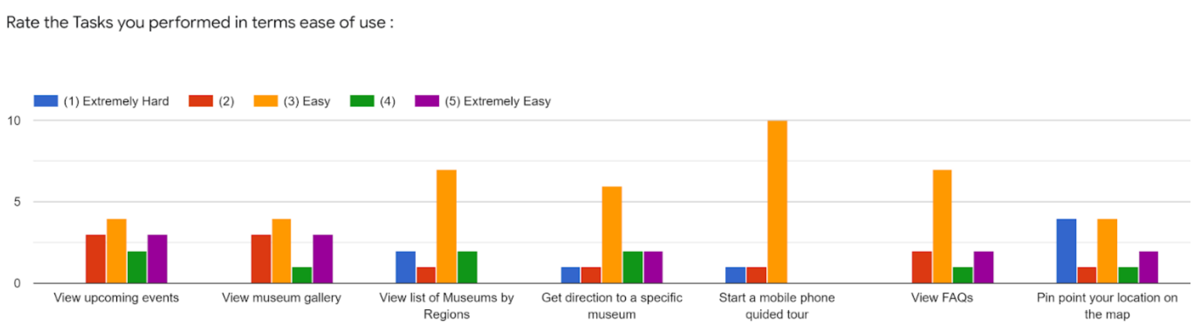


Figure 7.3-25: Ratings of tasks performed

The results for ratings of tasks performed are shown above and indicated an average rating and this is normal knowing that the testers were using the application for the first time yet we required to successfully complete tasks. The task list and all the usability instruction sheet is included at the end of this dissertation as appendices.

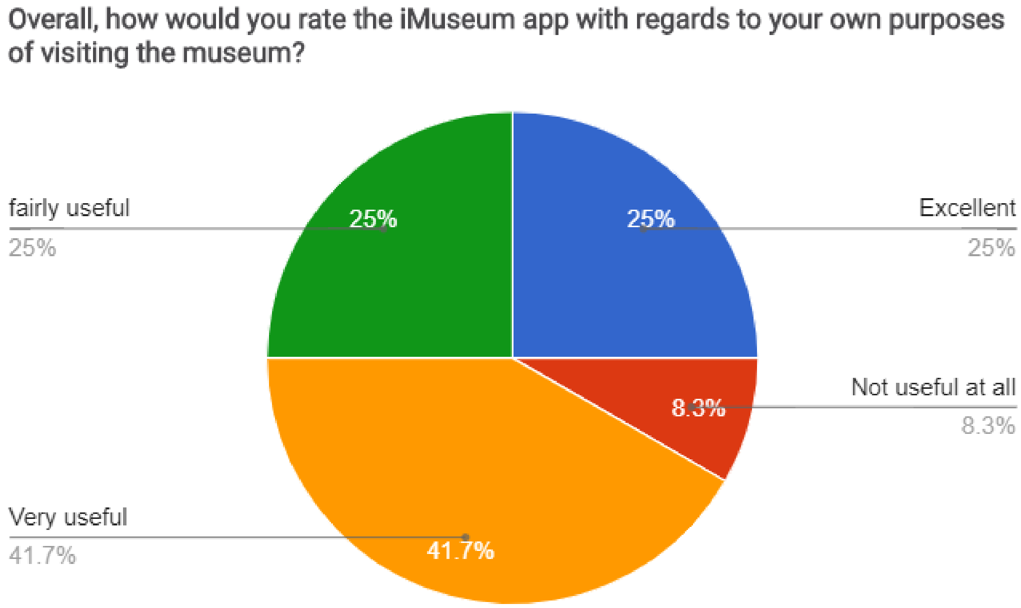
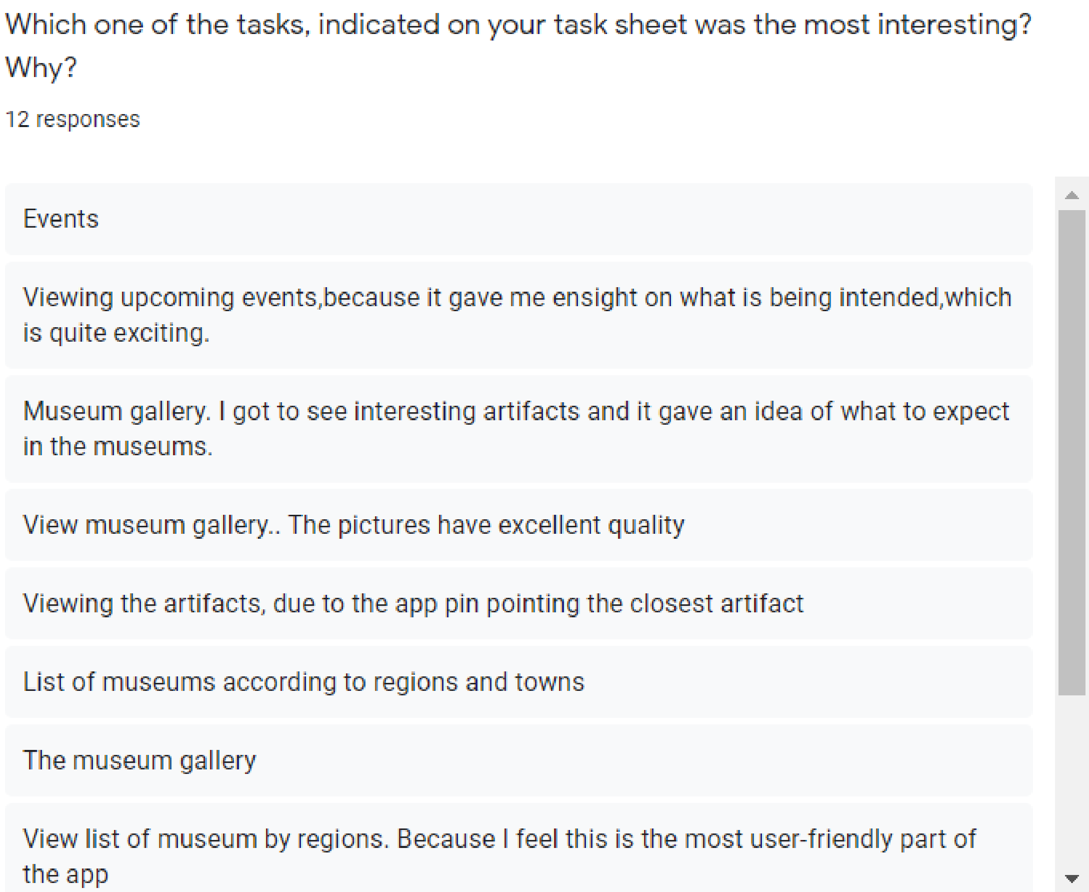


Figure 7.3-26: Rating of application on museum visit purposes

The last part of the usability section examined the mobile applications ratings in terms of the museum visit purposes. The result as shown above shows a promising rate as majority scored the application as being very useful to excellent whereas a good 25% indicated that it is fairly useful. This is an overall great rating and still in line with the study's objective of having the mobile application support visitors during their visits.

The next section provided conclusions and recommendation from the testers, here the testers provided thoughts and rationale behind most of the ratings and outcome of the usability study plus suggestions on improvements that could be done on the application.


Which one of the tasks, indicated on your task sheet was the most interesting? Why?

12 responses

Events

Viewing upcoming events,because it gave me ensight on what is being intended,which is quite exciting.

Museum gallery. I got to see interesting artifacts and it gave an idea of what to expect in the museums.

View museum gallery.. The pictures have excellent quality

Viewing the artifacts, due to the app pin pointing the closest artifact

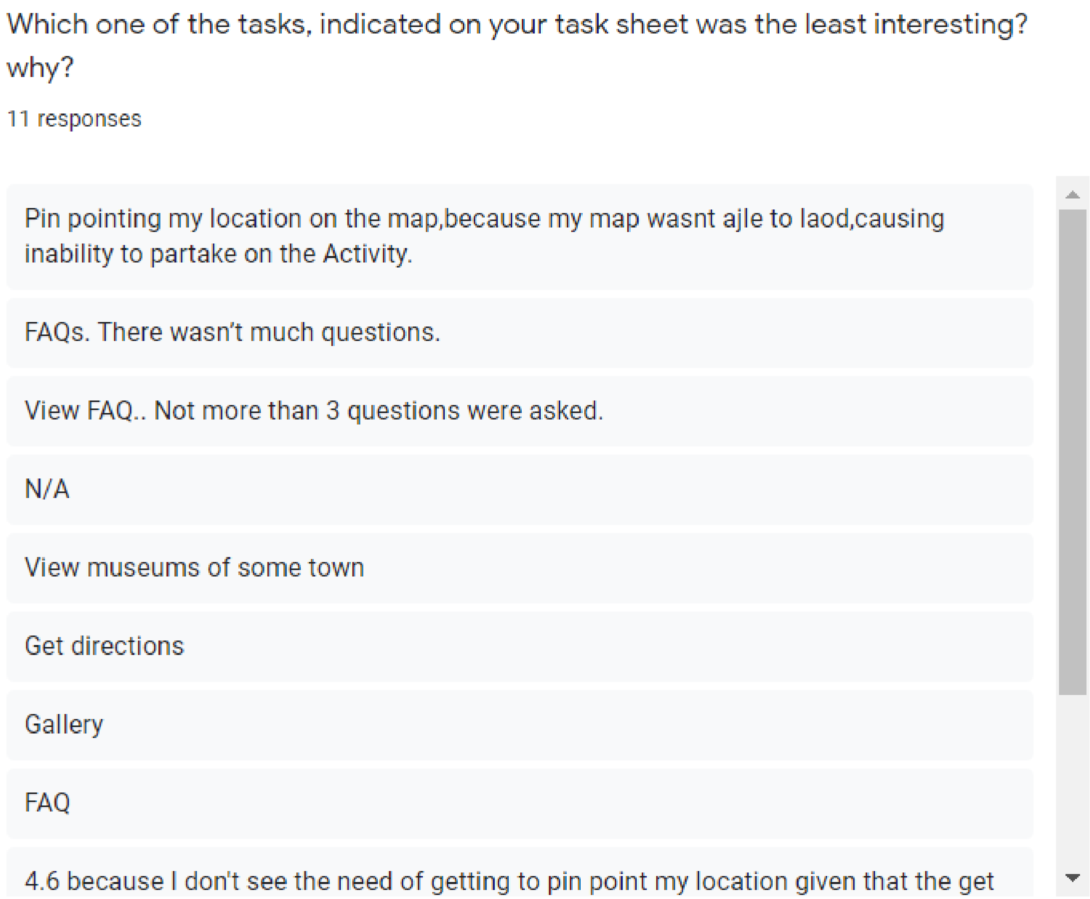
List of museums according to regions and towns

The museum gallery

View list of museum by regions. Because I feel this is the most user-friendly part of the app

Figure 7.3-27: Most interesting task carried out

Result clearly show that most of the testers were mainly impressed by the museum gallery and listing of museums by regions or towns. Two of the responses seem to have found the tour guide or pinpointing of artefacts closest very interesting and that is a relief as it shows a concentration on the applications main purpose and furthermore the overall aim of doing a museum tour.


Which one of the tasks, indicated on your task sheet was the least interesting? why?

11 responses

Pin pointing my location on the map,because my map wasnt ajle to laod,causing inability to partake on the Activity.

FAQs. There wasn't much questions.

View FAQ.. Not more than 3 questions were asked.

N/A

View museums of some town

Get directions

Gallery

FAQ

4.6 because I don't see the need of getting to pin point my location given that the get

Figure 7.3-28: Least interesting tasks

The results from the least interesting tasks carried out shows concern over FAQs not being well populated and issues with the application not being able to get correct directions. The issues of a few questions on FAQs is just for testing purposes hence they would be fully populated before deployment. The concern on direction and pinpointing depends on whether the device has Google maps installed and the application should provide warning or alert if the device doesn't have Google maps installed.

Which one of the tasks, indicated on your task sheet needs the most improvements? how?

12 responses

Get directions- just because it is not working for iphone users

Task 5. It can be improved by making the feature usable to android users

By regions and by town part

1. The town and region, could under one menu
2. Too many tabs

4.1 because it's no clear if the upcoming events are for the museum or all institutions connected to it.
4.3 I couldn't access the option of list by region. Whenever I click either region or town it still shows result of town

The directions are not clear

I think most of the things are fine it is just to work a little bit on locating towns and regions.

Figure 7.3-29: Suggestion on what needs improvements

Just as the results on the least interesting tasks, the testers suggested that the get directions needed to be more accessible or clear. This can still be attributed to the issue of Google maps not being installed and hence the application should make the users aware of this.

How can we improve the iMuseum app?

12 responses

By enabling it to work on all phone mediums,and also allowing the access to information much easier.

Add some videos for the artifacts.

Make the access of information easier,. Have a search bar to search for the direct region or town.

at 4.7 the apps menu feature disappears when reviewing the application tutorial

Apply suggested recommendations

Just do a few spelling checks

Making it more user-friendly. Font uniformity

By organise Gallery well

Improve ease of access of information and features, voice and video tour guide

Improving in terms of information integrity. Its uses and relevance

Its fine,no need of improvement

Add more options that satisfy the entertainment menu.

Figure 7.3-30: Suggestions on how to improve the application

Suggestions on how to improve the application were mainly centred at the provision of more information and user-friendliness. These results further confirm the initial findings that most users or museum visitors' experience are based on acquiring of information and being entertained during their visits, hence providing the relevant information is key to this application and more attention is to be paid on this aspects in the future.

What is your final thoughts, recommendations, comments and inputs for the iMusuem app?

11 responses

Overall the iMusuem app is excellent in that it provides relevant information and contains information that is equally important.

Overall it's an okay application. Maybe add a few more features.

I think it will be easier if you put a search bar in the museums section, where you can search the town or region.. Instead of placing both regions and towns, just place the region option which will allow you to access all the towns in that specific region.

the app is quite efficient as well as user friendly which allows anyone to use it effectively.

Very interesting. Just recommend more

Wrong spelling of museums- just double check.
The get directions does not work for IOS users.
Vidoes inactive

I think there are a lot of functions in the app. It is a bit tiring to navigate to them all.

Just to make thr app more faster and very interesting.

It's a brilliant idea and will prove useful for those who are interested in the history and culture

Relevant application. But I would recommend an improvement of certain features that are still unaccessible

well done the app looks good...

Figure 7.3-31: Final recommendations on application

The last sub-section covers recommendations or final thoughts from the testers on the application. The results even though very positive is very detailed and straight to the point showing the tester's attention to details and dedications. Two comments stood out from the results one being on adding a search option hence making the application more friendly and allowing ease of access to information. The other recommendation has been recurring more than once and that the feature on getting directions not being accessible to most option. The recommendations further praised the overall application's functionality and with future works targeted at user-friendliness and inclusivity, the application could really target the user experience in museums.

7.4. Summary

This chapter shows a breakdown of results obtained during the usability studies of both the web and cross-platform mobile application, special attention and extensive analysis was done on the usability of the mobile application mainly based on the study objective to evaluate the system and interactive museum guide in forms of the mobile application.

In order to have a successful usability test, an acceptance test was carried out on three major tasks of the application and the results were all positive hence leading the researcher to conclude that most application features were working as expected.

The extensive usability test on the cross-platform application was accompanied by a survey to find out the ratings, thoughts and recommendations from the users. The survey was carried out using Google forms and the results were automatically summarized at the end of the exercise, this was exceptionally helpful to the researcher as no additional analysis needed to be carried out but rather to provide final valuations on the summarized results as shown in sub-topic 7.3.4 above.

The results from the survey revealed concerns on the directions feature not accessible to platforms without Google maps and could be indicated to the users at the start of the application with an alert notifying them that some features might not function properly without Google maps. Another aspect noticed through the test is the detection of artefacts nearby. This feature works for devices with Bluetooth Low energy compatibility, but the application doesn't notify the users if their device is not compatible but rather the application attempts to run this feature hence freezing the phone.

Results also show concern on the overall user interface of the application and hence affecting the user's experience, this is attributed to the researcher being more concerned with the functionality of the application rather than the user interface. Information access also came out as a concern citing lack of information on the application and restricted access, which is mainly due to unfamiliar organization of information and challenges faced in collecting relevant information about museums and artefacts contained within the museums.

8. CONCLUSION AND FUTURE WORK

This chapter concludes the dissertation with a summary of the work carried out and the results obtained after an evaluation of the system developed. The researcher further examined the outcome of the study against the initial research questions and objectives. This chapter concludes with a recommendation on future work and improvement to the cross-platform mobile application and overall features required to have a fully-fledged computerised museum system.

8.1. Summary

This study is focused on the museum setting and exploring ways to enhance the overall visitor's individual experience and satisfaction. These two factors are not easily measurable but attempt to impact them can be made. In this study to fully understand the museum setting the researcher began by analysing challenges faced by both the museum guides and the actual expectations of the visitors, which revealed that the main issue is the ratio of museum guides versus the number of visitors they offer a guided tour to, at any given time. This ratio was discovered to be grossly inadequate leading to visitors not fully getting the expected attention and care, in turn, this leads to restricted access to information and overall diminished visitors' experience. Examining these factors further the study explored museum visitors' expectation on museum experience and satisfaction, this revealed that amongst all the visitors were more interested in receiving more information about artefacts and exhibits in the museum. Apart from this, it was also clarified that every museum visit should include entertainment and that an individualized experience is a key to the visitors' satisfaction.

After understanding contributing factors to museum visitors' experience, the study then explored wireless technology integration in the mobile application for micro localisation and information exchange. In the process of examining wireless technologies, the use of Bluetooth Low Energy (iBeacon) tags were selected on the basis of its affordability and low consumption of battery life on the mobile devices, hence iBeacons were to be placed on every artefact and be used as identifiers in searching for artefacts close by. The integration of wireless technology posed an issue that not all mobile devices or platforms support Bluetooth Low Energy, however with the advancement of technology it is to be expected that most platform will be able to support these wireless technologies.

The study's objective could further be broadened into increased inclusivity of visitors from different age groups and social levels. This in turn led to a sub-objective in the study to develop a cross-platform mobile application that would be both stable, easy to use and user-friendly. The researcher based on the study period, technologies to be used and the base-line study, concluded on the concentration of the design and development of an application for Android and iOS devices, these were due to the fact that they are the most popular platform used in Namibia and hence the issue of inclusivity could be addressed with this consideration. The concentration on these platforms meant that museum visitors would be familiar with the platforms hence the application will offer them a personalised view. Another approach to increase the inclusivity was to develop as a system compatible with basic feature phones, however, the study excluded this idea due to the fact that feature phones will be faced with the biggest challenge in the transfer of information mainly media files such as videos, audio and image files.

During the design process, the researcher considered the interactive museum guide as a complete museum system comprising of two main components; the web component that is a management platform and the mobile component to be used as the museum guide. These two components are further linked to a database server for which Firebase was selected to handle all data components due to its compact nature and ease of integration into any system. After the design, development of the web application was carried out using Angular and the cross-platform application was developed with Ionic, as outlined above both of these components were linked to a Firebase database and the overall system API was maintained by Firebase. The mobile application even though created from a single codebase required the researcher to examine features closely and their behaviours in the selected mobile platforms hence some conditions had to be considered while developing the application. Agile software development approach was adopted for this study mainly to make up for the incomplete user requirements hence the incremental builds allowed the researcher to collect requirements and accumulatively improve the application continuously.

After a few development iterations, the application prototype was run through acceptance tests based on three main features of the application, these were getting directions to a specific museum, starting a museum tour and loading the application offline. The mobile application passed all three scenarios as expected and following the sub-objectives of this study an intensive usability study was carried out on the developed application to evaluate if the requirements were met and to further explore the user-friendliness and ease of use of the application. A similar usability test even though not extensive was also carried out on the web application. The results of the acceptance and usability test have been summarized and explained in Chapter 7, subsection 7.3.

8.2. Research Achievements and Results

The main objective of this study was to examine possible ways to enhance museum visitors' individual experience and satisfaction, in turn, this led to the use of mobile devices and hence designing and implementing a cross-platform mobile application. This objective was further divided into sub-objectives of which the actions are taken to fulfil the objectives have been summarized in section 8.1 above.

The overall objective of the study is based on the cross-platform mobile application, this objective was achieved by designing and implementing an interactive museum guide in forms of a cross-platform mobile application. The success of this objective was based on the researcher finding out the challenges faced by museums in an attempt to preserve historical artefacts at the same time offer the pleasant experience expected by museum visitors despite the museums' constraint budgets. The tangible outcome of this approach was a mobile-based interactive museum guide which consists of two components, the web application to be used in managing artefacts or museums information and to serve as a marketing plus information sharing platform, and the cross-platform mobile application serves as the main interactive guide for museum visitors within and around the museum.

A focused group was then used to extensively evaluate the cross-platform application of which results have been analysed in Chapter 7, section 7.3 and summarized in section 7.4. The focused group tested the mobile application using different mobile devices and this provided the study with broad views and opinions as clearly outlined by the recommendations of the testers involved in the usability study. The results of the usability study show that the cross-platform mobile application behaves differently amongst various mobile devices and that it fulfils the main purpose that it was developed which is to provide a personalised view of artefacts nearby. Results from the usability study also indicated that the mobile application clearly tackles user satisfaction, its ratings on ease of use and ease of information access is above average to excellent which could make an impact on the overall museum visitor experience following the fact that museum visits are improved by access to information and provision of personalised tours.

The mobile application when running on a device with Bluetooth Low Energy capabilities is able to detect artefact using iBeacon tags which would later be used in the museum by being place on every artefact, these tags provide unique ids that are used by the application to pull relevant information about the artefact from the Firebase application. The exchange of information between the application and Firebase is seeming less as if data is stored locally on the mobile devices, even the streaming of media files is fast enough for normal application or as clearly clarified in the usability study, fast enough for museum use.

In addition to the mobile application, a web application to manage the firebase database was developed. This web application was tested by museum staff members and results are also summarized in section 7.3.4. The usability study of the web application was not as extensive but the results showed that with sufficient information the web application is visually attractive and easy to use hence would definitely serve the purpose of managing museum or artefact information.

8.3. Lesson Learned

In carrying out this study, a few lessons were learned regarding museum operations and software development practices. The first lesson learned is on museum set up, It was noticed that Namibian museums because of constraints on the budget have outdated artefact setups and run repetitive exhibits annually without any improvement. These setups have a negative impact on the museum image and most importantly on the museum visitors' overall experience. It could further be seen that little to no effort is applied to exercises meant to improve museum experiences. During the baseline study and through the literature review, it was acknowledged that museum visitors often times are appealed to artefacts when they are provided sufficient information and most visitors go to museums for educational or research and entertainment purposes. These expectations are however not met in Namibian museum, including the Independence Memorial museum which is considered one of the states of the art museums in the country. The Independence Memorial museum has a modern architectural design and appealing interior layout but in terms of modern museum setup, it has become obsolete and initial study further showed a reduction in the number of museum visitors. Despite the outdated museum setups, museums are heavily challenged by lack of information on all artefacts and it is much worse when it comes to digital information. These lack of information has been cited as a challenge when implementing digital systems to improve the overall museum setting and ultimately impact the visitors' experience.

This study despite all drawbacks and limitation has explored a tangible way to impact visitors' museum experiences by using resources that are readily available to the public such as personal mobile devices and access to the internet. In an attempt to address the entertainment aspects of museum visitors, the researcher discovered that interactivity is the key to keeping visitors involved and engaged with artefacts hence appeal to their interests better with active activities. Active learning and interactive engagement have been outlined as one of the most effective learning approaches in any institution of learning be it formal or informal education(OBrien, Millis, & Cohen, 2008), this interaction is completely absent in the Namibian museums.

Another lesson learnt is on the general public's unwillingness to participate in practices that would improve public institutions and impact change in the community on a voluntary basis. The researcher learnt with dismay that most people are not willing to take part in exercises that do not benefit them immediately whether it's monetary or other incentives, in turn, these becomes a tricky challenge when carrying out research, because opting to provide incentives to people taking part in any given research has a bigger probability of producing biased results which might obscure the correct situation on the research carried out.

This study adopted the agile development approach and from the beginning efforts to elicit complete system requirement prove futile, it was based on these grounds that the agile approach was selected. Studies show that one of the challenging factors in software design and development is the provision of incomplete user requirements (Sommerville, 2018) and the assumptions (Albayrak, Kurtoglu, & Bivakcr, 2009) made by the development team in order to cover for missing aspects of the system being developed. It was also learnt in this study that with incomplete requirements, assumptions do more harm and derails the project more than expected, however, the agile approach has been an impressive asset in this study's development stages as it allowed for continuous interaction between the researcher and the museum stakeholders plus the general public to elicit more detailed requirements on the system even at an advanced stage of the development.

The frameworks (Angular and Ionic) adopted in this study have taught the researcher lessons on tools and library management. These frameworks being relatively new meant that they are continuously updated and improved rapidly. These updates in most cases had backward compatibility issues, hence some functionally after an update become obsolete and the researcher is forced to re-implement such functionality or look for a workaround. The benefits, however, is the frameworks offer up-to-date blogs and discussion forums on all updates made to their libraries. Reading through these forums has taught the research lessons on how to keep track of libraries or third part functionality that have been included in one's software.

The last lesson learnt is on the adoption of wireless technologies in mobile development, even though all mobile platforms may support for example Bluetooth Low Energy, the behaviour and features around its usage is totally different. The researcher has learnt flexibility in ranging and searching for Bluetooth Low energy tags in Android devices but this flexibility means no stable range is set when trying to discover tags within the phones range hence leading to provide incorrect information, the iOS devices, on the other hand, are quite stable and offered most accurate information on tags within the range of the device.

8.4. Future work

The usability study carried out on both the mobile and web application had two common concerns – the user interface/experience and the lack of information. The outcomes of this study even though considered as deployable products are mere prototypes of the envisaged systems and hence the researcher concentrated on the main functionalities such the mobile application's ability to detect artefacts with Bluetooth Low Energy tags and display relevant details of that artefact allowing for further interactions with the artefact such as liking and making their artefact of choice popular. Future work on the mobile application could allow for social media integration and options for visitors to review artefacts and overall exhibits with comments. Acknowledging the user experience concern and based on the idea that museum visitors experience is heavily reliant on their experience and interactions with artefacts it is imperative for any future work to closely look at the user interface of any system develop so as to positively impact the visitor's experience.

Lack of digital information on artefacts and museums has also been cited as a concern and challenge in digitalisation of Namibian museums, future works can also start off with information gathering and digitalisation of these data, in some cases information is available in hard copies in terms of history textbooks or pamphlets but all this are outdated methods of preservations and sharing knowledge. The topic on digitalisation of historical data cuts through many fields of study and aspects of society, hence trying to tackle it is a research topic on its own.

The next aspect that needs to improve or worked on is the detection of artefacts using Bluetooth Low Energy tags, the produced cross-platform mobile application can impressively detect tags within range and list then in order of the closest to the mobile device, however, a key concepts in indoor localisation is being able to pinpoint the exact direction of the artefacts hence future work could look at only displaying tags in front of the users rather than the closest which might be behind. The current approach has not specific algorithm nor did this study explore algorithms on BLE tags localisation, future work could possibly explore algorithms and approaches to optimize and detect such tags correctly.

Google has been actively working on their Indoors map API and integration for mobile application is clearly possible, future works to improve indoor localisation and users' access to points of interest information. An extensive study can be done on how to implement Google's Indoor maps in museum systems such as mobile tour guides and emergency situation guides.

This study whilst exploring its sub-objectives discovered the need for related artefacts and museum being linked, such that while viewing a certain artefact the application could suggest related artefacts within the museum and at the end of the tour suggest other museums were the visitors could find similar artefacts. This could work as a referral system and could easily allow visitors to have targeted tour around specific parts of any given museum.

The directions to museums of the current systems filter according to towns and regions, however, this might not be ideal for people that are new in the country hence future work can explore algorithms to list all museums or cultural institution within a given radius from the user's current location. The approach can be easily be attained knowing the current users geo-locations against those of museums nearby. A common approach used is the "haversine" formula (Nichat, 2013) that calculates the shortest distance between two geo-locations over the earth' surface.

8.5. Research Conclusion

After examining the challenges faced by museums and museum visitors expectations, this study explored and implemented a technological solution using mobile devices. Mobile devices were mainly selected due to their vast usability and high population penetration, hence it is almost guaranteed that visitors would have a personal device in their possession which they are familiar with. This study's solution is targeted at capitalizing on this aspect to try and impact the visitors' experience. The system runs on the device that a given visitor is used to but now its functionality is extended to allow interactions with artefacts and at the same time entertain the visitor. Through the initial study and literature review, it has become clear that museum digitalisation is imperative in today's societal setting in order to stay abreast with the rapid advancement of technology.

Museum visitors' experience and satisfaction are not easily measurable factors nor do they have clear cut approaches to enhance them. This study's approach, covers aspects and factors that directly impact visitor experience and satisfaction. It is against this grounds that any study on enhancing museum experience cannot clearly conclude that it has results that will definitely enhance visitors' experience nor totally satisfy everyone's expectations. The result of this study's usability shows the potential impact that small technological additions to museum settings could bring about. These approaches may not be acknowledged by all but they do provide room for staying relevant and in line with the latest technological advancements.

The impact of this study may however not be easily recognised, seeing that the produced prototype was not fully deployed for the public to continue using it, however, the researcher has demonstrated through the web and mobile application the possibility of having a completely digital museum and allow museum visitors to see artefacts and exhibits of their choice at pace that suits their personal liking. A complete design and development process would lead to close and continuous engagement with the museum and all relevant stakeholders to make sure the museum's core values and objectives are closely considered. The possibilities of technological adoption in museums and other cultural institution are limitless, this study has simply exposed the tip of the iceberg and with more effort, a radical change with a positive impact on the museum setting can be attained.

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10. APPENDICES

Appendix A : Letters to Museums

Museums experience research

Kandjimi, Herman (CSI)
Wed 07/08/2019 19:19
To: goagoses@hotmail.com
Cc: Muyingi, Hippolyte (CAI)

Reply all |

Sent Items

I'm a master student at the Namibia University of Science and Technology carrying out an academic research on museums visitors' experience and our research opted to adopt a computerized system(iMuseum) with an overall aim to enhance visitors' experience and interaction with museum artefacts. The main focus is to impact museum visitors and subsequently increase the overall number of visitors to the museum.
The museum system has two main components:
- Web application(website) : information sharing ,marketing and be able to reach more users. The website is also used as a content management platform for information on the website and all the data needed for the mobile application
- Mobile application(iOS and Android): Mainly to act as a mobile interactive guide for museum visitors in and around the museum.

Our research is mainly anchored at enhancing visitors satisfaction and experience within and around the museum. The system as it is developed further aims to provide a marketing platform for the museum and we have gone further to include features where potential visitors can find out museums close to them and what they offer. All the content information provided on both the website and mobile application is to be controlled by museum management and in no way does the system render the current museum system obsolete, but rather it is an add-on that preserves the artefacts and exhibitions as they were, with an additional virtual argumentation by providing more information and interaction with the visitors.

The mobile application away from the museum also acts just like the website as it becomes more of an information-sharing platform for events happening at the museum and offers directions for visitors to get to the museum. once in the museum the application with the help of wireless technology is able to detect artefact close to the visitors and offer further information.

I would like to humbly request your good office to give us a chance to demonstrate the overall system and further discuss the aims of our research.

regards,
H Kandjimi

Appendix B: Development Tools and Devices

Laptop : MacBook Pro(13-inch, Mid 2012 model),

2.5GHz Intel Core i5 Processor,

16GB 1600MHz DDR3 RAM,

Intel HD Graphics 4000 1536MB Display card

MacOS Mojave version 10.14.6 Installed

Development Tools: Visual Studio Code Version 1.39.2 used as main IDE

Xcode Version 11.2.1(11B500) use for iOS bulding and testing on iOS Devices

Android Studio Version 3.4.2 for Android APK builds

Moon Modeler (online platform) ERD for NoSQL databases

FireBase Console managing Firebase database rules and data connectivity

Creately (Online tool) Creating Usecase diagrams

Mobile Devices: iPhone 6S used for Acceptance Test

Various Android Devices (Samsung,Huawei and Hisence) and iOS devices used for usability testing.

iBeacon Tags: Bluetooth Low Energy beacon by BEACON inside model No. B0001-A

Appendix C : Code Snippets

```
//Method to calculate distance for android
calculateDistance(txPower: number, rssi: number) {
    if (rssi == 0) {
        return -1.0; // if we cannot determine distance, return -1.
    }

    let ratio = (rssi * 1.0) / txPower;
    if (ratio < 1.0) {
        return Math.pow(ratio, 10);
    }
    else {
        let accuracy = (0.89976) * Math.pow(ratio, 7.7095) + 0.111;
        return accuracy;
    }
}
```

Code 1: Distance from device to iBeacon tags for Android

```
//get all artefacts in database
getArtefacts() {
  return this.firebase.list('/artefact');
}
//get the 5 most popular artefacts
getPopularArtefacts() {
  return this.firebase.list('/artefact',{
    query: {
      orderByChild:'likes',
      limitToLast:5
    }
  });
}
```

Code 2: Retrieving data from Firebase

```
//Update artefacts popularity
updateArtefacts(name, count: number) {

  this.artefactsRef = this.firebase.list('/artefact/', {
    query: {
      orderByChild: 'title',
      equalTo: name
    }
  }).take(1);

  this.artefactsRef.subscribe(snapshot => {
    this.artefacts = snapshot;
    console.log(this.artefacts[0]);
    let newLikes = this.artefacts[0].likes + count;
    this.firebase.object(`artefact/${this.artefacts[0].$key}`).update({ "likes": newLikes })
  });

}
```

Code 3: Changing the like(popularity) count of an artefact

```
export class NetworkService {
  //internet status observer
  private online$: Observable < boolean > = Observable.create(observer => {
    observer.next(false);
  }).pipe(mapTo(false));

  constructor(private network: Network, private platform: Platform,
    public toastController: ToastController) {
    //set observer to false by default
    this.online$ = Observable.create(observer => {
      observer.next(false);
    }).pipe(mapTo(false));

    //detect network disconnection and change observer status to FALSE
    this.network.onDisconnect().subscribe(()=>{
      console.log("DISCONNECTED")
      this.online$ = Observable.create(observer => {
        observer.next(false)}).pipe(mapTo(false));
    });
    //detect network connection and change observer status to TRUE
    this.network.onConnect().subscribe(()=>{
      console.log("CONNECTED")
      this.online$ = Observable.create(observer => {
        observer.next(true)}).pipe(mapTo(true));
    });
  }
```

Code 4: Service to check Internet Connectivity

```
//Open Google maps with provided Geo-Location
openMaps(lat,long){
  let App;
  if(this.launchNavigator.isAppAvailable(this.launchNavigator.APP.GOOGLE_MAPS)){
    App = this.launchNavigator.APP.GOOGLE_MAPS;
  }else{
    console.warn("Google Maps not available - falling back to user selection");
    App = this.launchNavigator.APP.USER_SELECT;
  }
  this.launchNavigator.navigate([lat, long],{
    app: App
  });
}
```

Code 5: Function to launch Google maps or native navigation app

```
ionViewDidLoad() {
  // Start searching for beacons within visitors
  this.platform.ready().then(() => {
    this.beaconProvider.initialise().then((isInitialised) => {
      if (isInitialised) {
        this.recordedTime = new Date();
        this.currentTime = new Date();
        this.listenToBeaconEvents();
      }
    });
  });
}
```

Code 6: Start searching for iBeacons once the Start tour oprion is opened

```
getCloseArtefact() {
  let currentList = [];
  this.beacons.forEach(element => {
    let Artefact = this.artefactList.find(x => x.major_id === element.major);
    //let Artefact = this.artefactList.find(x => x.major_id === x.major_id);
    currentList.push(Artefact);
  });
  return currentList;
}
```

Code 7: Get information of the closest artefact

```
//Present alert when artefact is detected
async presentModal(currentBeacon: any, albumImages: any[]) {
  const modal = await this.modalController.create({
    component: MediaModalPage,
    componentProps: <null>{ 'beacon': currentBeacon, 'images': albumImages, 'type': "artefact'
    showBackdrop: true
  });
  return await modal.present();
}
validList():boolean{
  console.log("valid =>"+(this.beacons.length > 0));
  console.log(this.beacons);
  return this.beacons.length > 0;
}
}
```

Code 8: Function to present user with an alert of artefacts close by