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Creating a Personalised Learning Experience in Museums using Facial Expression Analysis

Alecsandria Missangu
1509001

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Brunel University
Department of Computer Science
Uxbridge
Middlesex
UB8 3PH
United Kingdom
T: +44 1895 203397
F: +44 (0) 1895 251686

Abstract

Museums preserve the world's history, providing the ability to interpret the past and understand our place in the future. With increasing, yearly visits students, families, tourists, professionals and hobbyists visit museums for various reasons, the important being to learn something new. Learning is the good acquired from the museum experience, however, how can we be sure that learning is being achieved? This is easy to measure in education, teachers teach students, students revise and later tested on the subject. This approach is not suitable for museums as learning happens in an informal manner.

The M-ARS application will provide a solution to this problem by creating a personalised learning approach. The user will be presented with generic information, to which the application will determine whether the user has understood the information by performing a facial expression analysis. The results will be recorded over-time and learning can be tracked through the application. Once the application has enough data on the user, it will be able to predict how the user will react to various information, therefore, creating a personalised learning experience.

Memorable and good experiences can create life-long museum visiting habits, therefore, this dissertation will provide details on how technology can be used to create a memorable experience, how learning can be achieved and personalised, so visitors have a good museum experience.

Acknowledgements

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Special thanks to Yata and Isaac, for always being there ☺

I certify that the work presented in the dissertation is my own unless referenced.

Signature _____Alecsandria Alec Missangu____

Date _________05 April 2019__________

Total Words: 2005

Table of Contents

List of Tables

List of Figures

1 Introduction

Over two decades ago, museums were just dusty old buildings, whereas now there an increase of public awareness (John F and Lynn D, 2018), making them one of the top attractions in London alongside Tower of London and St Paul's Cathedral (Visit Britain, 2016). By December 2018, there were a total of 3.4 million visits made to the DCMS sponsored museums and galleries, an increase of 6.1 in comparison to the previous year as seen in Figure 1. Museum visits fluctuate throughout the year; however, the general trend is to expect higher numbers during school holidays (GOV.UK, n.d.).

Department for Digital, Culture, Media & Sport

Museum and Gallery Visits Statistics Overview
December 2018

Museum / Gallery	Monthly visits	Change from previous year	Percentage change on previous year	Museum / Gallery	Monthly visits	Change from previous year	Percentage change on previous year
The British Museum	459,485	▲ 96,204 ▲	26.5%	Science Museum Group	335,379	▼ -14,928 ▼	-4.3%
The Geffrye Museum of the Home	616	▼ -14,976 ▼	-96.0%	National Portrait Gallery	122,674	▼ -22,248 ▼	-15.4%
Horniman Museum & Gardens	40,742	▼ -6,013 ▼	-12.9%	Royal Armouries	138,333	▲ 12,047 ▲	9.5%
IWM	150,578	▲ 27,205 ▲	22.1%	Sir John Soane's Museum London	9,860	▼ -91 ▼	-0.9%
The National Gallery	530,125	▲ 121,284 ▲	29.7%	Tate	534,490	▼ -26,250 ▼	-4.7%
Natural History Museum	424,729	▲ 37,685 ▲	9.7%	V&A	312,550	▼ -25,457 ▼	-7.5%
Royal Museums Greenwich	143,887	▲ 12,770 ▲	9.7%	The Wallace Collection	31,576	▼ -4,386 ▼	-12.2%
National Museums Liverpool	151,218	▲ 1,441 ▲	1.0%	TOTAL	3,392,274	▲ 194,300 ▲	6.1%

Figure 1: Museum and Gallery Visits Statistics Overview (GOV.UK, n.d.)

The term learning has been defined as "the acquisition of knowledge or skills through study, experience or being taught" (Oxford Dictionaries, n.d.). The quantity of information is ever-growing, so is our thirst for knowledge which remains unsatisfied. Those who seek to gain more knowledge turn to books, despite the decrease in the numbers, others turn to television, which is no surprise with the growing views in broadcast media, even though there has been a decrease in traditional television usage due to the astounding growth of the internet and let's not forget about museums. Museums provide reliable, authentic and comprehensive information about numerous objects in art, science, history and natural history to name a few, making museums a trustworthy source for learning.

Learning is the main reason people go to museums and this is the "good" acquired from their experience (John F and Lynn D, 2018). Since museums provide a place for children and adults to leisurely uncover the past, present and future, it not surprising many within the museum community question whether any learning is achieved in museums. This dissertation aims to uncover how learning is achieved, which technologies can help improve visitor experience and how learning can be measured within the museum.

1.1 Aims and Objectives

The aim of this project is to improve the learning experience in museums by developing an application that delivers a personalised learning approach. The application will scan the user's facial emotion to assess and challenge users' current knowledge on the subject. In order to achieve the aim of this project, the following objectives need to be met:

1. Review literature relevant research to the role Augmented Reality (AR) plays in museums and education., how is learning achieved in the digital era and how personalised learning is achieved. Demonstrate the need for the application in order to meet the project's aim.
2. Based on findings from the literature review, select an appropriate design approach for the application, develop design diagrams which will lead to a functional prototype which uses AR technologies.
3. Using design diagrams from objective 2, investigate, identify and select technologies which will be integrated into the application and implement a working prototype.
4. Ensure information about the artefact is altered correctly according to the user's level of understanding.
5. Identify and select appropriate test methods and evaluate plans, then apply them to the prototype to show that it functions correctly.
6. Identify how the prototype can be further improved given more time and resources and whether the aim has been met.
7. Demonstrate engagement with the university's ethics by gaining formal ethical approval using the BREO system.

1.1 Project Approach

Figure 2 shows the process of how the project will be approached. The flowchart shows how each chapter links with the next and what would be need be accomplished before moving on.

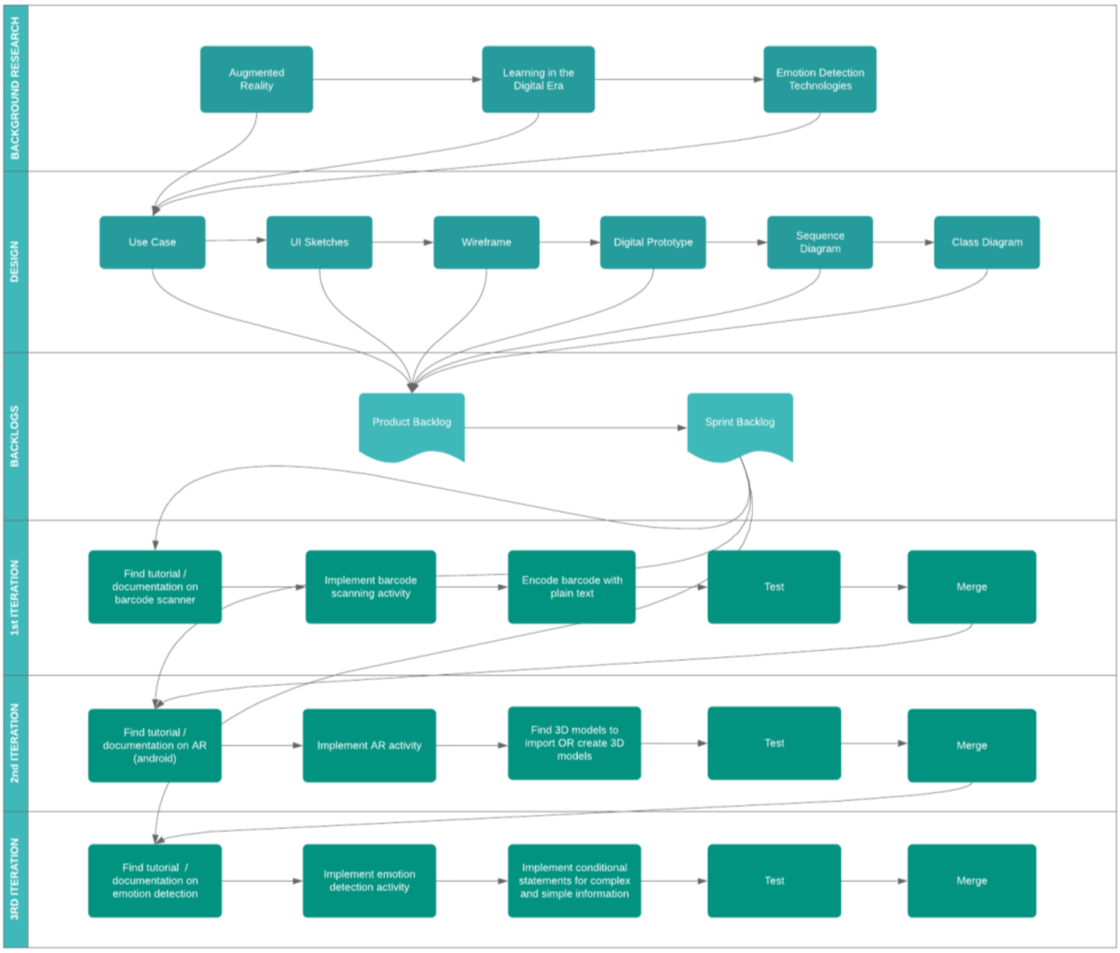


Figure 2: Project Approach Flowchart

1.2 Dissertation Outline

- Chapter 2 discusses the background research undertaken for the project. It identifies the key features integrated into the application and they would be used
- Chapter 3 identifies the software development approach used in this project and the steps taken to achieve the aim
- Chapter 4 discusses the design stage of the project
- Chapter 5 describes the implementation of the QR code feature
- Chapter 6 describes the implementation of the AR Core feature
- Chapter 7 describes the implementation of the facial expression detection feature
- Chapter 8 describes gamification techniques implemented into the M-ARS application
- Chapter 9 discusses testing methods used for the M-ARS application
- Chapter 10 evaluates the whole project
- Chapter 11 provides a conclusion of the whole project and discusses future work

1.3 Summary

This chapter has uncovered how museums are an informal place for learning and that is “good” acquired from the experience is learning. With increasing yearly visits, the importance of ensuring learning is achieved is becoming a necessity to ensure visitors have a good experience. However, there is more to learning than just reading information, the next chapter will explore how technology can be used to assist in learning. The next chapter will also explore various learning techniques and approaches used in the digital era.

2 Literature Review

This chapter aims to discuss relevant literature which will uncover how technology can be used in museums, how learning achieved in the digital age can be used to enhance learning before finally discussing approaches to personalising learning. This chapter will justify why these technologies, methods and techniques are suitable for this project.

2.1 Augmented Reality (AR) Technology

We are living in an era of emerging technologies, Augmented Reality (AR) being one of them. AR has a long history since it was first introduced in 1968 by Ivan Sutherland, who developed the first head-mounted display system. The system was used to display wireframe drawings using computer-generated graphics (Augment News, 2016). Since then, AR has been developing at a rapid pace in various sectors such as education, gaming, health care and e-commerce.

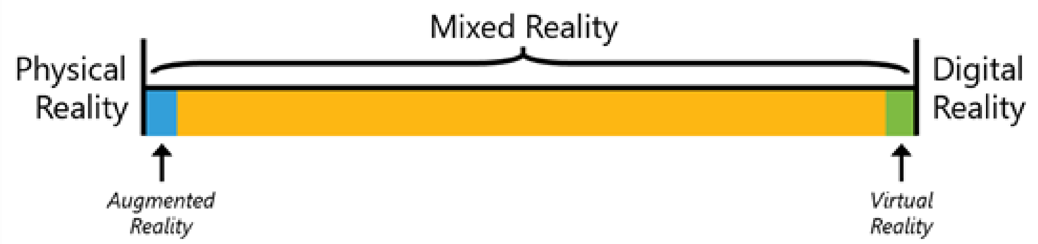


Figure 3: Mixed Reality Spectrum (Microsoft, 2018)

AR is part of the reality technologies family which includes Virtual Reality (VR) and Mixed Reality (MR) as seen in Figure 3. VR aims to submerge the user into an artificial environment, where the user cannot see the real world around them while inside this environment (Greg K, Joseph R, 2012). The experience is accomplished using head-mounted displays with headphones connected to them and sometimes hand-held controllers are used for providing a fully immersive experience. Whereas, MR is a combination of the virtual and physical world. MR is experienced in two ways, virtual objects can be placed in the real world or physical objects which are represented virtually can be placed in the artificial world, both allowing full interaction with the user and the artificial world. The merging of computer processing, human and environmental input allows movement in the real world to be translated into the artificial world. The use of holographic and immersive devices creates a seamless MR experience (Microsoft, 2018).

Augmented Reality	**Virtual Reality**
Creating the experience	
Achieved without completely submerging the user into the virtual world, allowing the user to see the real world. This is critical in the museum environment as the user must be aware of their surroundings to costly damage and accidents	Achieved by completely submerging the user into the virtual world. Even though this may create a more memorable experience for the user, the museum would have to invest in this technology by providing enough space for users to manoeuvre to avoid costly damage and accidents
Devices compatible with the technology	
With the launch of Apples AR Kit and Googles AR Core, AR is made available on mobile phones, devices users are familiar with. This would create a seamless experience within the museum	Even the experience can be replicated on mobile phones, VR requires the use of head-mounted displays in order to take full advantage of the technology. This would create long queues in the museum which may affect the overall experience

Table 1: AR vs VR

AR technology works using several methods (New Gen Apps, 2017):

- Simultaneous Localization and Mapping (SLAM) – Simultaneously localizes sensors with respect to the surroundings while mapping the structure of the environment at the same time. Therefore, it's the best way to render virtual images over real-world objects.
- Recognition based AR – Also referred to as marker-based AR. The camera is used to identify visual markers such as QR codes to produce an augmented image once the marker has been identified by the device.
- Location-based AR – Data provided about the location is dependent on GPS, digital compass, velocity meter or accelerometer which are used as input to provide the augmented visualization.
- Projection Based AR – Works by projecting light onto real-world surfaces. Interaction is achieved sensing interaction (i.e. touch) of the projected light. The interaction is distinguished between known projected and the altered projection caused by the user's interaction (Reality Technologies, n.d.).
- Superimposition Based AR – Either partially or fully replaces the view of an image with an augmented view of the same object. Object recognition plays an important role because the original view cannot be replaced with an augmented on if it cannot determine what the image is (Reality Technologies, n.d.).

Implementing recognition-based AR would be the best option because major changes are not required within environment and the artefact remains to be the centre of attention, creating a seamless museum experience. SLAM would also a good alternative to recognition-based AR however, SLAM is not suitable in large scale environments (Simon Burkard, 2017), this is problematic because users would have to scan the object, some objects in museums are large, therefore, users would have to stand back a few meters to fit the object in the frame. This can cause costly damage and accidents as users may be careless while performing this action. Superimposition poses a similar problem, however, due to lighting conditions object recognition may be difficult as the application may have difficulties identifying the object. Using location-based AR would be problematic because museums have "dead spots" where all connection is lost, therefore the application would not be able to provide data as the location would not be picked up by the application. Projection based AR poses a different problem since light must be projected onto real-world objects, this increases the chance of users causing accidents when trying to view the artefact.

AR is redefining various sectors such as entertainment and education. Often museums can be identified as a way of providing entertainment while educating the general public. Applications such as Google Sky Map and Star Walk have been developed for educational purposes. They allow users to learn about stars, constellations, planets and satellites in the sky above the user at any location and time. Such applications become educational tools which can help a variety of users interested in the Astronomy (PC World, 2012). This is one of many examples showcasing how AR is currently being for educational purposes. Learning is achieved in a non-traditional method where a teacher is not required to teach the student(s). With increasing numbers of AR and VR technologies being introduced in classrooms, students have been given the opportunity to learn in an immersive manner instead of using computer screens. AR has opened the doors in the growing world of gaming and education. Introducing gaming in education has chosen to increase motivation, therefore, becoming essential in children and teenagers (Ching Hui, Chia-Huei and Jau-BiLinc, 2014). Therefore, introducing gamification in museums will certainly increase public engagement for families and students by allowing various age groups to interact with artefacts in a way they find most suitable, thus, enhancing learning compared to standard methods currently being used.

More recently The National Museum Cardiff undertook a 16-week pilot of a new hand-held device which used AR to make the exhibitions come to life by superimposing animated models that were true to the creature's skeletons displayed within the museum. The pilot augmented three exhibitions, Underwater Life experience, the Dinosaur experience and the French Expressionist Gallery. The aim was to enable visitors to gain a deeper understanding and learn more about the collection and the narratives behind the collections. It was impressive how they managed to offer a tour considering the user's location without any loss of connectivity or data transfer requirements. Considering museums have dead spots where the visitor is guaranteed to lose connectivity implementing a solution which provides the user with the information required while they are not connected to the internet is important. It was concluded that 77% of the visitors read or paid attention to the additional 3D descriptive labels. This suggests that displaying augmented artefacts does not distract the user from the overall exhibition and in turn, increases the overall visitor experience. From the graph (Figure 4) displayed below, museum visitors would like to see more experiences available, therefore, establishing a need for introducing AR in museums (Museums + Heritage Advisor, 2018).

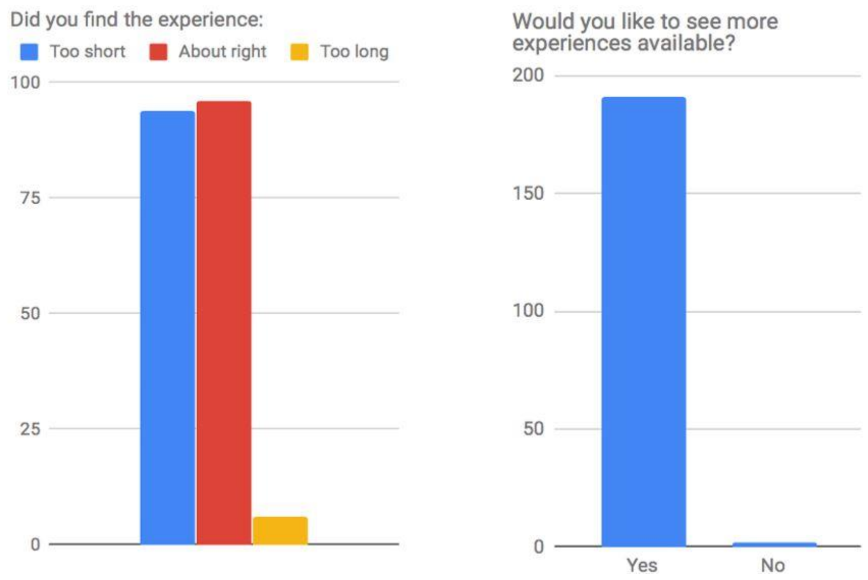


Figure 4: ExplorAR Visitor Feedback (Museums + Heritage Advisor, 2018)

New advances in technology have provided exceptional advantages over traditional methods of teaching by providing new techniques for students to learn and for teachers to share knowledge. However, since the technology is still relatively "new" and developments are still being made, both software and hardware. Development is slowed down as people are still learning about this technology even though it has been around since 1986. The technological gap in AR devices also causes limitations to what can be made possible on a device e.g. Microsoft HoloLens and smartphones. Another issue is security and privacy, currently, there are no regulations which depicts what is allowed and what is not allowed in the virtual world, and therefore, the technology can be used with malicious intent. Furthermore, there is the potential of physical harm, (The App Solutions, n.d.) when Pokémon Go was released in July 2016, it was reported $500,000 of vehicle damage, 31 injuries and two accidental deaths were related to Pokémon Go (Jones, Rhett. Study Estimates That Pokémon GO Has Caused More Than 100,000 Traffic Accidents). Therefore, it's important to ensure visitors are always aware of their surroundings.

2.2 Enhancing Learning in the Digital Age

In December 2018, the number of museum visits increased by 6.1% compared to December 2017 (GOV.UK, n.d.). With increasing numbers, it's not surprising that museums play a vital role in education from children in schools to adults as well as shaping the community. Museums provide an informal learning environment by inviting students and engaging them in varies exhibits and activities. 80% of parents believe museums and galleries are one of the most important resources for educating their children (NMDC, 2014).

Trends show an increase in visits during school holidays (GOV.UK, n.d.), highlighting the importance of personalising learning to maximise learning. Museums attract explorers, facilitators, experience seekers, professionals, hobbyists and rechargers (Walker, n.d.) varying in learning capabilities and styles. It is well-known that different people prefer different approaches when learning, while others may prefer a mix two or three learning styles, others may stick to one. Seven types of learning style have been identified (Learning Styles, n.d.):

- Visual - Refers to people who prefer using pictures, images and other visual cues such as mind maps and colours
- Physical – Refers to people who prefer using their body i.e. learn by doing. This is achieved by drawing diagrams or role-playing
- Aural – Refers to those people who prefer learning using sound and music
- Logical – Refers to those who prefer using logic and reasoning. This type of learning is achieved when the reasoning behind the concept is understood.
- Verbal – Refers to those who prefer using words, both speech and in writing
- Social – Refers to those who people who prefer working in groups or with other people
- Solitary – Refers to those who prefer to work alone through self-study

Those who visit museums out of interest and curiosity (i.e. explorers), would have less knowledge about an artefact compared to those whose interests range by their role (i.e. professionals and hobbyists), a teacher or photographer. A professional photographer may visit a gallery in search for inspiration on a new project while an explorer may visit a gallery because of a popular photography exhibition. These two people seek information but at different levels, the photographer may be interested in the creative process of the photographer being showcased whereas the explorer may be interested in the key interesting facts. The photographer may prefer information displayed in a different manner, i.e. showing a video of the photographer capturing a moment, with the narrative instead of reading descriptive text. Personalising how content is displayed depending on the user's current knowledge is a potential method of maximising learning as the user would be able to absorb the information according to their preferred learning style.

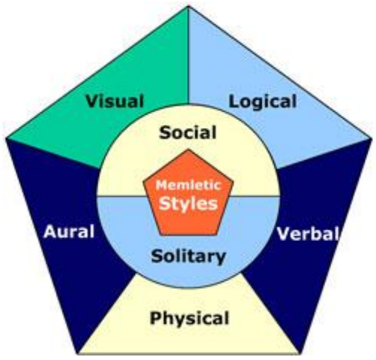


Figure 5: Learning Styles (Learning Styles, n.d.)

Having a good and memorable experience can influence lifelong museum visiting habits (Mike Murawski, 2014). Traditional methods of teaching provided in schools undertake a formal learning structure which is typically led by a teacher. Everyone goes through this stage of learning and while some may find it difficult to understand information at their learning capacity, others may not. Therefore, it's important to understand how different people absorb information using different techniques. Digital learning is a modern approach to teaching which gives students control over time, place, path and pace. This means learning is no longer restricted to school boundaries, the internet enables students to learn at any time and place. The pace no longer pre-set by the teacher, interactive and adaptive software allows students to learn in their own style and at their pace. Collected data gives teachers and parents information needed to adjust and meet the student's unique needs. Digital learning goes beyond the technology used, a combination of technology, digital content and instruction are needed. The technology allows the student to connect to the internet to get access to the academic digital content which can range from interactive and adaptive software to literature and video. Educators will always be necessary for learning and it also applies to digital learning. Technology will never eliminate the role of teacher, teachers ensure the student learns and stays on track in their personalized path (The Governor's Office of Student Achievement, n.d.).

Introducing digital learning into the museum environment may be another potential method to maximise learning while creating a good and memorable experience. Learning will no longer be restricted inside the museum, enabling users to learn outside the museum will help reinforce learning and aid in the transition from short-term to long-term memory. This can be achieved by implementing a post-museum journey, which will present a journey the user has taken within the museum. Using emotion AI to detect which content the user found to be most interesting, this information can be presented back to the user in the post museum journey. Moreover, it will provide the visitor with the chance to learn outside the four walls of a museum and getting the chance to find out more about a specific topic or exhibition in their own time. Data collected from the M-ARS application can be used to monitor and track overall learning of artefacts to assess how users engage with the information as well as recommend exhibitions they may be interested in based on their previous journeys.

Another method of creating a memorable and good experience can be achieved by introducing gamification techniques. Gamification means introducing gaming techniques and design into a non-game environment (Top Hat, 2018). Gaming has been known to increase engagement, therefore it's no surprise that gamification has been introduced to education to increase engagement. Play and interactive learning are minimised as we progress in education (The Power of Gamification in Education, 2018), resulting in students being bored and distracted. Current methods of testing knowledge involve using tests which we prepare for in advance, even though the person may not understand what they are writing, if they can recall what they memorised, it is qualified as they have understood the content. Since the main problem in education is related to lack of motivation and low engagement levels, new techniques and approaches such as gamification are being introduced to incite students (Gabriela, Nadezhda and Lina n.d.). There are various links that can be found in gaming and in education as shown in Table 2

Gaming	**Education**
Overcoming obstacles to reach the goal (i.e. win)	Learning objectives are achieved by interacting and overcoming (i.e. understanding) educational content
Tracking player progress, since the next steps and moves are generated from these results	Tracking student progress is vital to achieving learning objectives since the student's learning path is determined by knowledge and learning (Glover, 2013)
Collaboration is used to achieve a goal as a team	Collaboration is used to actively learn as a team

Competition between friends encourages them to better than the other	Friendly competition between friends can entice productivity

Table 2: Gaming vs Education

In a similar manner, these approaches can be used in the M-ARS application to ensure users are engaged and motivated to find out more about the artefact they are viewing. For example, implementing tasks which users can complete to achieve points. This can encourage and engage visitors to complete/unlock more tasks which increase in difficulty in order to gain more points. These points can be used as rankings within the app to show overall progress against friends and family and even other museum visitors.

2.3 Personalising Learning

Verbal communication coexists alongside non-verbal communication, and in some ways, nonverbal communication has more meaning than verbal communication because the meaning behind someone's words can be interpreted differently than the literal translation (LIVESTRONG.COM, 2018). A study conducted at UCLA revealed a majority of communication to be nonverbal. The study showed 7% of messages were presented through words, 38% vocal elements and 55% being nonverbal elements. There are different forms of nonverbal communication which can provide more insight into how a person is feeling or what they are thinking such as facial expressions, eye contact and movements, posture, gestures and tone of voice (Good Therapy, 2015).

Artificial emotional intelligence uses nonverbal communication to detect emotion. Using a facial expression to determine the user's emotion is a suitable option because the AI can automatically determine whether the user has understood the content. An alternative approach would be using like or dislike buttons, however, this gives the user the option to choose whether they have understood the content or not. Giving the option means fewer data would be gathered as the user may or may not provide feedback and the feedback provided may be biased due to the fear of looking unintelligent to those around them. Therefore, the M-ARS application would be able to determine if the user has understood the content displayed from how they reacted. If the user reacts positively, this would suggest they have understood the information and find it interesting, therefore the application would alter the information and make it more complex to challenge the user's current knowledge. If the user reacts negatively, the application would alter the information and make it simpler to ensure to meet the user's current knowledge. However, if the user has a neutral reaction, information displayed will be dependant on the overall learning rate of the user.

Alternatively, implementing artificial intelligence (AI) into the application can aid in creating a personalised learning experience. Below are some key approaches to personalised learning (Sukant Khurana, 2018):

- Adaptive learning – a method of delivering personalised learning by addressing the user's unique needs using just in time feedback, pathways and resources rather than a generic all in one learning experience (Smart Sparrow, n.d.).
- Individualised learning – the pace of learning is adjusted to meet the individuals learning needs
- Differentiated learning – the approach of learning is adjusted to meet the individuals learning needs
- Competency-based learning – the individuals learning outcomes are central to the learning process (Teach Thought Staff, 2018)

These approaches would require the use of supervised learning algorithms, such as Bayesian networks and decision trees. Bayesian networks are probabilistic graphical models which use the Bayesian inference for probability computations (Towards Data Science, 2018). Bayes classifier has been used to determine students learning styles by training students' number of attempts, duration and grades (Feldman et al, 2014). In a similar manner, Bayes classifier can be to determine learning styles by training user's engagement levels from the emotion AI. This approach can be used to deliver adaptive learning in the application. When creating implementing this method into the application, it's important to keep in mind how each approach works with the other, for example, how can adaptive and differentiated learning be used together to create to set the pace of learning. Designing the personalised approach is as important as implementing the solution to take full advantage of the approach.

2.4 Summary

From the research undertaken in this chapter, it has been discovered that a good and memorable experience can impact lifelong museum visits. Current solutions do not provide a personalised learning experience for the user, therefore, it's not surprising that the question "Is learning actually achieved in a museum?" remains unanswered. This chapter has explored how technologies such as AR create a memorable experience. A study conducted by The National Museum Cardiff has shown how visitors positively reacted to the technology. This chapter also uncovered various methods and approaches to how personalised learning can be achieved by looking at the modern approach to learning. The M-ARS application will build on these methods and approaches to create a personalised experience for the user. The next chapter will discuss how the software will be developed.

3 Software Development Approach

This chapter will discuss why the selected software development approach is suitable for the project. It will also discuss how the approach has been adapted to suit the project. A plan will be developed as part of the chosen methodology.

3.1 The Agile Framework

In the 1990s, software development faced "the application development crisis". Projects were abandoned because of changing businesses, requirements and systems because businesses moved at faster than the time it took to develop a software or application. A software was estimated to take three years to develop, others taking even longer. A well-known example being the Space Shuttle program which was launched in 1982 but used requirements and technologies from the 1960s (Tech Beacon, n.d.). The constant development of unusable software led to the development of Agile. Agile introduced iterative development, which follows a set of principles and values. It provides the option to select the most appropriate methods and procedures for a project, it does not provide a method to how a team should operate (What is Agile Methodology? 2018).

Plan-Driven Process	Agile Process
Predictive	Adaptive
Fixed scope	Fixed schedule
Adjusts schedule to preserve scope	Adjustable scope to preserve schedule
Long development cycle (e.g., 6 months)	Short development cycle (e.g., 2—4 weeks)
Linear	Cyclic
Organizes work into major phases	Organizes work into small deliverables
Delivers value at project completion	Delivers value incrementally over time

Figure 6: Waterfall (Plan-Driven) Process vs Agile Process (cprime, n.d.)

Before deciding which approach to follow, the following questions had to be answered:

- **Are all the requirements for the project known?**
  A core principle of the waterfall methodology is to what will be developed at an early stage. This allows progress to be easily tracked at the beginning of the project. Documentation will also need to be developed to ensure new developers easily catch up during the maintenance stage (The Digital Project Manager, 2017). Whereas a core principle of the agile framework is individuals and interactions over processes and tools. This allows the people who are responsible for the business needs to drive the development progress. Therefore, as business needs change, requirements can change accordingly, communication being a key factor (Smartsheet, 2016).
  Since the M-ARS application proposes a new solution, it's difficult to know all the requirements at the beginning of the development life cycle. Therefore, following an

adaptive approach which encourages change would be more suitable. If the M-ARS application was building upon an existing solution, it would be easier to set all the requirements for the application at the beginning of the lifecycle.

- **Can the project be predicted sequentially?**
  A core principle of the waterfall methodology states each stage in the life cycle has been completed before moving on the next. Therefore, the project can be tracked, and the process can be measured easily (The Digital Project Manager, 2017) as seen in Figure 7. Whereas, a core principle in the agile framework values working software over comprehensive documentation. This allows the developer to achieve what is needed without being delayed with documentation. Agile does not neglect documentation, agile documents are recorded as user stories, which provides the developer with enough information to get started on developing new functionality (Smartsheet, 2016).
  Requirements for the M-ARS application cannot be identified in the early stage of the lifecycle, developing software incrementally would be an advantage over planning how the project would be completed. Another question arose at this stage, is there a need to plan the whole project? Is it even possible? Both answers were no, following the agile frameworks would be appropriate. Since a working solution is required to pass this project, focusing on delivering new functionality iteratively is more beneficial than trying to figure out the effort required to complete the project. Taking this route may result in not having a solution at the end of the lifecycle.
- **Can testing be done at the end of the project?**
  Building from the previous point, the waterfall methodology follows a sequential approach where each stage must be complete before moving on to the next. Therefore, testing would have to occur towards the end of the lifecycle. However, a core principle in the agile framework encourages responsiveness to change rather than following a plan. The iterative approach allows a change in priorities; therefore, new functionality can be added given it has a higher priority (Smartsheet, 2016).
  The M-ARS application would require testing each time new functionality is added to the application because more than one technology would be embedded into the application. Therefore, it's difficult to predict the behaviour of these technologies and whether they would work well together. Unforeseen changes may need to be made during the development lifecycle. However, if there was evidence to prove that these technologies work together without an issue, following the waterfall methodology would be more appropriate.

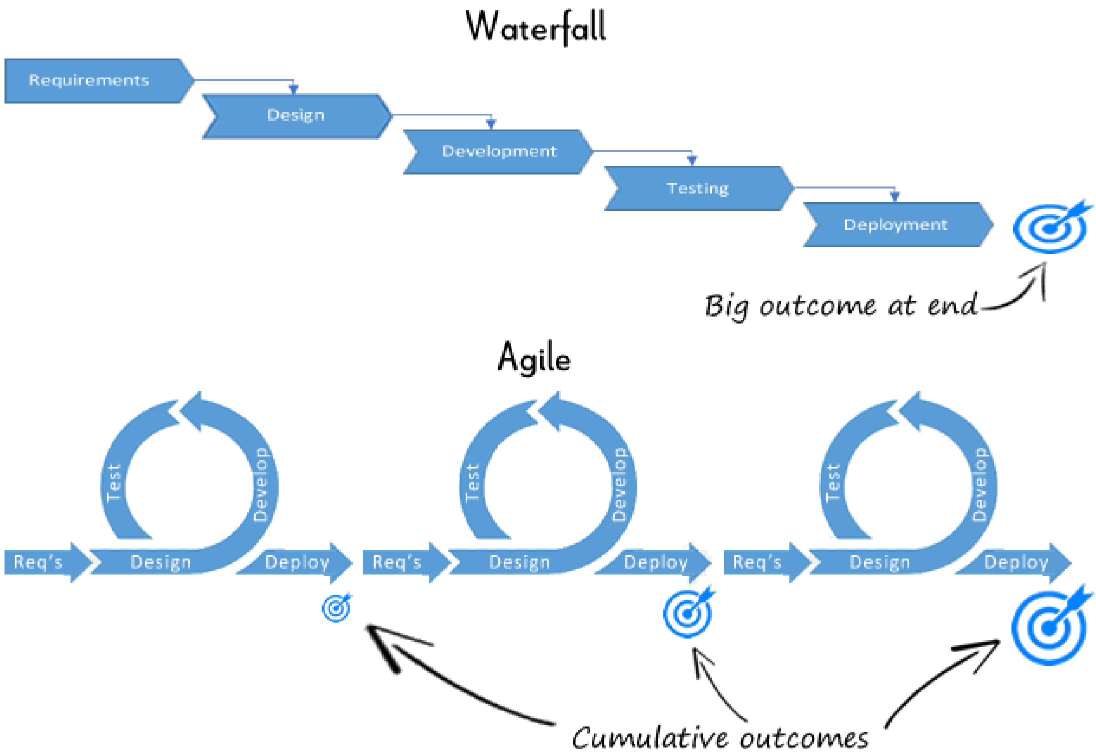


Figure 7: Waterfall and Agile Approaches (crmsearch, n.d.)

Agile consists of four core values and twelve principles which have been adapted to suit this project. The four core values: **"Individuals and Interactions Over Processes and Tools", "Working Software Over Comprehensive Documentation", "Customer Collaboration Over Contract Negotiation"** and **"Responding to Change Over Following a Plan"** are incorporated into the twelve principles. Considering only one person will be coding, the following principles where followed (Smartsheet, 2016):

- **"Customer satisfaction through early and continuous software delivery"** – This principle states customer satisfaction is increased when they receive working software in regular intervals rather than waiting long periods. The M-ARS application will follow this principle by focusing on continuous delivery rather than customer satisfaction since there are no customers.
- **"Accommodate changing requirements throughout the development process"** – This principle emphasis on the responsiveness to change. The M-ARS application will follow this principle by welcoming changing requirements even during the late stages of the development life cycle.
- **"Frequent delivery of working software**" – This principle follows the Scrum framework, to ensure the team works in sprints/iterations to ensure regular software delivery. The M-ARS application will follow this principle by following the Scrum framework. A product and sprint backlog will be developed to keep track of various tasks within a sprint. Since there is only one developer, this would be a good method to

keep track of what has been done and what needs to be done. The product backlog will also provide a way to prioritise the user stories so that the important ones are focused on and delivered at an early stage in the life cycle.

- **"Working software is the primary measure of progress"** – This principle states, delivering functional software to the customer is a measurement of the process. The M-ARS application will follow this principle by focusing on delivering functional software frequently to measure the project's progress since there is no customer.
- **"Agile processes to support a consistent development pace"** – This principle states, the pace of development should be maintained throughout the project's life cycle. The M-ARS application will follow this principle by ensuring the pace of development is maintained throughout the project's lifecycle. Since the project is time-blocked, this will ensure working software is being delivered efficiently.
- **"Attention to technical detail and design enhances agility"** – This principle states, the team can maintain the pace, improve the product and sustain change by using the right skills and having a good design. The M-ARS application will follow this principle by producing continuous high-quality technical detail and design to move the project forward quickly and efficiently.
- **"Simplicity"** – This principle states, software should be developed in a manner which gets the job the done is essential. The M-ARS application will follow this principle by maximising the amount of work not done.
- **"Regular reflections on how to become more effective"** – This principle states, the team should reflect on self-improvement, process improvement, skills and techniques to become more effective. The M-ARS application will follow this principle by reflecting on how to become more effective then altering behaviours accordingly.

Since this is a one-man team, these principles are important as they ensure the project progresses efficiently due to the short development life cycle.

3.2 Sprints

Scrum is a subset of the Agile framework which provides a framework to following the agile values and principles. However, just following the scrum processes does make a project agile, the processes should be followed because it helps in being agile because "it provides powerful methods and processes to get work done" (What is Agile Methodology? 2018). Scrum is often used software and product development efficiently, following iterative and incremental practices (Figure 8). The scrum processes enable the ability to deal with changes smoothly in order to produce a product which meets changing business goals by increasing productivity as time is significantly reduced by cutting out the waterfall methodology (cprime, n.d.)

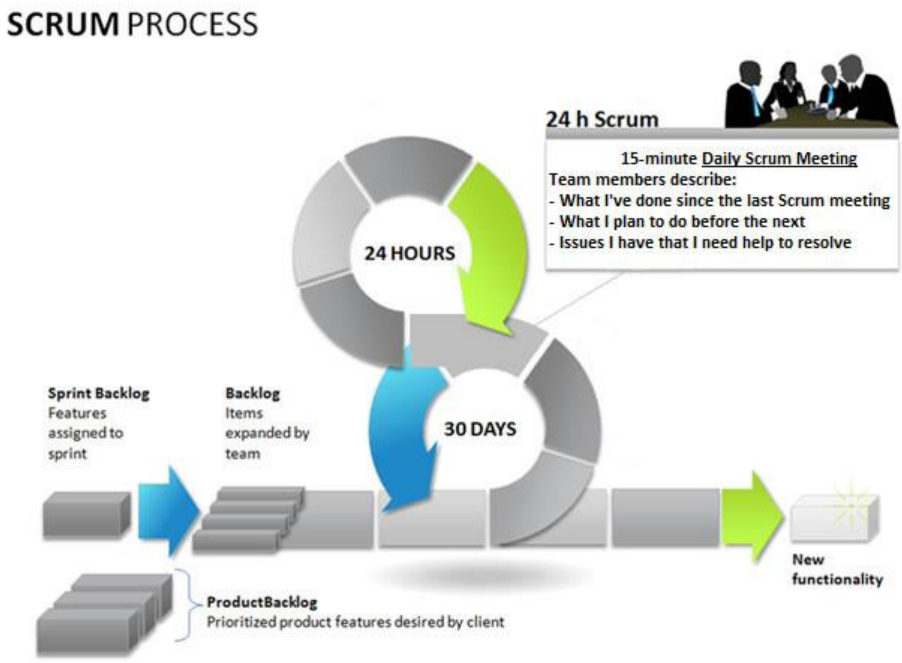


Figure 8: Scrum Process (cprime, n.d.)

The M-ARS application will the Scrum framework to efficiently deal with expected changing requirements during the development lifecycle. Tasks have been broken down into sprints (Table 3) with estimating each sprint will last 2 weeks. The scrum process will be adapted to suit this project. Scrum meetings will be omitted from this project because only one person will be managing and developing the M-ARS application.

Sprint 1	2 Weeks	Sprint 2	2 Weeks	Sprint 3	2 Weeks
Implement barcode scanner using Firebase API		Implement AR Core using Sceneform plugin		Implement emotion AI using Affectiva SDK	

Table 3: Sprint Planning

3.3 Iterations

The M-ARS application will follow an iterative development approach, breaking down large tasks (Table 3) into smaller tasks. The code is design, implemented and tested in repeated cycles, each iteration adding new features until the software is ready to be deployed (in context of the M-ARS application, until the aim has been met). Functional code is expected at each iteration (Search Software Quality, 2011). At the end of each iteration, an evaluation will be performed reflecting on how to become more effective. Each iteration has been broken down into user stories (Table 4).

3.4 Personas

Personas “a fictional representation of actual users” (The Segue Creative Team, 2016) as seen in Figure 9, were created to represent potential users of the M-ARS application, a full list of personas can be found in **Error! Reference source not found.Error! Reference source not found.**. Personas were created to gain insight on what they consider important, this would be beneficial when accessing the priority of user stories. Since the application would be user centred, it was important to place myself in various scenarios to better understand what each user would deem important. This not only helped to understand the potential users, but it also helped to isolate critical features, therefore saving development time.

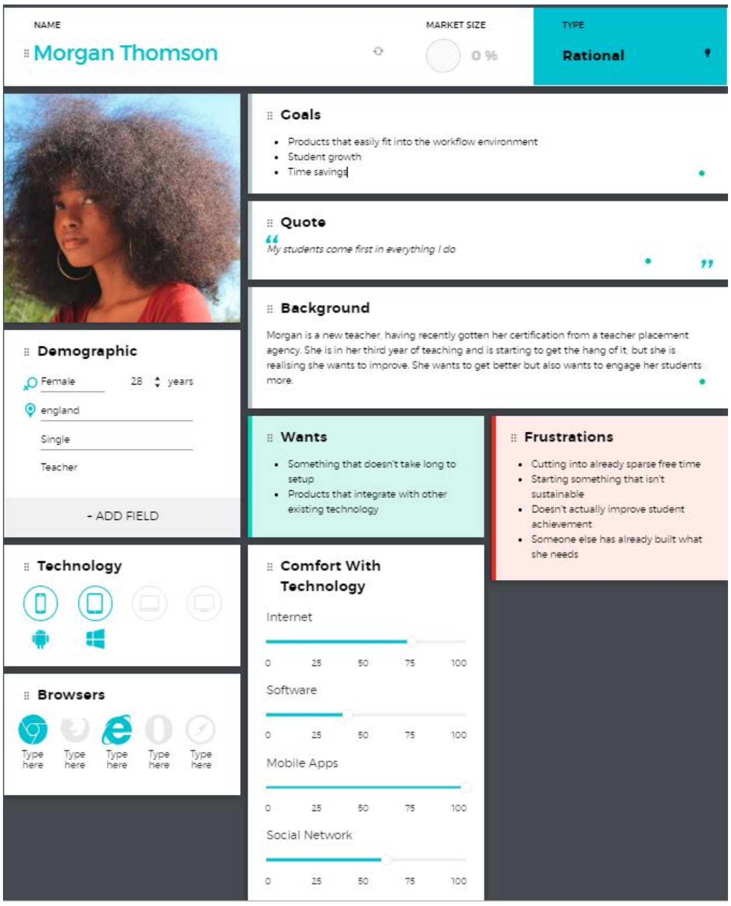


Figure 9: Persona (Morgan Thomson)

3.5 Product Backlog

The product backlog (Table 4) consists of a list of tasks which need to be completed to achieve the aim of the project. This replaces the requirements documentation found in the waterfall methodology with user stories. User stories describe a functional feature/requirement in a narrative form. A user story is marked as complete once it passes acceptance tests developed for it (cprime, n.d.). The user stories were derived from the tasks in Table 3. A priority will be assigned according to how the features in the application will build on the previous.

ID: U001	**As a user, I would like to be able to scan a barcode, so that I can easily get information about the artefact**	**Priority: 1**
Description: The user would align the QR Code with the square frame on the screen within the app to scan the barcode. The app would need to be granted permission to the camera prior to scanning the barcode. Selecting "Allow" would grant permission, "Deny" would deny permission resulting its failure to use the M-ARS application.		
How to test: Tester verifies the application requests for camera permission, once permission is granted, a QR code is scanned and embedded information is displayed in the next activity.		
Screens: Figure 12: Scan Activity Digital Prototype		
Source: Chapter 2.1 identified using marker-based recognition is most suitable for the M-ARS application because more information can be embedded into the QR codes, therefore not limiting what information fetched from the QR code.		
ID: U002	**As a user, I would like to be able to view the artefact on my device, so that I can see interact with it**	**Priority: 1**
Description: The user would be able to view an augmented version of the artefact they have scanned. The user would be able to interact with the 3D model by turning it around, enlarging the model and viewing an animation.		
How to test: Tester moves the phone to scan for flat surfaces. Once the surface has been detected, tester taps the screen to place the model into the plane.		
Screens: Figure 13: AR Activity Digital Prototype		
Source: Chapter 2.1 identified having a good and memorable experience can influence lifelong museum visiting habits. A study performed in The National Museum Cardiff concluded visitors enjoyed using AR within the museum and they would like to see more AR experiences. Considering how AR has already been positively accepted by visitors, implementing this solution into the application to create a personalised learning experience can create a memorable experience, therefore creating lifelong museum visiting habits.		
ID: U003	**As a user, I would like to receive personalised information about the artefact, so that I am able to comprehend the content at my level of understanding**	**Priority: 1**
Description: A summary of the artefact currently being viewed. Selecting "Read more" will provide personalised content according to how the user's response to the summary.		
How to test: Tester would ensure the emotion AI is functioning correctly. Once the SDK detects a face, the correct output should be displayed. When the SDK fails to detect a face (i.e. null outputs), the application should handle this exception by displaying generic information.		
Screens: Figure 14: Default Info and Tailored Info Activities Digital Prototype		

<table>
<tr><td colspan="3">Source: Chapter 2.2 identified the impact of introducing digital learning in education. Using these techniques has enabled students to learn at their own pace, time, path and place. Since museums offer informal learning, giving providing control over how a visitor learns reduces the pressure to cram as much as possible at ago.</td></tr>
<tr><td>ID: U004</td><td>As a user, I would like a simple interface, so that I navigate through the app easily</td><td>Priority: 1</td></tr>
<tr><td colspan="3">Description: The M-ARS application should provide a simple interface which is not overwhelming to the user</td></tr>
<tr><td colspan="3">How to test: Tester should be able to navigate through the digital prototype and highlight “hit zones” to emulate interaction of various tasks.</td></tr>
<tr><td colspan="3">Source: From the personas in Appendix B.1, users mentioned they would want a simple interface which is not confusing nor overwhelming</td></tr>
<tr><td>ID: U005</td><td>As a user, I would like helpful information, so that I know what do to within the app</td><td>Priority: 2</td></tr>
<tr><td colspan="3">Description: The M-ARS application should provide helpful information to the user to inform the user what they need to accomplish on each activity. Help icons should be present on each activity providing useful information to the user.</td></tr>
<tr><td colspan="3">How to test: Tester selects help icon to view helpful information about each activity</td></tr>
<tr><td colspan="3">Source: From the personas in Appendix B.1, users wanted an app that is easy to use and navigate.</td></tr>
<tr><td>ID: U006</td><td>As a user, I would like a way of keeping track of my activities within the app, so that I see my overall progress</td><td>Priority: 2</td></tr>
<tr><td colspan="3">Description: A notification informing them an achievement has been unlocked. When the user selects “View”, the user is taken to the achievements activity where they can view the latest achievement unlocked along with a list of current achievements which have been unlocked</td></tr>
<tr><td colspan="3">How to test: Tester checks unit tests written for achievement logic have passed.</td></tr>
<tr><td colspan="3">Screens: Figure 15: Achievement Activity Digital Prototype</td></tr>
<tr><td colspan="3">Source: Chapter 2.2 identified the impact of gamification in education. A current issue in education lack of engagement with learning materials. Gaming has been known to improve productivity and engagement, therefore implementing gamification techniques can help increase engagement levels by pushing users to explore without the fear of failing.</td></tr>
<tr><td>ID: U007</td><td>As a user, I would like the application to me to be aware of their surroundings, so that accidents are minimized</td><td>Priority: 3</td></tr>
<tr><td colspan="3">Description: A dialogue will appear informing the user to be aware of their surroundings</td></tr>
<tr><td colspan="3">How to test: Tester checks unit test written for accelerometer logic have passed.</td></tr>
</table>

Source: Chapter 2.1 identified some of the challenges AR has previously faced. The launch of Pokémon GO caused lots of accidents because users were not aware of their surroundings. In hopes to avoid costly damage in museums, the M-ARS application will instruct users to be aware of the surroundings.

Table 4: Product Backlog

3.6 Test Strategy

The M-ARS application will use black and white box testing methods to judge whether each user story has met its test acceptance criteria. Black box testing will be used to identify errors from the user's point of view (Software Testing Fundamentals, 2017 a), whereas, white box testing will be used to identify internal errors within the application (Software Testing Fundamentals, 2017 b).

3.7 Sprint Backlog

The sprint backlog (Table 5) is a subset of the product backlog, it contains tasks which need to be completed during each sprint. The idea behind having a sprint backlog is to complete the long list of tasks which have been created in the product backlog. Tasks which need to be completed are discussed during sprint planning meetings. Since the M-ARS application is a one-man team, tasks were planned before implementation. Not during sprint planning meetings. Once tasks have been set, they remain unchanged during the sprint. Tasks which cannot be completed by the end of the sprint are added back to the product backlog and are addressed in the next sprint. In the context of the M-ARS application, incomplete tasks would be added back to the product backlog, upon reflection of the sprint, next steps will decide what happens in the next sprint (Project Manager.com, 2018)

Product Backlog ID & User Story		**Duration (Days)**
U001	As a user, I would like to be able to scan a barcode, so that I can easily get information about the artefact	14
	Implement a barcode scanner	9
	Encode artefact ID and name into the barcode	1
	Test feature	2
	Add feature to the M-ARS app	2
	Implement front end	1
U002	As a user, I would like to be able to view the artefact on my device, so that I can see interact with it	14
	Implement augmented reality functionality	8

	Test feature	2
	Merge feature with the M-ARS app	2
	Implement front end	2
U003	As a user, I would like to receive personalised information about the artefact, so that I am able to comprehend the content at my level of understanding	14
	Implement facial emotion detection SDK	6
	Identify which emotions imply the user understands the content	1
	Handle null outputs by displaying default information	1
	Implement conditional statements so the correct content is displayed depending on SDK output	1
	Implement tailored information activity	1
	Test feature	2
	Merge feature with the M-ARS application	1
	Implement front end	1
U006	As a user, I would like a way of keeping track of my activities within the app, so that I see my overall progress	14
	Identify achievements and how they would be unlocked	2
	Implement achievement activity	6
	Implement unit testing	4
	Test feature	2
	Merge feature with the M-ARS application	1

Table 5: Sprint Backlog

3.8 Summary

In conclusion, this chapter addresses the reasons why the agile framework is suitable for this project. In order to meet the aim, the aim has been broken down into achievable tasks in section 3.2. A product backlog was developed breaking down the tasks in section 3.2 into smaller tasks, which were carried over to section 3.5 to create items needed for each sprint. The next chapter will discuss the design phase of the project.

4 Design

This chapter will discuss the design process of the M-ARS application. Each design component was development iteratively, following the agile framework. For readability of the report, this section focuses on design.

4.1 Use Case and Narrative

Use cases are used to capture the dynamic behaviour of a running system. In the context of the M-ARS application, it was used to capture the dynamic behaviour of the application. It consists of actors who are the different type of users of the system, uses case and their relationships (tutorials point, n.d.). Figure 10 shows a use case for the M-ARS application which is accompanied by a narrative (Table 6). Creating a use case showed the external and internal interactions that affect the application. User stories were developed after the use case was created because it was easier to see how the application will operate. The narrative helped to show the flow of events and which features would be implemented helped not getting caught up in the back and forth aspect of identifying which features to use and how the app would work while designing the UI.

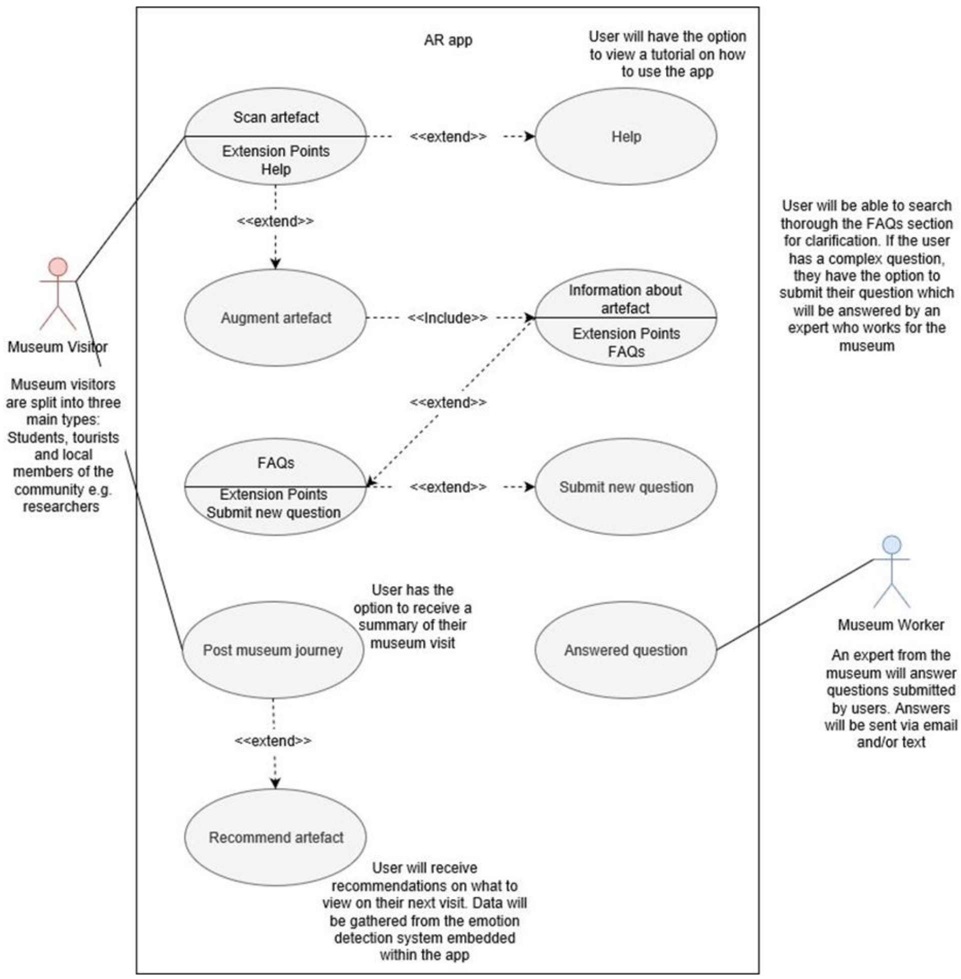
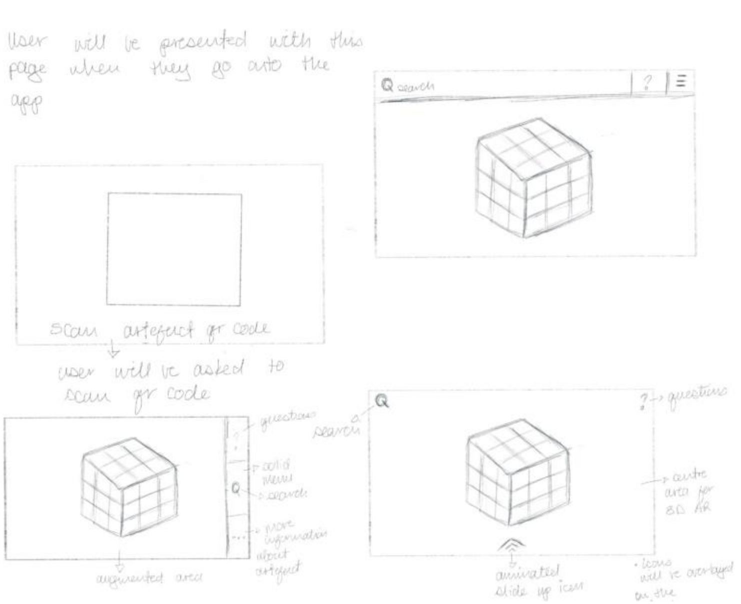


Figure 10: Use Case

Use Case Name: M-ARS Application	
Primary Actor	Museum Visitor (Students, Tourists, Teachers, Researchers, General Public)
Supporting Actors	Museum Worker
Pre-Conditions	The user is present at a museum and has the app installed
Trigger	The user wants to view artefact which is currently being displayed at the museum
Basic Flow	1. The application prompts the user to scan the QR code 2. An augmented version of the artefact will appear, otherwise, a message will appear asking the user to scan the QR code again 3. Emotion detection algorithm will detect the user's facial expression. Information is altered depending on the output. 4. The application prompts the user to swipe up, to display information about the artefact which is currently being viewed.
Alternate Flows	1 Help icon is selected 1.1 The help page is displayed, informing the user on how to use the application through a series of steps 2 FAQs icon is selected 2.1 FAQs page is displayed, a series most commonly asked the question the artefact is shown 3 The user wants to submit a new question, selects "add" icon 3.1 Submit new question page, the user is prompted to fill in a form 4 Museum expert answers the question 4.1 The answer is sent to the user via their preferred method of choice
Post-Conditions	1. Post museum journey will be sent to the user's email address. Will contain highlights and lowlights – data gathered from emotion detection algorithm 2. Recommendations will be made for future visits to the museum.

Table 6 – Use Case Narrative

4.2 UI Sketches



UI sketches were created using Procreate. Creating a low fidelity prototype meant less time was spent focusing on the details of the application. The aim was to create quick sketches, building on previous ideas to improve the design.

4.3 Digital Prototype

Digital prototypes are high-fidelity prototypes which provide a more realistic design of the application. Once the structure of the interface was decided in the low fidelity prototype, creating the high-fidelity prototype provided the chance to perform interface testing. This can be found in Chapter 10.1. The digital prototype was created using Adobe XD.

M-ARS Preview.mp4 (Command Line)

Figure 11: M-ARS Digital Prototype Preview

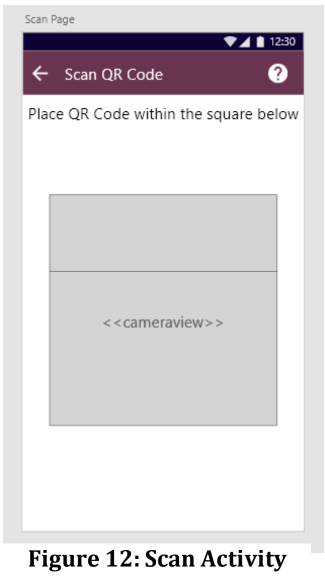


Figure 12: Scan Activity Digital Prototype

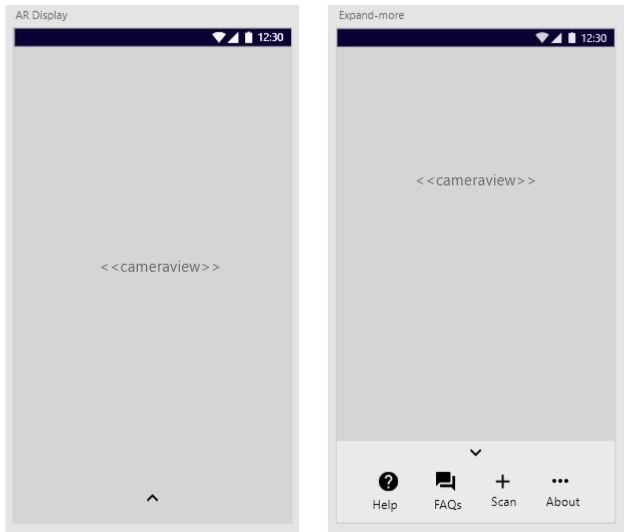


Figure 13: AR Activity Digital Prototype

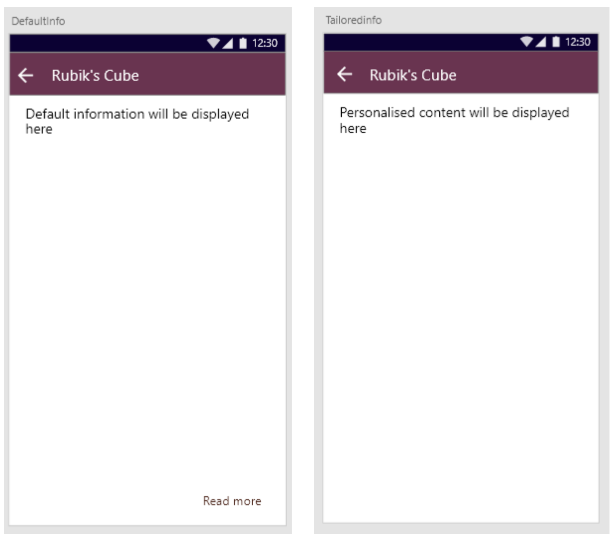


Figure 15: Default Info and Tailored Info Activities Digital Prototype

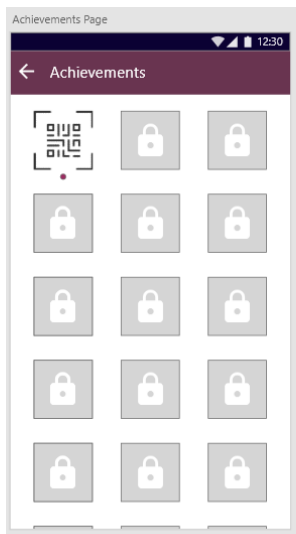


Figure 14:Achievements Activity Digital Prototype

4.4 Wireframe Storyboard

Wireframing is used to design the app on a structural level. They provide a visual representation of the flow of interactions within the application. While developing the digital prototype, a wireframe was developed to map the flow of interactions within the application. The prototype consists of back arrows within the interface, these icons will be omitted from during implementation because the user can use the hard or soft buttons on the phone to move back to the previous activity. The icons were added to the UI because interface testing was performed using a laptop. More details about the interface testing can be found in Chapter 10.1. Creating a wireframe demonstrated the key interface elements within the key pages.

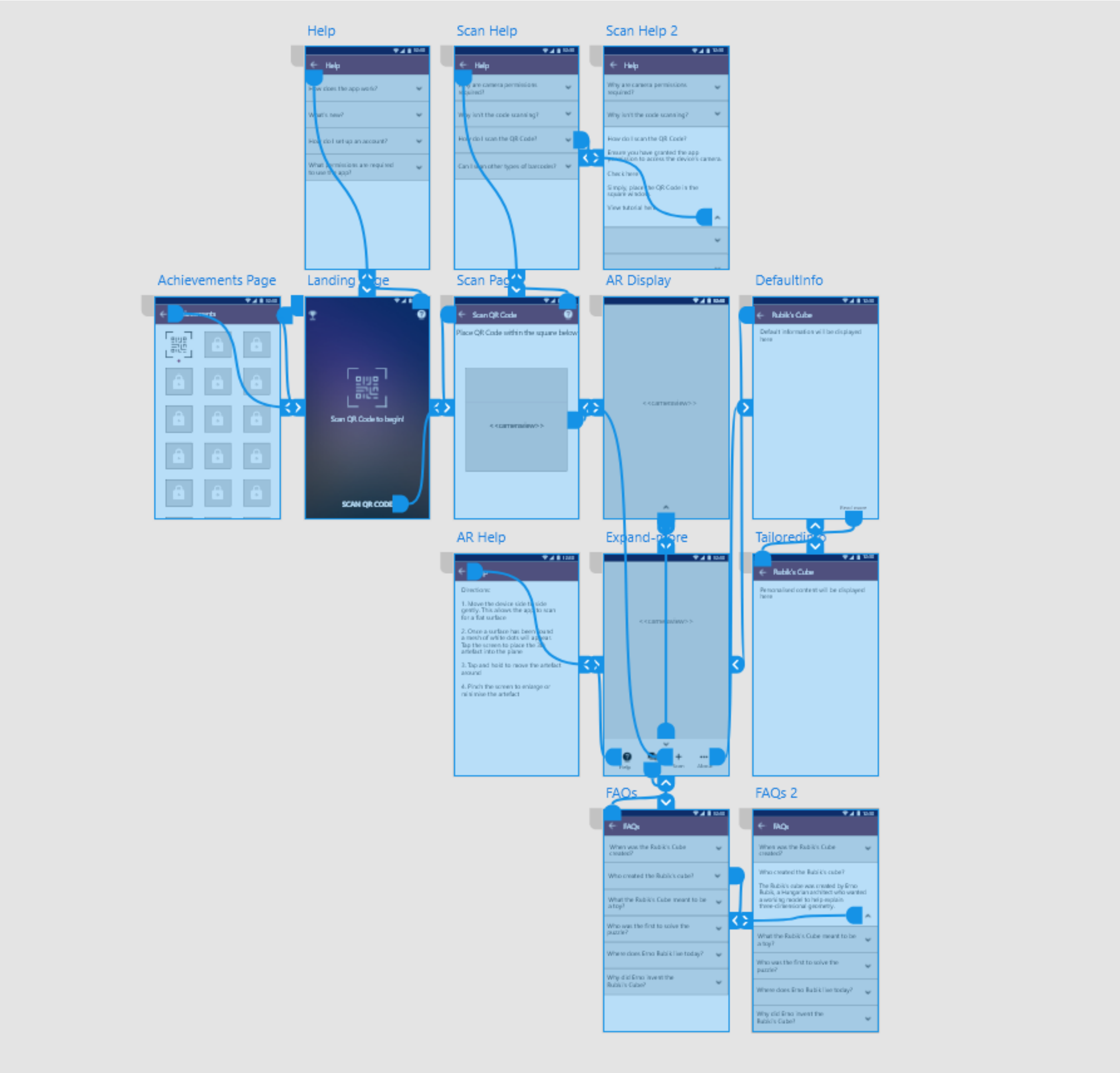


Figure 16 – Wireframe

4.5 Sequence Diagram

The sequence diagram shows how different activities in the M-ARS application interact with each other. Creating the diagram helped in understanding the flow of interactions, which activities are active and at what point, which actions are occurring at what stage and whether they are sequential or happening simultaneously. It provides details about the use case diagram in Chapter 4.1, primarily focuses on the core activities in the use case: scan artefact, augment artefact and information about the artefact. At this stage in the project, creating a sequence diagram helped in modelling the logic of different functions within activities which helped understand the detailed functionality of the potential solution at an early stage.

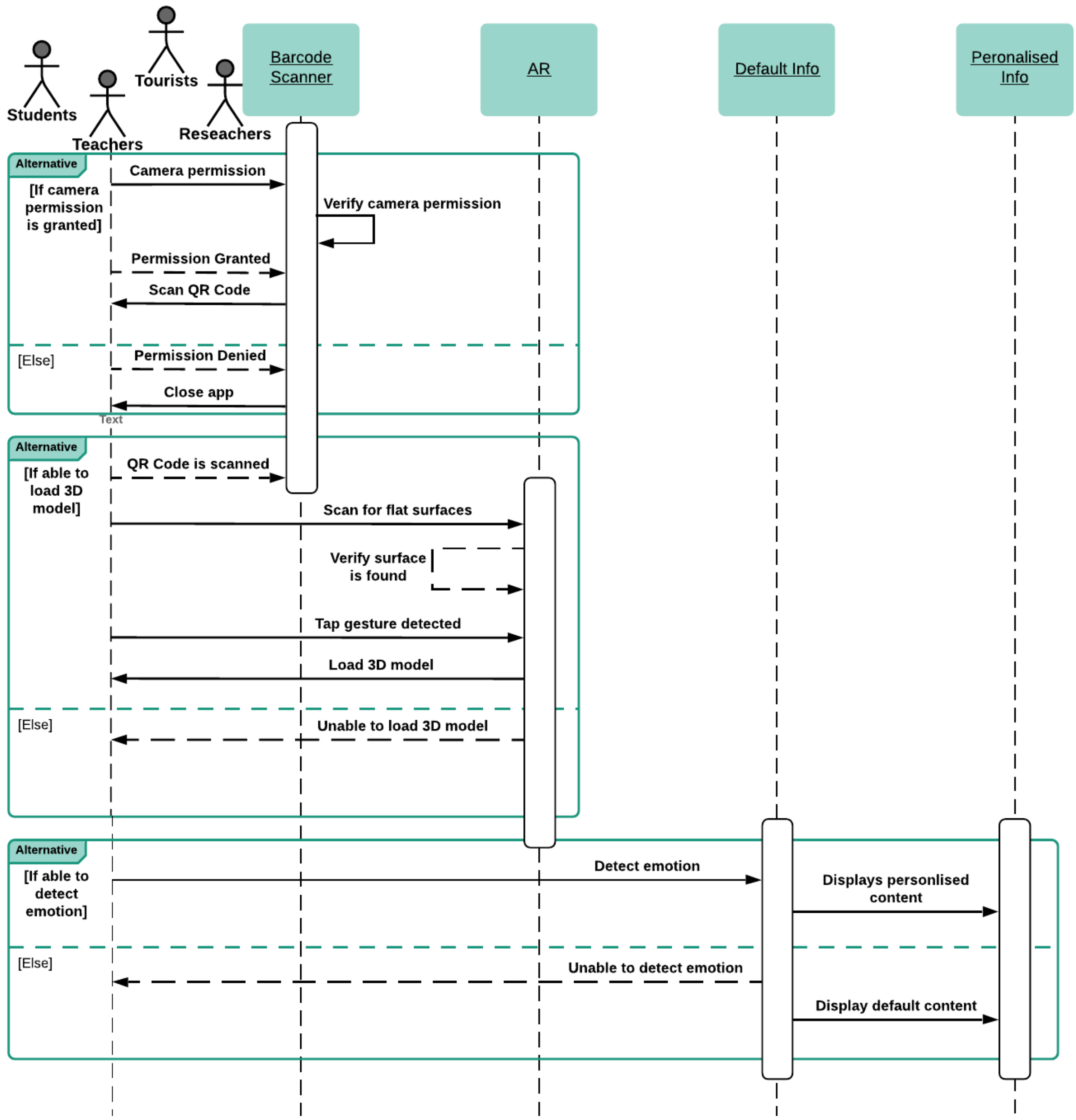
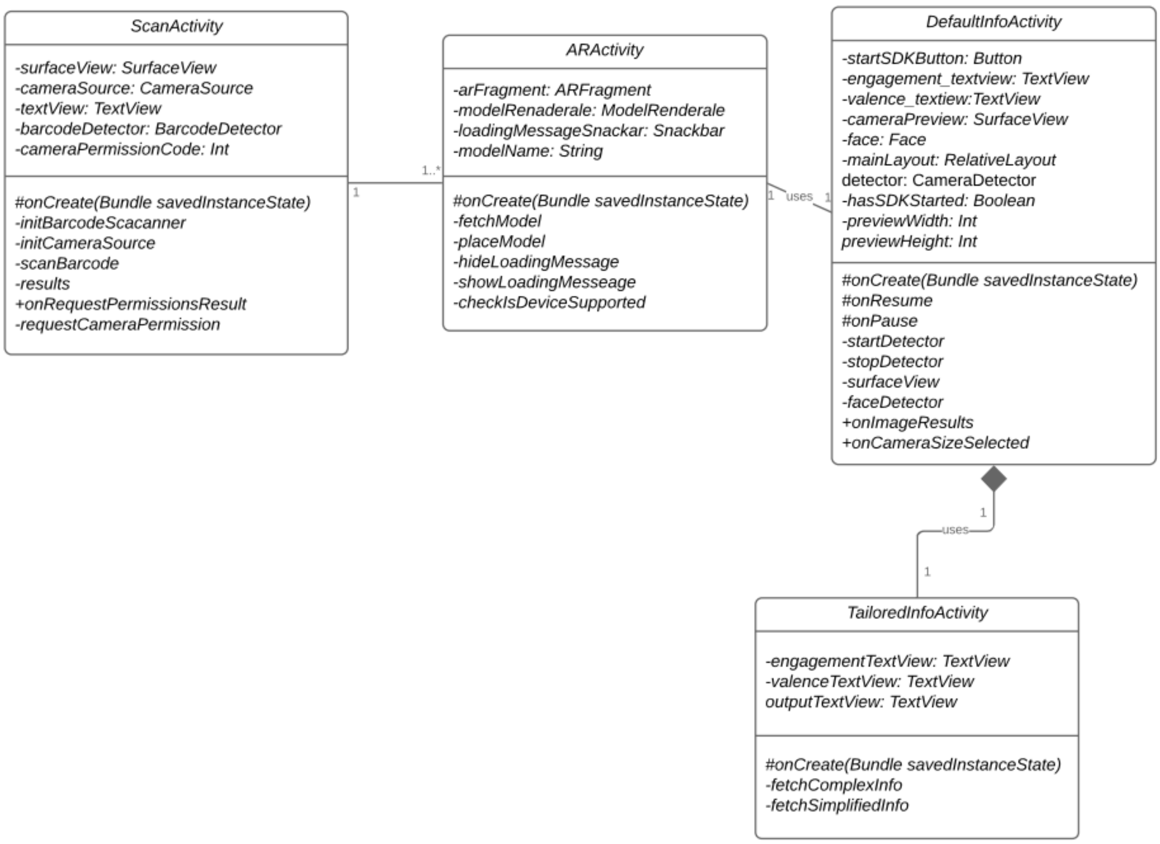


Figure 17: Sequence Diagram

4.6 Class Diagram

Class diagrams are used "clearly map out the structure of a system by modelling its classes, attributes, operations, and relationships between objects" (Lucid Chart, n.d.). A class diagram was created to get a better understanding of the simplified overview of the application. It was used to design the structure of the code in the activities in the sequence diagram.



4.7 Summary

In chapter concludes the design phase of the M-ARS application. At this stage of the project, a clear understanding and structure of the application were achieved. The next chapter describes the implementation of the barcode scanner.

5 QR Scan Feature

This chapter will provide details on the implementation of the barcode scanning feature.

5.1 Scan Activity

In chapter 2.1, it was concluded the marker-based AR (also referred to as recognition-based AR) was the suitable method for providing an AR experience for the application. The barcode scanning feature allows the user to get information about the artefact they wish to look at. QR codes are two-dimensional barcodes (matrix) which hold information both vertically and horizontally whereas, one-dimensional barcodes such as UPC barcodes only holds horizontal information (Create QR Codes, n.d.). The main advantage of using two-dimensional codes such as QR codes is they hold more information compared to one-dimensional codes (Table 7). This provides flexibility to what information I can store on the barcode. Alternatively, the AR marker can be used (Figure 18). However, this would cause crowds around the areas the marker is placed increasing the chances of causing costly damage. It may also be frustrating for users who would have to wait for crowds to reduce before getting the chance to explore the AR experience. QR codes provide a quick method to get information quickly while minimising crowds. Users can simply scan and move to another location.

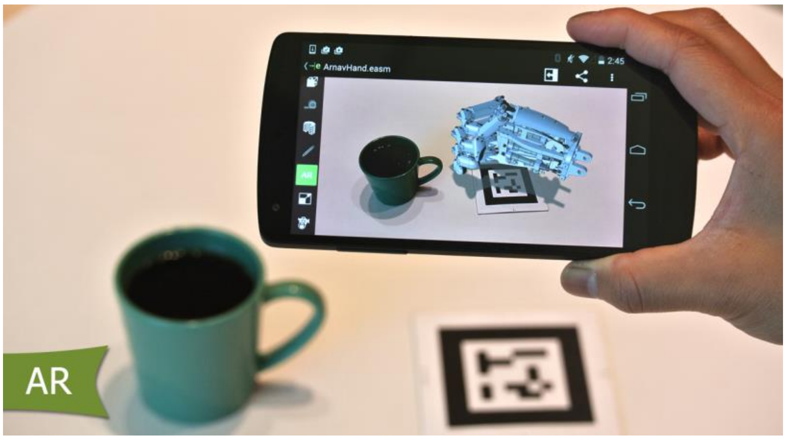


Figure 18: AR Code (Design Spark, 2017)

One-Dimensional barcodes	Two-Dimensional barcodes
Holds a limited amount of characters. The more characters encoded, the longer the barcode.	Stores more data than 1D barcodes. QR codes hold up approximately 1500 characters.
A most common type of barcode which has over 20 types of barcodes	Holds a variety of binary data such as images or websites

Suited for information which is associated with other information which changes frequently	Can be used in places where a 1D barcode wouldn't fit because it's not small enough. Used in specific industries or products because of its capability of being usable in small sizes
Database connectivity needs to be meaningful	No need to worry about scanner alignment

Table 7: 1D vs 2D barcodes (Lowry Solutions, 2015, All Barcode Systems, 2017)

The first attempt at implementing this feature was using the Firebase ML Kit API. Following a tutorial (Android Studio Tutorial - Barcode QR Code Reader with Firebase ML, 2018) on how to implement the scan feature. The tutorial's aim was to develop a scan feature which displays text, contact information and redirects the user to a webpage. The M-ARS application encountered a problem when it was trying to parse the data encoded into the QR code to the application. The application would scan the barcode successfully, however, the results were not being displayed in the next activity.

After spending some time debugging and not getting very far, the second attempt lead to using the Google Vision API (Application Programming Interface). The aim of the tutorial (QR code Scanner from Camera Android Studio Tutorial, 2018) was to display the encoded text on a text view created (Figure 19 – a screenshot of the output from the tutorial).

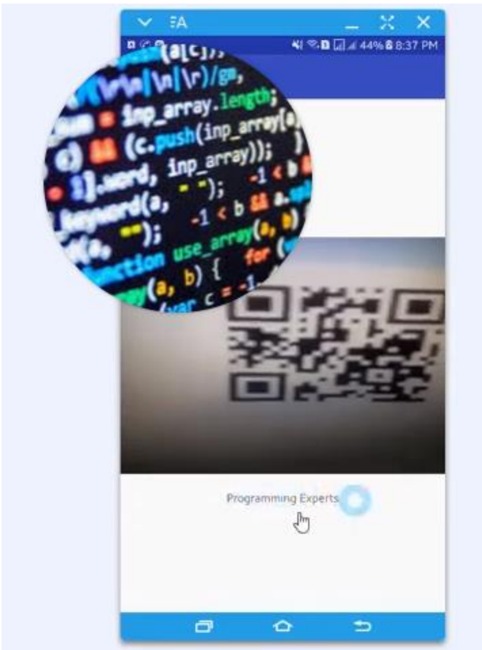


Figure 19: (QR Code Scanner from Camera Android Studio Tutorial, 2018)

The M-ARS application would use the embedded text to fetch the three-dimensional model which would be displayed in the AR Activity class. Therefore, the code was amended to meet this requirement (Figure 20 – lines 121 - 124), once testing was completed. Further details on testing can be found in Chapter 9.1. Data is parsed to the next activity using the Intent object via the `artifactName` string variable.

```java
104     private void results(){
105         barcodeDetector.setProcessor(new Detector.Processor<Barcode>() {
106             @Override
107             public void release() {
108 
109             }
110 
111             @Override
112             public void receiveDetections(final Detector.Detections<Barcode> detections) {
113                 //after QR code is scanned - get the data
114                 final SparseArray<Barcode> qrcodes = detections.getDetectedItems();
115 
116                 if(qrcodes.size() != 0) {
117                     textView.post(new Runnable() {
118                         @Override
119                         public void run() {
120                             //artifact details after qr code has been scanned successfully
121                             Intent intent = new Intent( packageContext: ScanActivity.this, ARActivity.class);
122                             intent.putExtra( name: "artifactName", qrcodes.valueAt( index: 0).displayValue);
123                             intent.putExtra( name: "scanCounter", scanCounter);
124                             startActivity(intent);
125 
126                             Vibrator vibrator = (Vibrator)getApplicationContext().getSystemService(Context.VIBRATOR_SERVICE);
127                             vibrator.vibrate( milliseconds: 1000);
128 //                            textView.setText(qrcodes.valueAt(0).displayValue);
129                             cameraSource.stop();
130                         }
131                     });
132                 }
133             }
134         });
135     }
```

Figure 20: Results Method - Scan Activity

5.2 Camera Permission

The M-ARS application requires camera permission to be granted to use the application otherwise the application cannot be used. Android clearly documents the importance of informing users what is being accessed and why the application needs to use it (Android Developers, n.d.). This information will be made available when the user selects the help icon.

Camera permission was implemented following android developer documentation (Android Developers, n.d.) and a YouTube tutorial (How to Request a Run Time Permission - Android Studio Tutorial, 2017). The `requestCameraPermission` method requests permission at runtime before the activity starts, the user is presented with a dialogue (Figure 21). When the user selects "DENY", the `onRequestPermissionsResult` method displays a toast message "PERMISSION DENIED". Another dialogue appears explaining why the permission is needed. When the user selects "ALLOW", a toast message "PERMISSION GRANTED" is displayed.

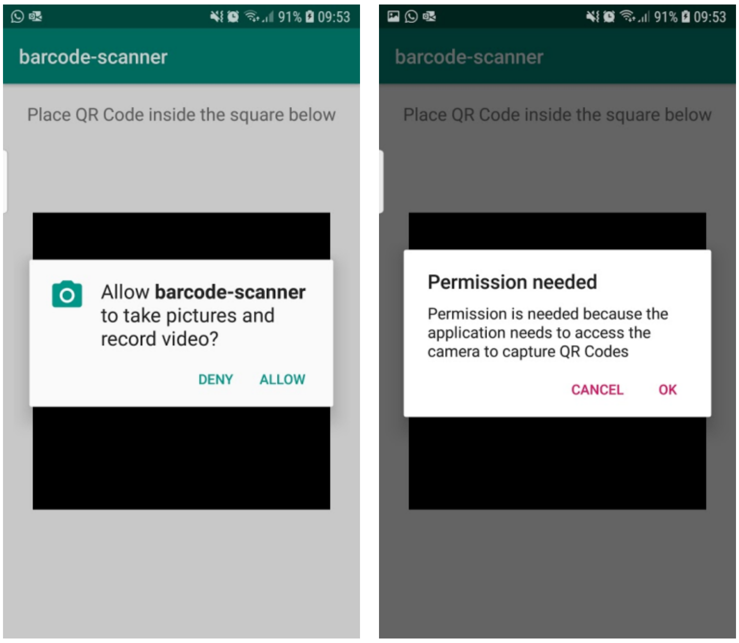


Figure 21: Camera Permission Screenshots

5.3 Sprint Review

This sprint was completed within the estimated number of days. The QR code scanning feature was developed, tested and added in the M-ARS application however, there feature a few issues need to be addressed to improve the usability of the application. Currently, the user would have to go back and forth between the Landing Page Activity and the Scan Activity when the following occurs:

- If the user selects "DENY" the dialogue would disappear. The user would have to navigate back to the Landing Page Activity for the permissions dialogue to reappear in the Scan Activity. This also happens when the user selects "CANCEL" on the Permissions needed dialogue.
- When the user selects "ALLOW", the surface view area remains blank. The user would have to navigate back the Landing Page Activity for the surface view to show a live camera feed.

To fix this issue, the following user story will be added into the product backlog: **U005: As a user, I would like a simple interface, so that I navigate through the app easily.**

This sprint is marked as complete since it has passed the acceptance test.

5.4 Summary

This chapter explained the process of implementing the Scan Activity. The sprint was marked as complete because it had met the acceptance test. To issues that arose during the sprint, a new item was added into the product backlog. The next chapter will describe the implementation process of the AR Activity.

6 Augmented Reality Feature

This chapter will provide details on the implementation of the AR feature.

6.1 AR Activity

AR Core was developed by Google to create AR experiences, enabling the device to track the environment, understand the world and interact with the virtual world. There are three key features integrated into AR Core, creating the AR experience: "motion tracking", "environmental understanding" and "light estimation". Essentially AR Core is tracking the position of the device at it moves and building its understanding of the world (Google Developers, n.d.). This is how the AR experience is achieved. Since this SDK was launched in March 2018, it's fair to assume that more features will be rolled out. In Chapter 2.1, it was discussed how even though AR has been around for several years, the technology is still relatively new. Ideally more can be achieved using a head-mounted display, however, to create a seamless experience and reducing costs, using a mobile device is beneficial for this project. AR Core has been selected because of the technology available (i.e. an Android mobile device and a windows laptop).

Alternatively, a web VR solution can be implemented into the M-ARS application. However, in Chapter 2.1, a study conducted by the National Museum Cardiff implemented an AR experience which did not require internet connectivity. Considering museums have "dead spots", the M-ARS application will take this forward during implementation by implementing a solution which does not internet connectivity to ensure the user can the application anywhere in the museum.

AR Core	**Web VR**
A familiar software, providing a less steep learning curve	Uses AR toolkit to deliver AR experiences to the web
An Android SDK, therefore, makes it easy to add to the project	AR toolkit has limited documentation and tutorials
Plenty of documentation and tutorials available	AR experience can be quickly coded
The Internet is not needed to access the three-dimensional assets	Using a web solution means there needs to be internet access. This is not always guaranteed in museums

Table: Comparison between AR Core and Web VR

Performed research in AR Core by looking documentation (Google Developers, n.d.) to better understand how the SDK works. Changes had to be made to the app's `build.gradle` file for Android Studio to gain access to the SDK's library. AR Core also requires access to the device's camera, this was already implemented in the previous feature, however, changes had to be made to the `Android Manifest` file to ensure Google Play Store downloads and install AR Core when the application is installed into the device (Figure 22)

```
<uses-feature
    android:name="android.hardware.camera.ar"
    android:required="true" />
```

Figure 22: AR Core Permissions

AR Core needs to be installed and up to date in the device for this feature to work, a check is automatically performed because the M-ARS application is using the `ARFragment` before the AR session is created. `ARFragment` is used in the activity_scan.xml file.

The next step was creating the AR experience which was achieved using Google Scenefrom. More details can be found in Chapter 6.2. Using sample code (Hello Sceneform) made available from GitHub (Google Developer n.d.), the AR experience was created. The code was merged with the M-ARS application after successfully importing a new 3D model into the application. When the code was merged with the M-ARS application, the method of fetching the 3D model had to be altered. Currently the model is fetched my calling the name of the model with is stored in res\raw file (Figure 23 – line 113).

```
110 // When you build a Renderable, Sceneform loads its resources in the background while returning
111 // a CompletableFuture. Call thenAccept(), handle(), or check isDone() before calling get().
112 ModelRenderable.builder() Builder
113     .setSource( context: this, R.raw.wolves) Builder
114     .build() CompletableFuture<ModelRenderable>
115     .thenAccept(renderable -> modelRenderable = renderable) CompletableFuture<Void>
116     .exceptionally(
117         throwable -> {
118           Toast toast =
119               Toast.makeText( context: this, text: "Unable to load andy renderable", Toast.LENGTH_LONG);
120           toast.setGravity(Gravity.CENTER, xOffset: 0, yOffset: 0);
121           toast.show();
122           return null;
123         });
```

Figure 23: AR Activity Screenshot

In the AR Activity, the model is fetched using a string variable which is parsed from the Scan Activity (Figure 24).

```
modelName = getIntent().getStringExtra( name: "artifactName");
```

Figure 24: AR Activity Screenshot 2

The `fetchModel` method in the M-ARS application was altered to fetch the model from the app\assets folder instead of the res\raw folder. This change had to be made because a string variable was now being called, otherwise an error would occur (Figure 25). After testing (details can be found in Chapter 9.3) was performed, it was identified that helpful information was needed in the activity to inform the user what was happening. `showLoadingMessage` and `hideLoadingMessage` were implemented to inform the user, the application is

“Searching for flat surfaces …”. This code was taken from the Solar System code sample. The user will now be able to understand what is happening i.e. if the surface is being searched.

```
private void fetchModel(){
    //Fetch model
    ModelRenderable.builder() Builder
            .setSource( context: this, Uri.parse(modelName + ".sfb")) Builder
            .build() CompletableFuture<ModelRenderable>
            .thenAccept(renderable -> modelRenderable = renderable) CompletableFuture<Void>
            .exceptionally(
                    throwable -> {
                        Toast toast =
                                Toast.makeText( context: this, text: "Unable to load" + modelName +" renderable", Toast.LENGTH_LONG);
                        toast.setGravity(Gravity.CENTER, xOffset: 0, yOffset: 0);
                        toast.show();
                        return null;
                    });
    fetchModelCounter++;
}
```

Figure 25: fetchModel method- AR Activity

6.2 Google Sceneform

Sceneform enables 3D models to be rendered into AR and non-AR applications, eliminating the need to learn OpenGL. The M-ARS application uses Sceneform and AR Core to deliver an AR experience. The Sceneform plugin was installed following the documentation (Google Developers, n.d.). Sceneform accepts obj, fbx and gift files. The 3D where downloaded from various sources:

- Andy – Hello Sceneform Sample
- Wolf – Poly (2017)

6.3 Sprint Overview

This sprint was completed within the estimated number of days. The AR feature was developed, tested added into the M-ARS application, however the usability of this activity can be improved ensure the user doesn’t get confused and/or frustrated when starting to use the application. Currently the user would have to manually install AR Core for this feature to work. To improve the apps usability, a method which checks if AR Core is installed on the device needs to be implemented. If the AR Core is not installed, the M-ARS application should redirect the user the Google Play Store to install the application manually in the case where AR Core has failed to install during the M-ARS application installation.

To fix this issue, a new task can be added to **U005**: Implement checkARCore method.

This sprint is marked as complete since it has passed the acceptance test.

6.4 Summary

This chapter explained the process of implementing the AR Activity. The sprint was marked as complete because it had met the acceptance test. To address the issues that arose during the sprint, a new task will be added in U005. The next chapter will describe the implementation process of the Default and Tailored Info Activities.

7 Emotion Detection Feature

This chapter will provide details on the implementation of the facial emotion analysis feature which delivers personalised learning.

7.1 Default Info Activity

Chapter 2.3 discussed how personalised learning can be achieved, one of the methods discussed was implementing an emotion AI which analyses whether the user has understood the information displayed. Research about facial emotion detection lead to the iMotions software which uses the Affectiva API to achieve facial expression analysis. The M-ARS application uses the API to perform its facial expression analysis. The API works by using the camera feed as input to identify key facial landmarks such as the corners of a person's mouth. Deep learning algorithms are used to analyse the pixels in these places in order to classify facial expressions. Results produced are unbiased and unfiltered facial expressions which are mapped to emotions. There is a total of seven emotions: anger, disgust, contempt, fear, joy, sadness and surprise and twenty facial expression metrics (Affectiva n.d. a).

After reviewing the documentation (Affectiva n.d. b), the app's build.gradle and root build.gradle files had to be amended, for Android Studio to access the API libraries. The following permissions had to be implemented for the SDK to work properly:

- Access to external storage
- Access to the internet when available

The SDK also requires access to the camera for the API to work, without it, the API won't be able to classify the user's facial emotions. Therefore, the M-ARS requires the camera permission to be granted for the app to be used. Without it, all the features implemented in the app won't work.

The API has different methods of capturing facial expressions:

- Analysing camera feed – this method is most suitable because, the user may start by not understanding the information or being thrown off by the usage of certain words. This won't affect the results because the API would capture and analyse the expressions as the user is reading the information. So even if the user may get confused at some point but manage to understand the content at the end, the API would classify that the user has understood the information, therefore, capturing the users learning process.
- Analysing a photo: this method is not suitable for the M-ARS application because the photo would have to be captured. Figuring out when the photo needs to be captured is vital when analysing whether the user has understood the information. Perhaps

capturing a photo at the beginning (when the user navigates to the activity) and the end (before the user navigates away from the activity) maybe an approach to analysing if the user has indeed understood the information. However, this leaves a lot of guess work as no data is captured to illustrate the users learning process.

- Analysing a recorded video file – this method would not be suitable for the M-ARS application because the recorded video would have to analysed before the personalised content is displayed causing a delayed between the Default Info Activity and Tailored Info activity. Because the time taken to analyse the video in unknown this method has been ruled out.
- Analysing a video frame stream – this method would also be suitable because the learning process would be captured in real-time. However, there is a privacy which would have to be addressed to the user. Audio would be captured along with the video stream, users may not feel comfortable with this. User's may also be uncomfortable with a video recording being captured even if it's not being stored.

The M-ARS application used sample code available on GitHub (GitHub, n.d.). The sample code would not import properly into Android Studio because the SDK location could not be found. This problem was resolved by manually copying the code into a new project. The sample code worked by selecting the "START SDK" button, located at the bottom right of the device. The SDK won't work unless the surface view button is selected, this shows camera feed view (Figure 27). The M-ARS application does not require this feature because this activity will display a general summary of the artefact being viewed. However, Android requires an active surface view for the camera function to work, therefore, the `surfaceView` method was altered to be 1px by 1px and `setAlpha(0)` was called to hide the surface view (Figure 28).

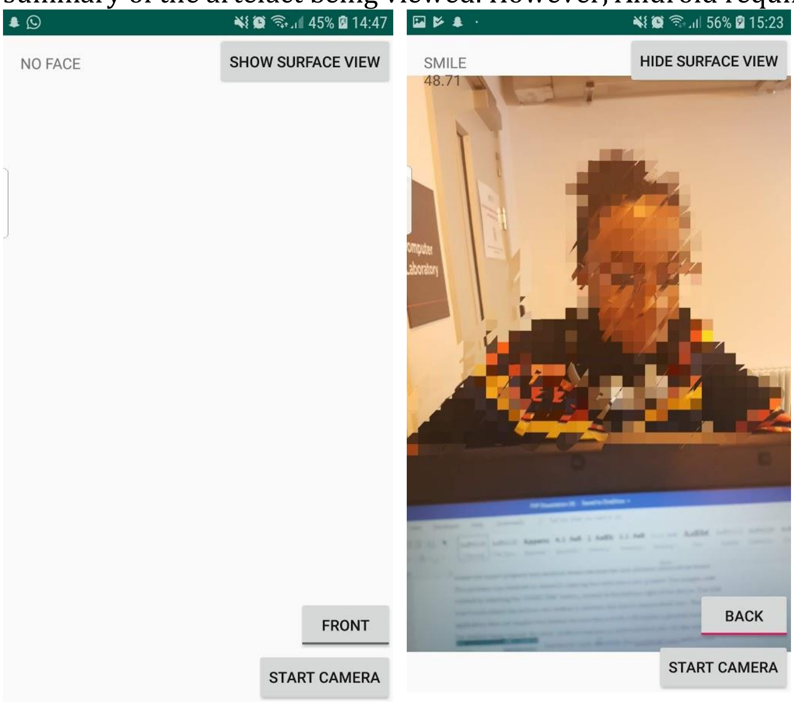


Figure 26: Affectiva Sample Code Screenshot

```java
//We create a custom SurfaceView that resizes itself to match the aspect ratio of the incoming camera frames
mainLayout = (RelativeLayout) findViewById(R.id.main_layout);
cameraPreview = new SurfaceView( context: this) {
    @Override
    public void onMeasure(int widthSpec, int heightSpec) {
        int measureWidth = MeasureSpec.getSize(widthSpec);
        int measureHeight = MeasureSpec.getSize(heightSpec);
        int width;
        int height;
        if (previewHeight == 0 || previewWidth == 0) {
            width = measureWidth;
            height = measureHeight;
        } else {
            float viewAspectRatio = (float)measureWidth/measureHeight;
            float cameraPreviewAspectRatio = (float) previewWidth/previewHeight;

            if (cameraPreviewAspectRatio > viewAspectRatio) {
                width = measureWidth;
                height =(int) (measureWidth / cameraPreviewAspectRatio);
            } else {
                width = (int) (measureHeight * cameraPreviewAspectRatio);
                height = measureHeight;
            }
        }
        setMeasuredDimension(width,height);
    }
};
RelativeLayout.LayoutParams params = new RelativeLayout.LayoutParams(ViewGroup.LayoutParams.WRAP_CONTENT, ViewGroup.LayoutParams.WRAP_CONTENT);
params.addRule(RelativeLayout.CENTER_IN_PARENT,RelativeLayout.TRUE);
cameraPreview.setLayoutParams(params);
mainLayout.addView(cameraPreview, index: 0);
```

Figure 27: surface view - sample code

```java
private void surfaceView(){
    //Add into surfaceView method
    // a surface view is required for the SDK to work
    mainLayout = findViewById(R.id.main_layout);
    cameraPreview = new SurfaceView( context: this) {
        @Override
        public void onMeasure(int widthSpec, int heightSpec) {
            int w = 1;
            int h = 1;
            setMeasuredDimension(w, h);
            cameraPreview.setAlpha(0);
        }
    };
    RelativeLayout.LayoutParams params = new RelativeLayout.LayoutParams(ViewGroup.LayoutParams.WRAP_CONTENT, ViewGroup.LayoutParams.WRAP_CONTENT);
    params.addRule(RelativeLayout.CENTER_IN_PARENT,RelativeLayout.TRUE);
    cameraPreview.setLayoutParams(params);
    mainLayout.addView(cameraPreview, index: 0);
}
```

Figure 28: surfaceView Method

The M-ARS application was now able to analyse the user's emotion without displaying the camera feed. There was no longer a need for the SHOW SURFACE VIEW button, therefore, it was removed along with the FRONT button which shows which camera is currently being used. This button allowed the user to use both cameras i.e. the front and back to detect the emotions in the sample code. The M-ARS application set the front camera to analyse the facial expressions as the user is reading the information on the page (Figure 29).

```java
private void faceDetector(){
    // Add into faceDetector method
    detector = new CameraDetector( context: this, CameraDetector.CameraType.CAMERA_FRONT, cameraPreview);
    detector.setDetectAttention(true);
    detector.setDetectAllEmotions(true);
    detector.setImageListener(this);
    detector.setOnCameraEventListener(this);
}
```

Figure 29: faceDetector Method

The sample code was analysing whether the user was smiling, once the API has detected a face, the API will attempt to identify the persons age and ethnicity. The M-ARS application does not require these features and the code was removed. The M-ARS application required the seven emotions, engagement and valence to be detected, however, after testing it was identified that the seven emotions where not needed to be identified because the engagement and valence score provided enough information to determine how the user is responding to the information (testing details can be found in Chapter 9.4). Figure 30 shows how the results are achieved, the `getEngagement` and `getValence` methods are used to get the float values. The results from the API produce a float number ranging between 0 (expression is not present) and 100 (expression is fully present). The results are then parsed to the Tailored Info Activity using Intent object (Figure 32).

```
    private float getEngagement(){
        float engagement;
        if (noFaceDetected == 0){
            engagement = 0;
        } else {
            engagement = face.emotions.getEngagement();
        }
        return engagement;
    }

    private float getValence(){
        float valence;
        if (noFaceDetected == 0){
            valence = 0;
        } else {
            valence = face.emotions.getValence();
        }
        return valence;
    }

    @Override
    public void onImageResults(List<Face> list, Frame frame, float v) {
        if (list == null) {
//              noFaceDetected = 0;
            return;
        }
        if (list.size() == 0) {
            noFaceDetected = 0;
//              engagement_textview.setText("Detecting Engagement ... ");
//              valence_textview.setText("Detecting Valence ... ");
        } else {
            face = list.get(0);
            getEngagement();
            getValence();
//              engagement_textview.setText(String.format("engagement\n%.2f",getEngagement()));
//              valence_textview.setText(String.format("Valence\n%.2f",getValence()));

        }
    }
```

Figure 30: onImageResults Method

Further testing revealed another problem, in the scenario where the API fails to detect a face, the M-ARS application would crash and throw an exception of null object reference. Figure 30 shows how the M-ARS application deals with this scenario. The variable `noFaceDetected` is set to zero when a face has not been detected, conditional statements in the `getEngagement` and `getValence` methods check whether this condition is met. If the condition is met, `engagement` and `valence` variables are set to zero, otherwise the API gets the values.

Furthermore, the M-ARS application needed to start the API when the user navigates to the activity automatically instead of the user selecting the "START SDK" button (Figure 31). This was achieved by changing the Boolean variable `hasSDKStarted` to true instead of false. This means the SDK would automatically start when the user navigates to the Default Info Activity and the SDK would stop when the user navigates to the Tailored Info Activity (Figure 32).

```
        startSDKButton = (Button) findViewById(R.id.sdk_start_button);
        startSDKButton.setOnClickListener(new View.OnClickListener() {
            @Override
            public void onClick(View v) {
                if (isSDKStarted) {
                    isSDKStarted = false;
                    stopDetector();
                    startSDKButton.setText("Start Camera");
                } else {
                    isSDKStarted = true;
                    startDetector();
                    startSDKButton.setText("Stop Camera");
                }
            }
        });
        startSDKButton.setText("Start Camera");
```

Figure 31: startSDK Sample Code

```
        //this can be the more button
        startSDKButton = findViewById(R.id.sdk_start_button);
        startSDKButton.setOnClickListener((v) -> {
                if (hasSDKStarted) {
                    hasSDKStarted = false;
                    stopDetector();
                    Intent intent = new Intent( packageContext: DefaultInfoActivity.this, TailoredInfoActivity.class);
                    intent.putExtra( name: "noFaceDetected", noFaceDetected);
                    intent.putExtra( name: "engagement", getEngagement());
                    intent.putExtra( name: "valence", getValence());
                    startActivity(intent);
                } else {
                    hasSDKStarted = true;
                    startDetector();
                }
        });
```

Figure 32: startSDK M-ARS

Finally, the application had to merged with the M-ARS application. When the code was imported into the M-ARS application, the app would crash when attempting to move from the AR Activity to the Default Info Activity (details can be found in Chapter 9.4). Therefore, alternative solutions were created as a work around (Table 8)

Alternative solution	Design
Keep the emotion detection app separate from the M-ARS application and share content between the two applications	
Implement the emotion detection as a windows solution using the webcam to capture facial analysis. Once information has been captured, share results with a web page which will display the personalised content.	

The M-ARS application will then access this information and display it to the user.	
Implement the emotion detection as a windows solution using the webcam to capture facial analysis. Once information has been captured, share the results with the M-ARS application and update the weblink which will display the personalised information from the app	

Table 8: Alternative Solutions

The first alternative solution was taken forward, using the Intent object (Figure 33), the M-ARS application can now access the M-ARS Emotion API without crashing creating the illusion of moving from one activity to another, therefore, creating a seamless experience for the user.

```
findViewById(R.id.moreImageButton).setOnClickListener(new View.OnClickListener() {
    @Override
    public void onClick(View view) {
        Intent intent = new Intent(Intent.ACTION_MAIN);
        intent.setComponent(new ComponentName( pkg: "com.example.m_arsemotionai",  cls: "com.example.m_arsemotionai.DefaultInfoActivity"));
        startActivity(intent);
    }
});
```

Figure 33: Alternative Solution

7.2 Tailored Info Activity

Tailored Info Activity displays the personalised information to the user according to the output gathered from the Default Info activity. This is achieved using conditional statements that checks if the `valence` equals `noFaceDetected`. If the condition is met, generic information will be displayed because the API was not able to detect the users face. Another conditional statement checks if `valence` is greater than zero. If the condition is met, complex information will be displayed, this indicates the user has positively reacted to the information displayed in Default Info Activity. Otherwise simplified information would be displayed, this indicates the user has negatively reacted to the information displayed in the Default Info Activity (Figure 34). Testing was performed to ensure the correct results are being displayed (details can be found in Chapter 9.4)

```

    public void emotionOutput(){
        if(valencef == noFaceDetectedf){
//              result = "Default information will be displayed since no face was not detected";
            outputtextView.setText("Default information will be displayed since valence was not detected");
        } else if (valencef > 0) {
//              result = "Complex information will be displayed here";
            outputtextView.setText("Complex information will be displayed here");
        } else {
//              result = "Simplified text will be displayed here";
            outputtextView.setText("Simplified text will be displayed here");
        }
//          return result;
    }
}

```

Figure 34: emotionOutput Method

7.3 Sprint Review

This sprint was not completed within the estimated about of days. An extra week of implementation was required to meet the acceptance test. Currently the personalised information has been hard coded into the application. This can be improved by implementing a database which stores information about various artefacts because hard coding information is not efficient in the long run.

To fix this issue, the following user story will be added into the product backlog: **U006: As a user, I would like a way of keeping track of my activities within the app, so that I see my overall progress.**

Another issue is currently when the API fails to detect a face, generic information is being displayed. This can be addressed by implementing data mining techniques discussed in Chapter 2.3, therefore this issue will be addressed in the next sprint.

This sprint is marked as complete since it has passed the acceptance test.

7.4 Summary

This chapter explained the implementation process of creating a personalised learning experience. The sprint was marked as complete because it had met the acceptance test. To address the issues that arose during the sprint, a new item was added into the product backlog. The next chapter will describe the implementation process of Achievement Activity.

8 Gamification Techniques

This chapter will provide details on the implementation of the achievement feature.

8.1 Achievement Activity

Chapter 2.2 discusses how gamification techniques have been incorporated into education to improve engagement levels. The M-ARS application aims to increase engagement levels by encouraging users to continue using the application by implementing gamification techniques discussed in Chapter 2.2.

Achievement Activity aimed to push the user to overcome tasks to meet a goal (unlock achievement). Conditional statements were used to check if certain conditions where met, if the condition was met, the achievement would be unlocked. The first achievement the user would unlock was titled “You’re getting the hang of this!”, this achievement would be unlocked when the user scans and interacts with one artefact. This achievement is implemented to show the user, they have made partial progress when they have starting using the application. This gives the impression of completion; this gamification tactic is known as endowed progress. To ensure the logic was correct, testing was completed (details can be found in Chapter 9.5)

```java
    private String achievementConditions() {
//          achievementArrList = new ArrayList<String>();
        bundle = getIntent().getExtras();
        int scounter = bundle.getInt( key: "scanCounter");

        if (scounter == 1 && modelCounter == 1){
//              isachievementUnlocked = true;
            achievementString = "You're getting the hang of this!";
//              achievementArrList.add(achievementString);
//              achievementArrAdapater = new ArrayAdapter<String>(getApplicationContext(), android.R.layout.simple_list_item_1, achievementArrList);
            showAchievementMesseage();
        } else if (modelCounter == 2 && fetchModelCounter == 2) {
//              isachievementUnlocked = true;
            achievementString = "Artifacts discovered";
            showAchievementMesseage();
        }

        return achievementString;
    }

    private void showAchievementMesseage () {
        achievementMessageSnackBar = Snackbar.make(findViewById(R.id.coordinatorLayout),  text: "Achievement Unlocked", Snackbar.LENGTH_LONG);
        achievementMessageSnackBar.setAction( text: "VIEW",  listener: this);
        achievementMessageSnackBar.setActionTextColor(Color.WHITE);
        achievementMessageSnackBar.show();
    }


    @Override
    public void onClick(View view) {
        Intent intent = new Intent( packageContext: ARActivity.this, AchievementActivity.class);
        intent.putExtra( name: "achievementString", achievementString);
        startActivity(intent);
    }
}
```

Figure 35: achievementConditions Method

8.2 Summary

This sprint was not completed because the project had reached the end of its development lifecycle. Therefore, a sprint review was not performed because the sprint was not completed. The next chapter will discuss the testing process of each sprint.

9 Testing

This chapter will provide a detailed explanation of testing methods used for each iteration.

9.1 Scan Activity Tests

Testing was performed to ensure the correct data is being parsed from the Scan Activity to AR Activity. Once the user has scanned the QR Code, the next activity should display the embedded string.

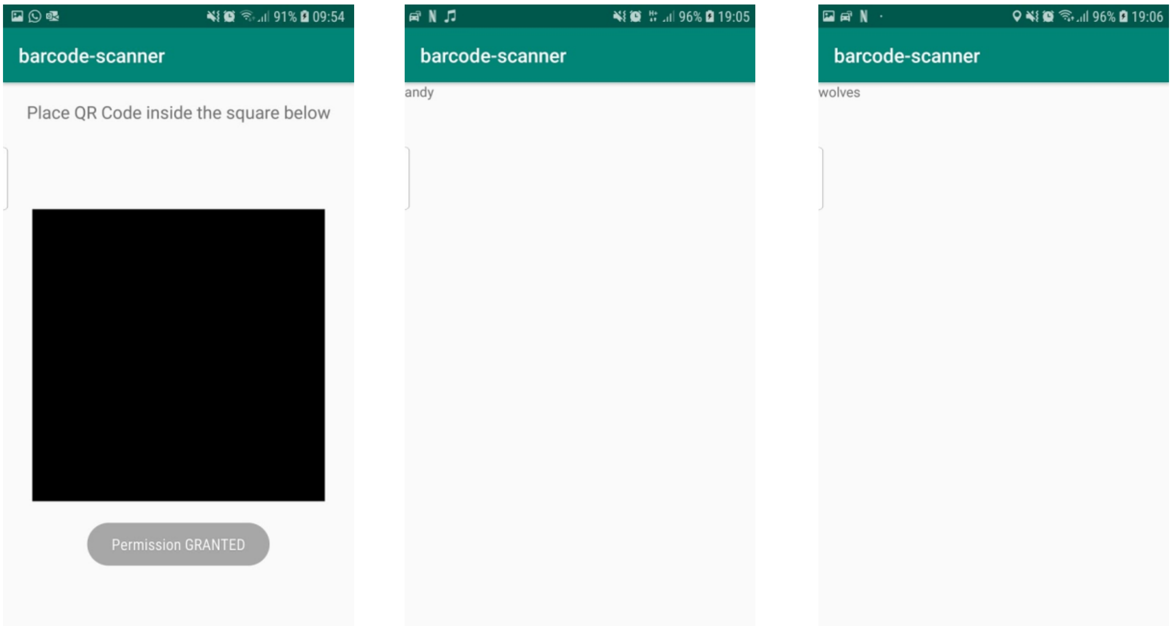


Figure 36: Scan Activity Test Results

Another test was performed to ensure the app requests camera permission when the user first installs the application. This test case was later added into the product backlog because this permission is needed for the application to run, without it the user won't be able to use the application. As expected, the M-ARS application requests camera permission, however, once the permission has been granted, the surface view remains black until the user navigates away from the activity. When the user navigates back to the Scan Activity after permission has been granted, the surface view displays the live camera feed. The code was merged, the same test was performed in the M-ARS application. Even though this unexpected behaviour is problematic, the acceptance test specified in the product backlog was met.

RESULT: **PASSED**

9.2 AR Activity Tests

Testing was performed to ensure the correct 3D model was being fetched and augmented according to what was embedded into the QR code. This was achieved by changing how the fetchModel method was loading the 3D model (explained in Chapter 6.1).

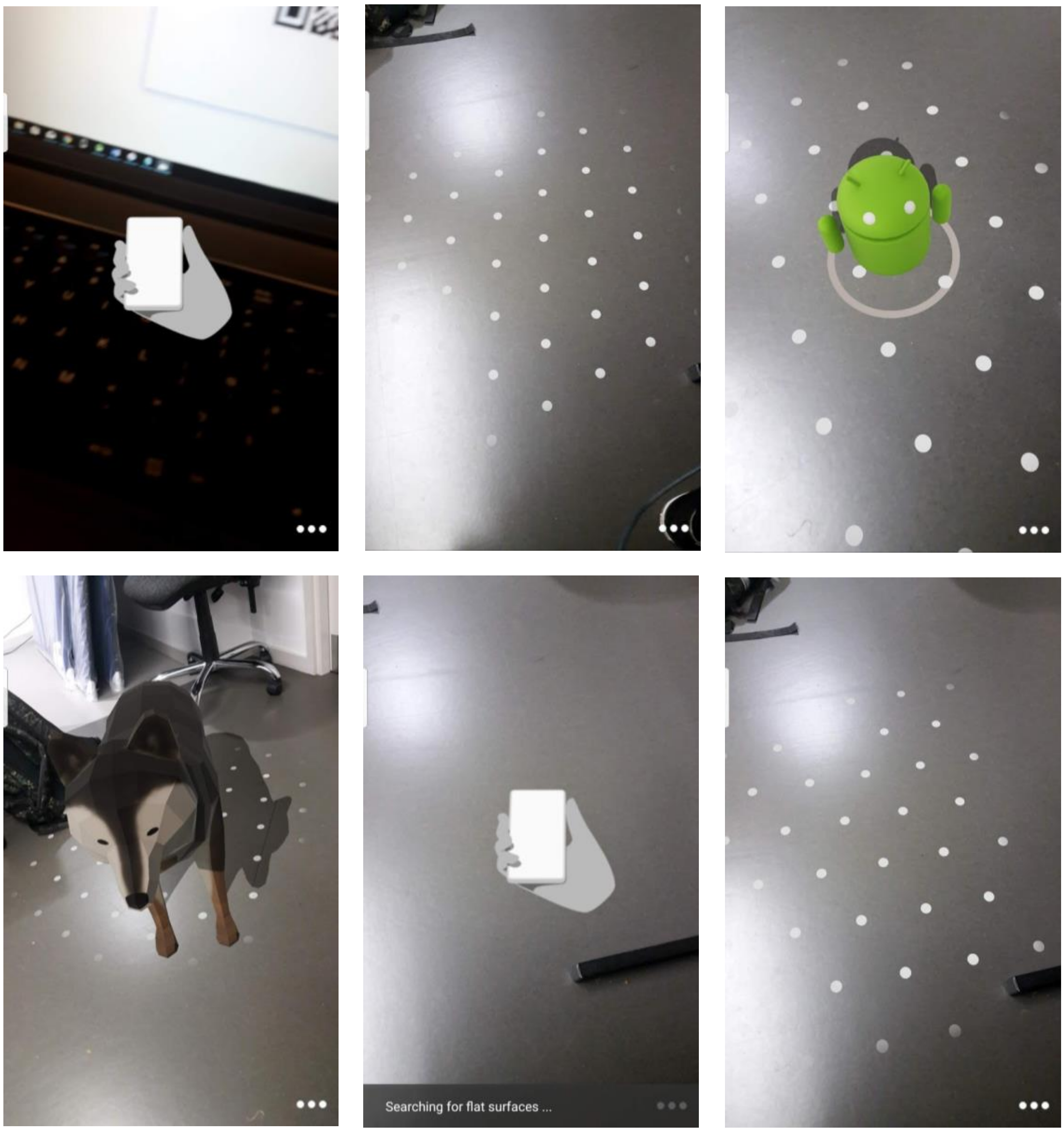


Figure 37: AR Test Results

However, the AR Activity was not very informative as the hand animation indicating the phone should be moved for the application to search for flat surfaces would disappear before the surface was found. To address this issue informative information needs to be added so the user is aware of the fact a search needs to be found before placing the model into the scene.

RESULT: **PASSED**

9.3 Default and Tailored Info Tests

The first test was performed to ensure the application can detect the user's facial emotion without displaying the camera feed. The application is expected to scan the user's emotion as they are reading the content on the page (Figure 38).

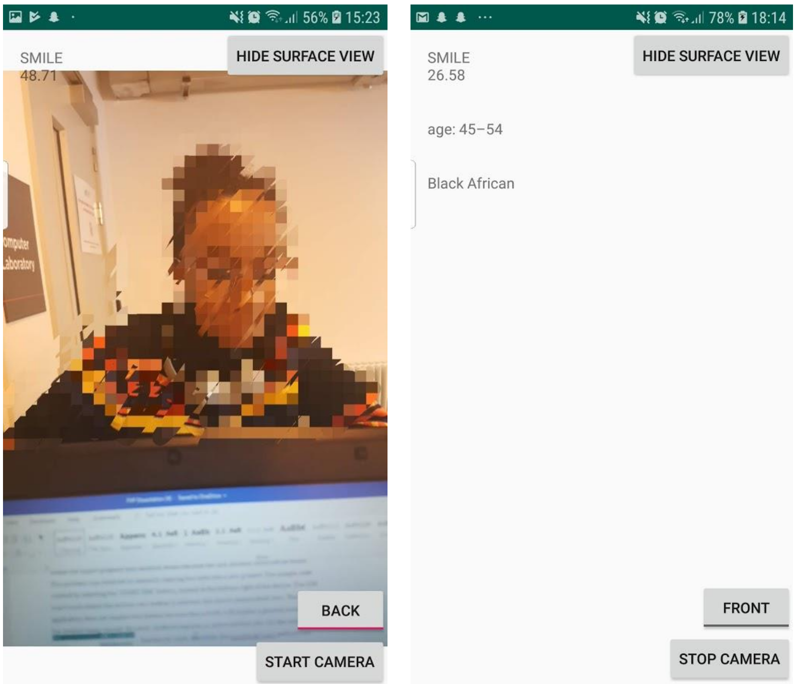


Figure 38: surfaceView Method Test (Before and After)

The second test was performed to ensure the front camera is set as the only functioning camera (Figure39). The third test was performed to ensure the correct emotions were selected to indicate the user's level of understanding. The seven emotions, engagement and valence were implemented into the Default Info Activity. Engagement produced a value which represented how expressive the user is. Valence produced a value which measured if the user was having a positive experience (Appendix D). A series of tests (Figure 39) revealed, an engagement scores higher than 50 were associated with a positive emotion (i.e. smile, joy and surprise) and a scores less than 50 were with negative emotions (i.e. anger, contempt, disgust, fear and sadness). This was also true for the valence scores; a positive score was associated with a positive experience and a negative score was associated with a negative experience. Therefore, the valence score will be used to determine whether the user is having a positive or negative learning experience, whereas, the engagement score will determine whether the user likes or dislikes the artefact. This score will be useful when implementing the recommendation system.

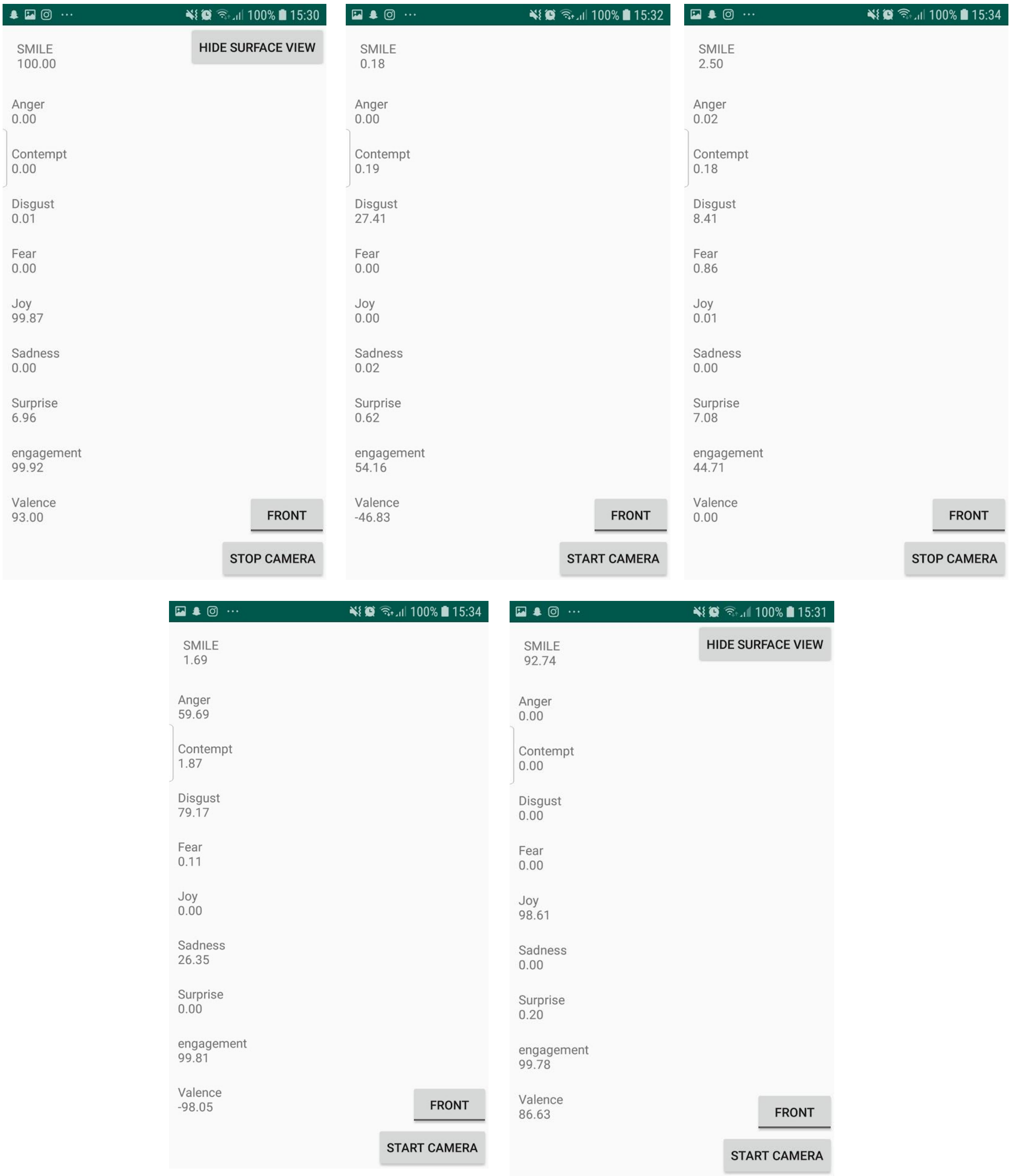


Figure 39: Emotion Analysis Test Results

The fourth test was performed to ensure the SDK would start when the user navigates to the Default Info Activity. Figure 40 shows the START SDK button has been placed with the more button. The expected outcome is seeing the engagement and valence scores being generated. The last generated value will be used to determine whether the user has had a positive or negative experience. This value is fetched and parsed to the Tailored Info Activity when the user stops the SDK by selecting “MORE”.

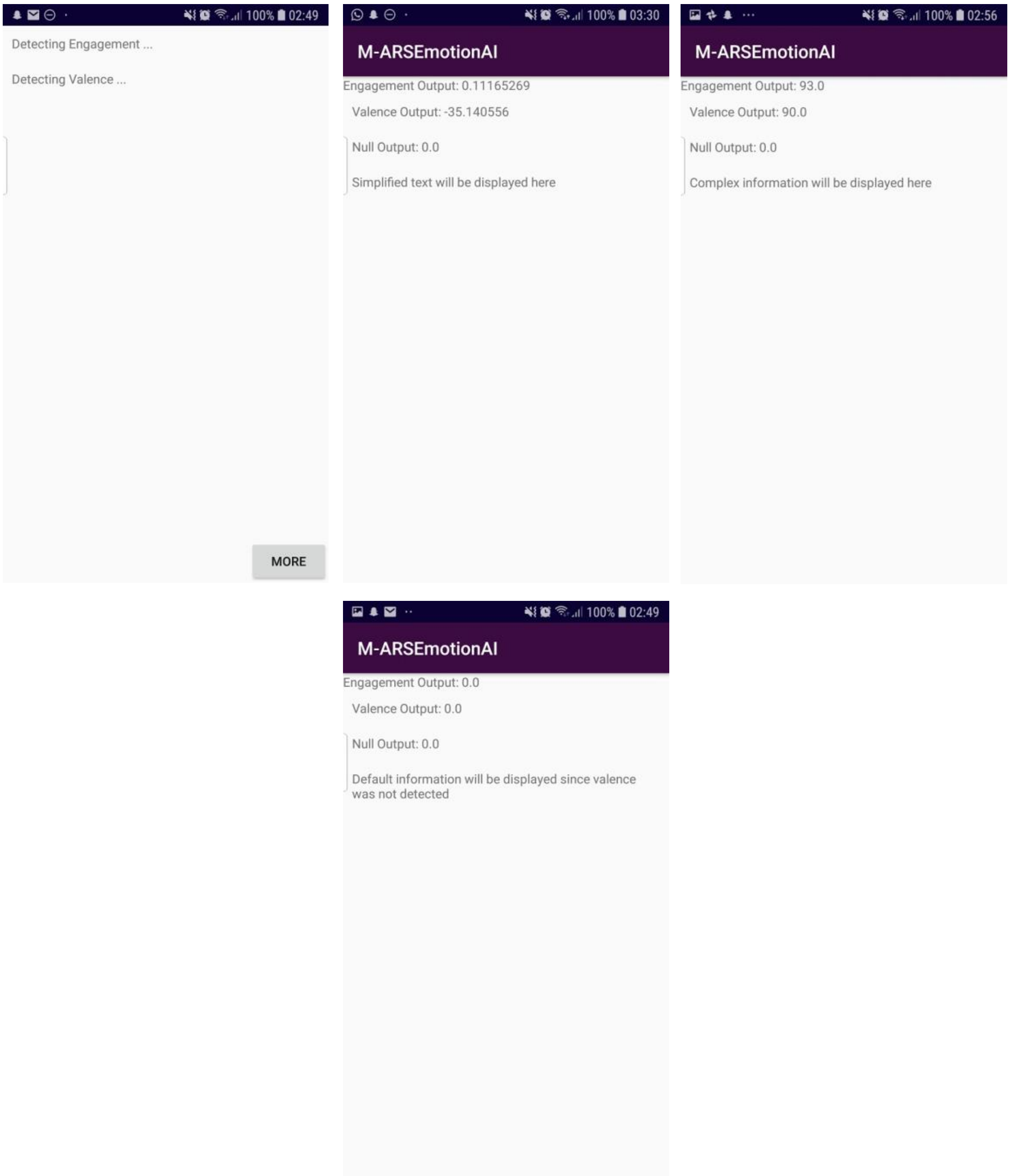


Figure 40: Tailored Info Test Results

The fifth test was performed to ensure the test application would integrate with the M-ARS application. After merging the test application into M-ARS, the application would crash when navigating from the AR Activity to the Default Info Activity. The error was occurring because of the ABI being selected while M-ARS was running. By default, Android Studio targets all non-deprecated ABIs, the Camera Detector class found in the Affectiva API uses a deprecated ABI, therefore, causing M-ARS to crash. The Affectiva API only supports armeabi-v7a ABI which contains the libaffdexface_jni.so file (Figure 41). Since M-ARS was developed on a 64-bit machine, the first attempt at resolving the issue was installing a 32-bit version of Android Studio. However, sceneform would not work on the 32-bit version of Android Studio because it was trying to load a 64-bit AMD on a 32-bit platform (Figure 41). Alternatively, targeting the armeabi-v7a would resolve this issue. After spending a 4 to 5 days trying to resolve the issue, alternative solutions where created to overcome this issue (Table 8). The expected result of implementing the alternative solution, was for M-ARS to access the Default Info Activity in M-ARS Emotion API (Figure 42).

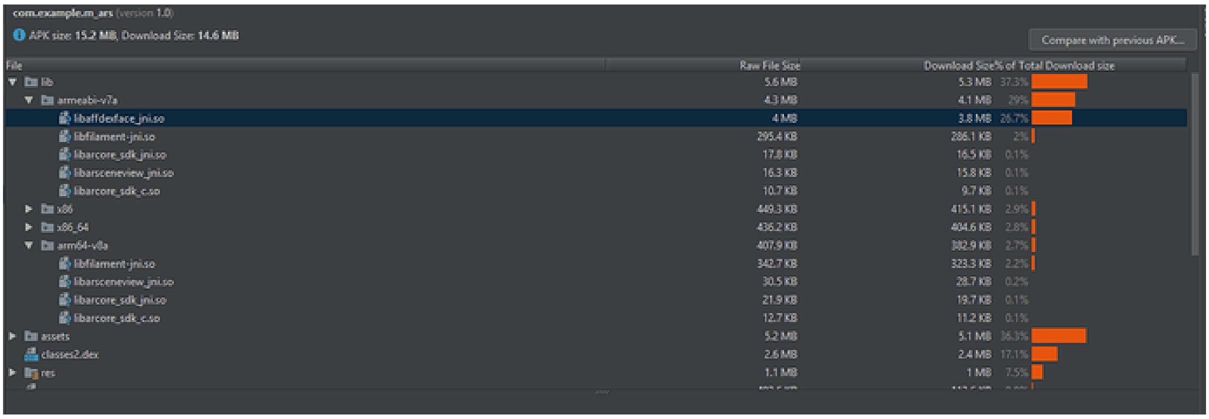


Figure 41: ABI Management Screenshot

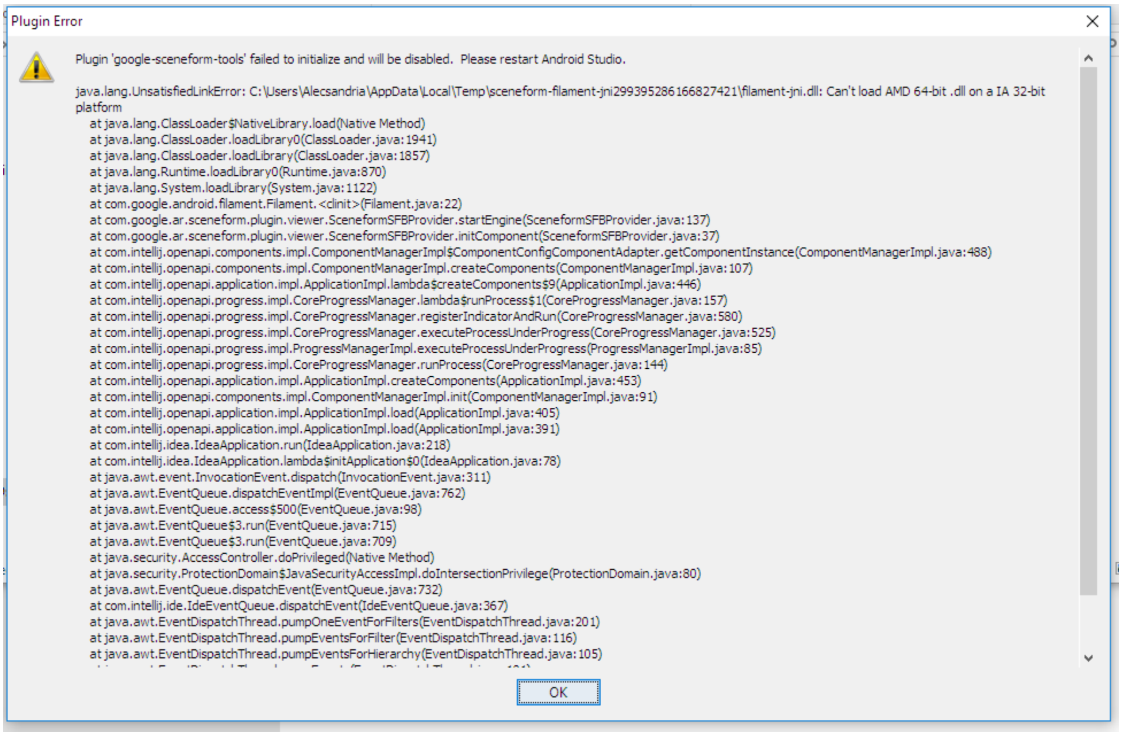


Figure 42: Sceneform Plugin Error

The acceptance test can now be marked as passed, because the application can perform facial analysis accurately when a face is detected, the correct output is then parsed to the Tailored Info Activity. When a face has not been detected, the application handles this by displaying generic information.

RESULT: **PASSED**

9.4 Gamification Tests

The first test performed was to ensure the achievement message was being displayed when the user has met the requirements defined to unlock the achievement (Figure 44). Testing was not completed because the project has reached the end of the development lifecycle.

RESULT: **INCOMPLETE**

9.5 Summary

This chapter has explained how various components of the M-ARS application were tested and whether the acceptance tests defined in the product backlog have been met. The core features of the M-ARS application have passed all acceptance tests. The next chapter will provide a detailed evaluation of the whole project.

10 Evaluation

This is where you will present your results and provide an evaluation of your solution against the problem. Try and structure your results in a meaningful way. Try and help the reader. Do not just take some numbers, load them into a statistics package such as SPSS and then present every statistical analysis technique in the known world. Use appropriate methods for analysing, presenting and summarising your data.

10.1 Methodology

The deciding factors of choosing the Agile framework over the waterfall methodology were (Chapter 3.1):

- An iterative approach was suitable over following plan-based development
- Delivering small deliverables was valued more than developing the whole application
- An adaptive rather than a predictive approach was more suitable when identifying requirements

Scrum is an agile framework which was followed during the implementation phase of this project. This framework was suitable because unforeseen problems were addressed productively during the development lifecycle to ensure a high-quality product can be produced. Since the M-ARS application is attempting to provide a solution for a problem that does not currently exist, the product backlog was amendded throughout the developed cycle to accommodate these changes. Even though the scrum framework is suitable for small teams, it can be adapted to suit this project. The key principles in scrum were adapted to suit the project as follows:

- Scrum consists of three roles: product owner, sprint master and development teams. Considering this project is a one-man team, placing myself in these three roles was essential to replicate the scrum process effectively.
- Scrum follows the following workflow:
  - Daily stand up meeting – This is when the team meet for a short brief meeting updating each other on tasks marked as complete, tasks that are in progress or problems they have encountered. Since the project is a one-man team, this has been omitted from the project because there is no need to update anyone who is not involved in the sprint.
  - Sprint planning – Usually, sprint planning meetings involve the product manager, scrum master and development team. The development team to discuss tasks needed to be completed at the end of the sprint. At this stage of the project, tasks which need to be completed within the estimated time were

planned and added into the sprint backlog. The sprint was marked as complete if all the tasks in the sprint were complete.

  - Sprint review meetings – This is when the development team present new features to the product owner and customers to get feedback on whether sprint has met their requirements. Since there is no customer or product manager to present new features too, the sprint was marked as complete if it has met its acceptance tests. This was a method of replicating whether the sprint has met the customer's and product owner's requirements.
  - Sprint retrospective meeting – Organised by the scrum masters, the team discuss what went well and what can be improved moving forward. At this stage of the project, problems which arose during the sprint and a potential solution were addressed.
  - Product backlog refinement meeting – Led by the product owner, the team discuss new features for the next sprint. Requirements are discussed in detail and potential challenges are addressed. At this stage of the project, problems which arose in the previous sprint are evaluated and taken forward into the next sprint. However, if the task cannot be taken forward to the next sprint, a new item is added into the product backlog and assigned a priority.

- Scrum consists of 3 artefacts:
  - Product Backlog – A list of user stories arranged by order of priority, needed to be completed to meet the projects aim. Prioritising helped identify the core features of application and potential challenges, therefore, saving time during the implementation stage as a plan was developed prior to starting a sprint.
  - Sprint Backlog – A list of tasks derived from user stories in the product backlog which need to be completed during a sprint. Tasks were tracked to measure the progress of the sprint, therefore, eliminating duplicate tasks during the development cycle, resulting in saving time and effort. Changes made throughout the developed lifecycle can be tracked easily and identified.
  - Increment – At the end of each sprint, the feature would be added into the M-ARS application incrementally. This helped measure the overall progress of the application.

The scrum framework helped to prioritise and deliver features within projected timelines. The sprint review, sprint retrospective and product refinement meetings where merged into one because issues can be addressed in one sitting (Sprint Review Chapters). Even though scrum helps prioritise, manage and deliver features within a specified time-block, core functionality may not be implemented in time because of too many changes being made during a sprint. Since the project does not have defined end-date from the beginning of the project, it's difficult to judge whether to final application would be ready when it's required. To overcome this issue the core features, have of the M-ARS application were given a high priority to ensure these features were developed first in a way that meant one feature builds upon the previous. Therefore, any changes or problems can be addressed in the next sprint.

Planning is also a key principle when using Scrum. If the sprint backlog items are not defined according, tasks would have to be carried forward into the next sprint. More tasks in a sprint lead to longer sprint lengths. To overcome this issue, the only small and medium size user stories were developed. The tasks needed to complete the sprint were clear because the steps needed to complete the tasks became logical, limiting the unforeseen challenges which may arise during the sprint. However, too much was spent planning each sprint, reducing the amount of time needed to complete the items on the product backlog.

10.2 Development

The AR feature was developed to not align with the Computer Science (Digital Media and Games) specialism but it's an existing solution which has already been used in museums successfully. However, using AR Core did pose some difficulties, for example it was not possible to implement AR buttons on the 3D model because AR Core did not have this functionality. The AR buttons would have generated brief summaries of the artefact being viewed. This is where the facial analysis would have happened. Instead, the Default Info Activity was created. Using a head-mounted display could have perhaps been better but because this technology was not available at hand. Implementing the AR feature creates a memorable as the study conducted by the National Museum Cardiff concluded, visitors enjoyed using the AR experience and they wanted more experiences similar to AR.

The most challenging feature to implement was the facial emotion analysis. Since this was the feature that creates the personalised learning experience it was vital the feature worked as expected. When merging the test application to M-ARS which contained the QR and AR features resulted in M-ARS crashing, a decision had to make on whether to spend more time trying to fix the issue or to implement the web VR solution into the application. In an attempt to avoid using a solution which requires access to the internet, alternative solutions were created with the assistance of my FYP tutor. Selecting a method which does not require internet connectivity, the sprint was completed in 21 days instead of 14. Spending an extra week finish this sprint meant the less time would be spent on the next sprint because the length set for development was 56 days (Appendix E).

10.3 Testing

Each feature within a sprint was developed as a test application which was then merged with the M-ARS application. Further testing was performed on the M-ARS application as each increment was added to ensure all features integrate well with each other and to ensure the correct data was parsed between various activities. At the end of the development life cycle, M-ARS had reached a point where user testing could be performed however, there wasn't enough time. Random data was generated to replicate the learning experience as described in Chapter 9.3. To ensure the logic used for the achievement activity is correct, white box and unit testing would have to be performed. Unit testing will ensure the correct methods used within the application produce accurately. This would be a better approach than using white box testing because the logic for achievements would grow exponentially over time. Therefore, this method is more efficient because errors can quickly be identified.

10.4 Results Analysis

Since the M-ARS application did not go through user testing, random data had to be generated to replicate the learning experience for the user. Testing was performed to ensure the M-ARS application can identify whether the user is learning efficiently.

Range: -100 to 100							
1	20		1	84		1	73
2	76		2	73		2	34
3	-67		3	-24		3	-74
4	25		4	10		4	-18
5	-65		5	-98		5	16
6	-40		6	-73		6	-35
7	91		7	-7		7	-35
8	-56		8	48		8	-27
9	57		9	-96		9	2
10	9		10	-63		10	-21
11	2		11	72		11	60
12	-70		12	-69		12	-76
13	-45		13	-59		13	-36
14	-96		14	74		14	28
15	-81		15	-15		15	-73
16	-16		16	90		16	-85
17	-79		17	95		17	52
18	94		18	-23		18	82
19	-99		19	-75		19	-98
20	84		20	-87		20	69
Average	**-12.8**		**Average**	**-7.15**		**Average**	**-8.1**

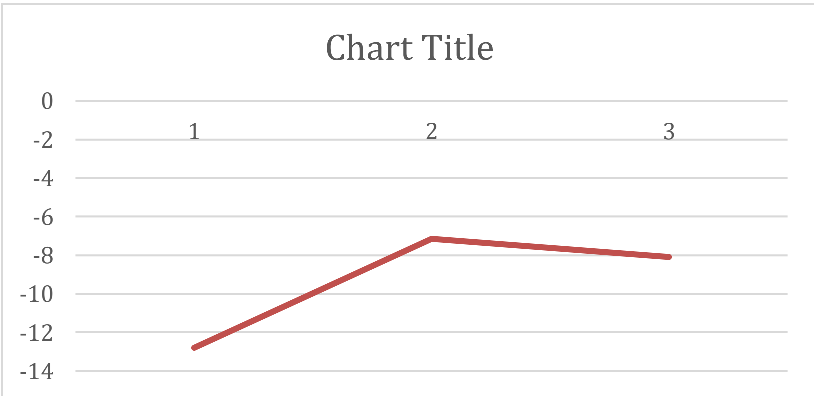


Figure 43: Result Analysis 1

Figure 43 shows the result of data which was randomly generated within between -100 and 100 (valence score range). The valence scores represent how the learning experience fluctuates over time as the user is reading the content in Default Info Activity. This random dataset represents an explorer (someone who visit museums out of interest and curiosity), an explorer is expected to have a fluctuating learning experience because they seek to learn out of curiosity. It's not guaranteed that they have previous knowledge of the artefact. An average of the valence scores is calculated to track the user's learning experience over time.

Range: 50 to 100							
1	87		1	96		1	97
2	52		2	52		2	96
3	85		3	63		3	64
4	63		4	52		4	61
5	58		5	54		5	58
6	53		6	50		6	67
7	60		7	72		7	51
8	67		8	64		8	73
9	66		9	80		9	94
10	60		10	90		10	79
11	66		11	95		11	74
12	97		12	87		12	80
13	50		13	54		13	73
14	72		14	74		14	77
15	92		15	71		15	82
16	92		16	81		16	76
17	60		17	94		17	90
18	95		18	65		18	90
19	77		19	85		19	68
20	57		20	68		20	94
Average	**70.45**		**Average**	**72.35**		**Average**	**77.2**

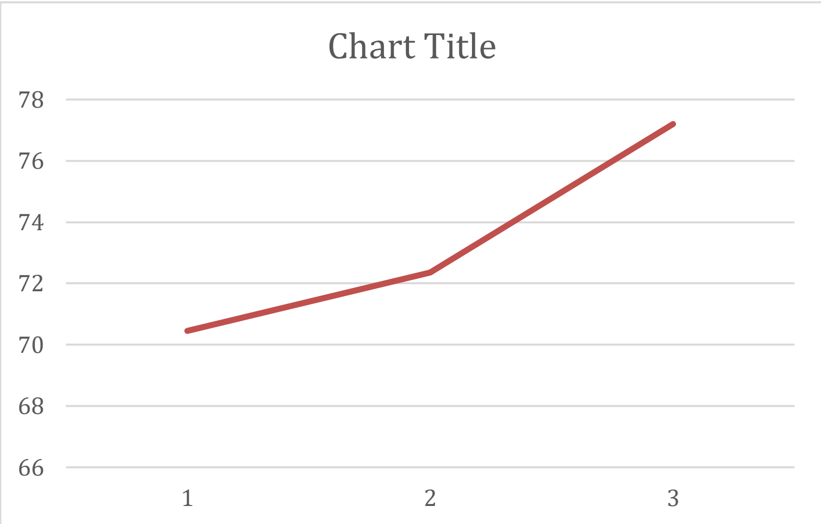


Figure 44: Results Analysis 2

Figure 44 shows the result of data which was randomly generated within between -50 and 100. This is randomly generated dataset, represents a professional or hobbyist (someone who has previous knowledge on the artefact). They are expected to have previous knowledge about the artefact they are viewing, even though learning process may fluctuate over-time, it's not expected to vary as much as the explorer. The average learning process is calculated to challenge their current knowledge over-time.

Figure 45 shows the result of randomly generated data between -100 and 0. This data was generated to judge how well the application can deal with a negative experience. The results how that even though a user may negatively react to the information (i.e. they don't understand the generic information in Default Info Activity), the average calculated can be used to track if they are progressing or not. If the average continuous to decrease over-time, the application would have to handle this scenario appropriately. This scenario can be handled by implementing learning styles in the application. Once the application learns which learning style is suitable for the user, appropriate content can be displayed accordingly.

Range: -100 to 0							
1	-91		1	-12		1	-31
2	-82		2	-94		2	-95
3	-97		3	0		3	-12
4	-56		4	-91		4	-77
5	-6		5	-87		5	-8
6	-93		6	-45		6	-60
7	-35		7	-6		7	-15
8	-75		8	-77		8	-86
9	-55		9	-34		9	-3
10	-38		10	-80		10	-95
11	-20		11	-52		11	0
12	-7		12	-70		12	-23
13	0		13	-26		13	-8
14	-7		14	-39		14	-38
15	-45		15	-35		15	-58
16	-23		16	-23		16	-73
17	-50		17	-5		17	-44
18	-12		18	-63		18	-26
19	-48		19	-18		19	-93
20	-80		20	-18		20	0
Average	**-46**		**Average**	**-43.75**		**Average**	**-42.25**

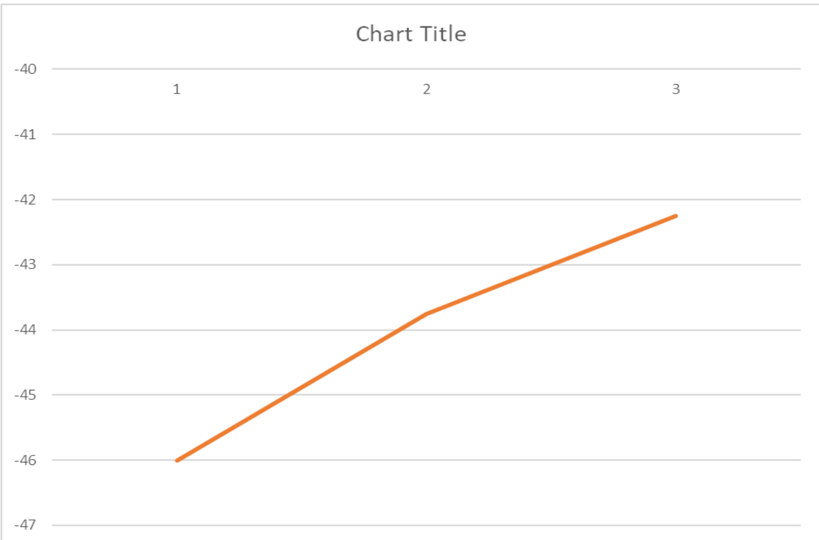


Figure 45: Results Analysis 3

10.5 Limitations of the application

Currently the application can develop an adaptive personalised learning experience if the user's face can be detected. The application fails to create a personalised experience when a face cannot be detected, and generic information is displayed.

11 Conclusions

This section will summarise how each objective was met and whether the project's aim has been met. The aim of the project was to develop a personalised learning experience for museum visitors by using facial emotion analysis which will assess and challenge the user's current knowledge on the subject. In order to meet the aim, the following objectives were developed:

1. Review literature relevant research to the role Augmented Reality (AR) plays in museums and education., how is learning achieved in the digital era and how personalised learning is achieved. Demonstrate the need for the application in order to meet the project's aim.
    - This objective was met by completing a literature review (Chapter 2). Chapter 2 identifies the role of AR is education and museums by discussing current solutions, how learning is achieved in the digital era by discussing traditional and modern approaches to learning which leads to how personalised learning can be achieved using facial emotion analysis and data mining algorithms.
2. Based on findings from the literature review, select an appropriate design approach for the application, develop design diagrams which will lead to a functional prototype which uses AR technologies.
3. Using design diagrams from objective 2, investigate, identify and select technologies which will be integrated into the application and implement a working prototype.
    - Objectives 2 & 3 were met by selecting an appropriate software development approach suitable for the application. Following the scrum framework, a product backlog was developed listing user stories in order of priority. The product backlog does not only contain a list of user stories, it contains the description and how the user story would be tested, providing a plan on how the application would be developed and evaluated. Scrum was a suitable framework because unforeseen problems could be dealt in a with while being productive, therefore, time was not wasted when a challenge arose during a sprint. Technologies were selected from research undertaken in Chapter 2. By implementing the AR and achievement
4. Ensure information about the artefact is altered correctly according to the user's level of understanding.
    - This objective was met by performing testing thoroughly on Default and Tailored Info Activities. The acceptance test stated "Tester would ensure the emotion AI is functioning correctly. Once the SDK detects a face, the correct output should be displayed. When the SDK fails to detect a face (i.e. null

outputs), application should handle this exception by displaying generic information." The test case was marked as pass because the M-ARS application would display the correct information depending on the valence score.

5. Identify and select appropriate test methods and evaluate plans, then apply them to the prototype to show that it functions correctly.
    - This objective was met by performing black and white box testing at the end of each sprint. Further testing was performed when the test application was merged with the M-ARS application to ensure each feature integrates well with the others and to ensure the correct were being produced before moving on the next sprint. Testing details can be found in Chapter 9.
6. Identify how the prototype can be further improved given more time and resources and whether the aim has been met.
    - This objective was met by performing a sprint review at the end of each sprint. The sprint review was a combination of sprint review, retrospective and product backlog meetings, typically performed separately in scrum. The sprint reviews consist of how each sprint can be improved by addressing issues that arose during the sprint, these items were then added into the product backlog or addressed in the next sprint.
7. Demonstrate engagement with the university's ethics by gaining formal ethical approval using the BREO system.
    - This objective was met by completing an ethical approval from using the BREO system. The M-ARS application did not require user testing because data would be replicated by generating random data to access how the learning experience within the application can be tracked. Ethical approval was granted because no there was no need of gathering user data. Email can be found in Appendix D

In conclusion, the aim of the project was met to some extent. The application does indeed provide an adaptive personalised experience, however, methods used to create this approach can be improved.

11.1 Future Work

Having achieved the aim of the project to some extent, there are some limitation to the proposed solution. To ensure the application creates a better personalised learning approach, the following need to be completed:

- Implementing a database to fetch data which should be displayed in the Default and Tailored Info Activities.

- Instead of using the generated valence value from the Default Info Activity to determine whether the user has understood the information on the activity, an average valence score should be calculated within this activity instead. The average score can then be parsed to Tailored Info Activity where appropriate data will be fetched from the database. The average score can be determined by adding valence values into an array while the SDK is running. When the user selects “MORE” to stop the SDK and move to the next activity, the average score of the array is calculated and dumped into a local file on the device. Learning experience can then be tracked by referring to this file to determine how the user is progressing over-time.
- The average scores can be used to display personalised summaries according to the user learning style instead of displaying generic information available on the display in front of them.
- Data mining algorithms should be used assess how the user is progressing over-time, in order to predict accurate scores. This resolve the issue of generic data being displayed when the SDK fails to detect a face.
- Gamification techniques can be introduced into the application. Implementing a solution like Pokémon GO, where users would have to walk around the museum to find hidden artefacts. This can replace a simple recommendation system where the application would suggest an artefact based on previous engagement scores. This gamification technique actively prompts the user to explore the museum, beyond what they came in to see. Once the user has successfully found a hidden artefact, the application can reward the user by unlocking more “quests” and/or achievements
- Instead of displaying text, the application should learn the user’s learning style by how they engage with different content.
- Considering the user’s age and current level knowledge, content displayed should be appropriate for their age. For example, simple text should be displayed to a student who is 14 years old, since they vocabulary is not as vast as a professional historian who is 50 years old.

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Appendix A Personal Reflection

A.1 Reflection on Project

Overall, the project went well and even though I was not able to achieve all that I wanted to achieve, a considerable amount of progress was made. With my current knowledge in this area, I would have approached the project by looking into the psychology of learning. Understanding this psychological process of learning, perhaps this would have helped tackle the problem by introducing new features which help improve the creation of personalised learning.

A.2 Personal Reflection

The experience gained from this project has emphasised the importance of planning ahead. Even though thorough planning was done during the development stage, a similar approach could have been used when planning how the project would be tackled. I often found myself working too much or not enough at different stages of the project. There were also periods where I was not sure were to start because of the huge workload which needed to be completed. Perhaps more the achievement feature would have been complete if the literature review was completed by the end of December 2018.

There are various methods used to achieve personalised learning. I would have spent more time researching how these methods work and attempted to incorporate this into the application. Since the little research was completed in the first 3 months, due to lack of planning I was not able to spend more time performing research in this area.

Overall, I think the project went well and I'm proud to say I developed an application which delivers a personalised learning approach.

Appendix B Project Plan Approach

The table below shows the plan created on how the project will be approached. The plan is a rough outline of tasks to be completed.

Task: Project Synopsis	**Month: October 2018**
Refine project's aims and objectives	
Complete project synopsis	
Task: Literature Review - AR	**Month: November 2018**
What is AR?	
Why choose AR over VR>	
How does it work?	
Challenges the project may face?	
Current solution of AR in education and museums?	
Write Chapter 2	
Task: Literature Review – Learning	**Month: December 2018**
Learning styles	
Who visits museums?	
What is learning? How is it achieved?	
Task: Design – Use Case & UI Design	**Month: December 2018**
Develop a use case for the application	
Design low fidelity UI Sketches of the main use case activity	
Task: Literature Review – Learning & Methodology research	**Month: January 2019**
Traditional vs modern approaches to learning	
How is digital learning achieved?	
Traditional vs modern methods	
Gamification in education	
Non-verbal vs verbal communication	
Facial emotion analysis	
How is personalised learning achieved	
Research suitable methodology for project	
Implement 1st sprint – 2 weeks	
Write about 1st iteration	
Write Chapter 2	
Task: BREO Ethical approval	**Month: January 2019**
Complete ethics form on BREO	

Task: Methodology	**Month: February 2019**
Write Chapter 3	
Task: Implementation	**Month: February 2019**
Implement 2nd sprint – 2 weeks	
Write about 2nd iteration	
Implement 3rd sprint – 2 weeks	
Write about 3rd iteration	
Task: Testing	**Month March 2019**
Test application – 4 days	
Task: Report	**Month: March 2019**
Re-write and complete chapters	

Appendix C Personas

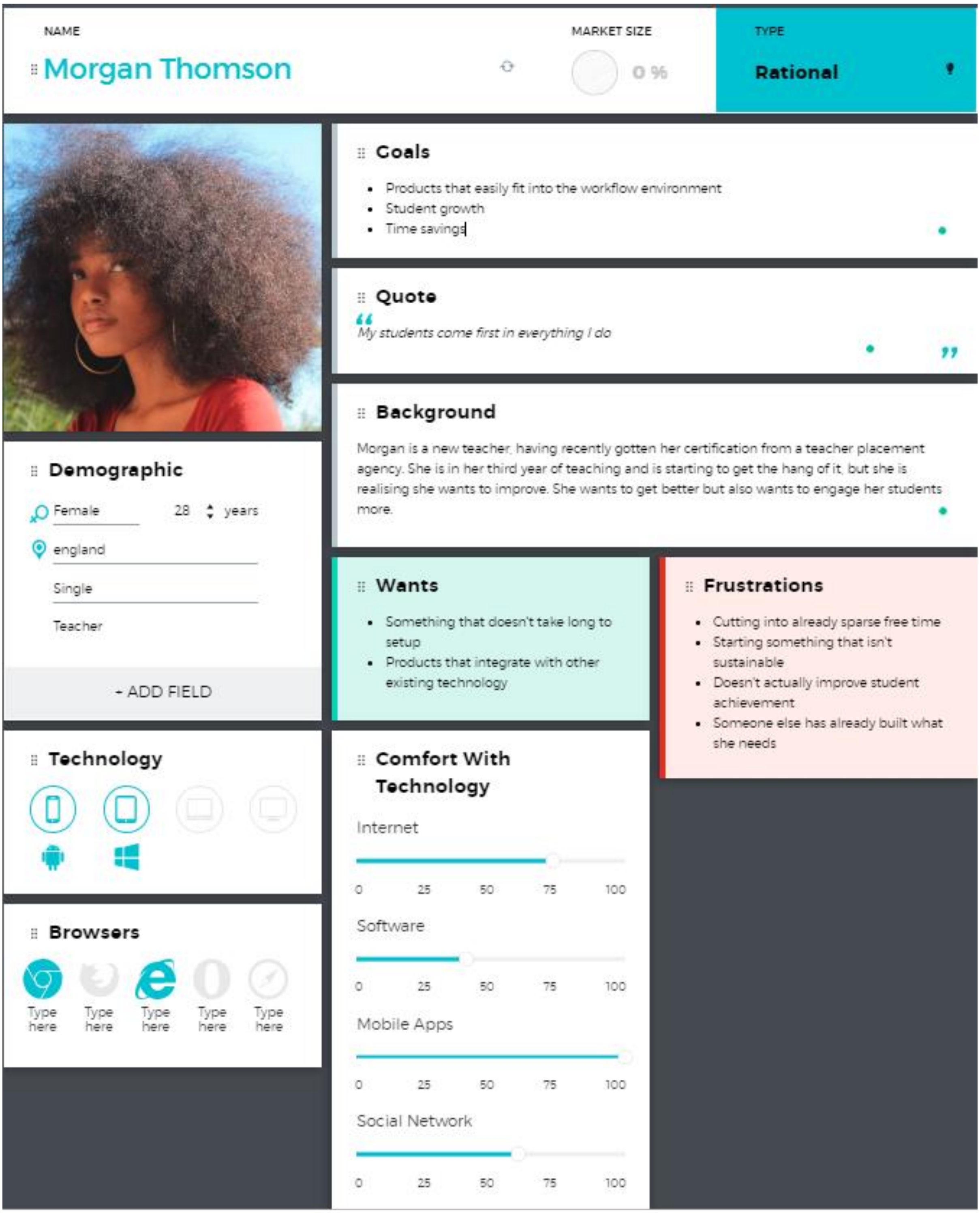

Figure 46: Morgan Thomson (Persona)

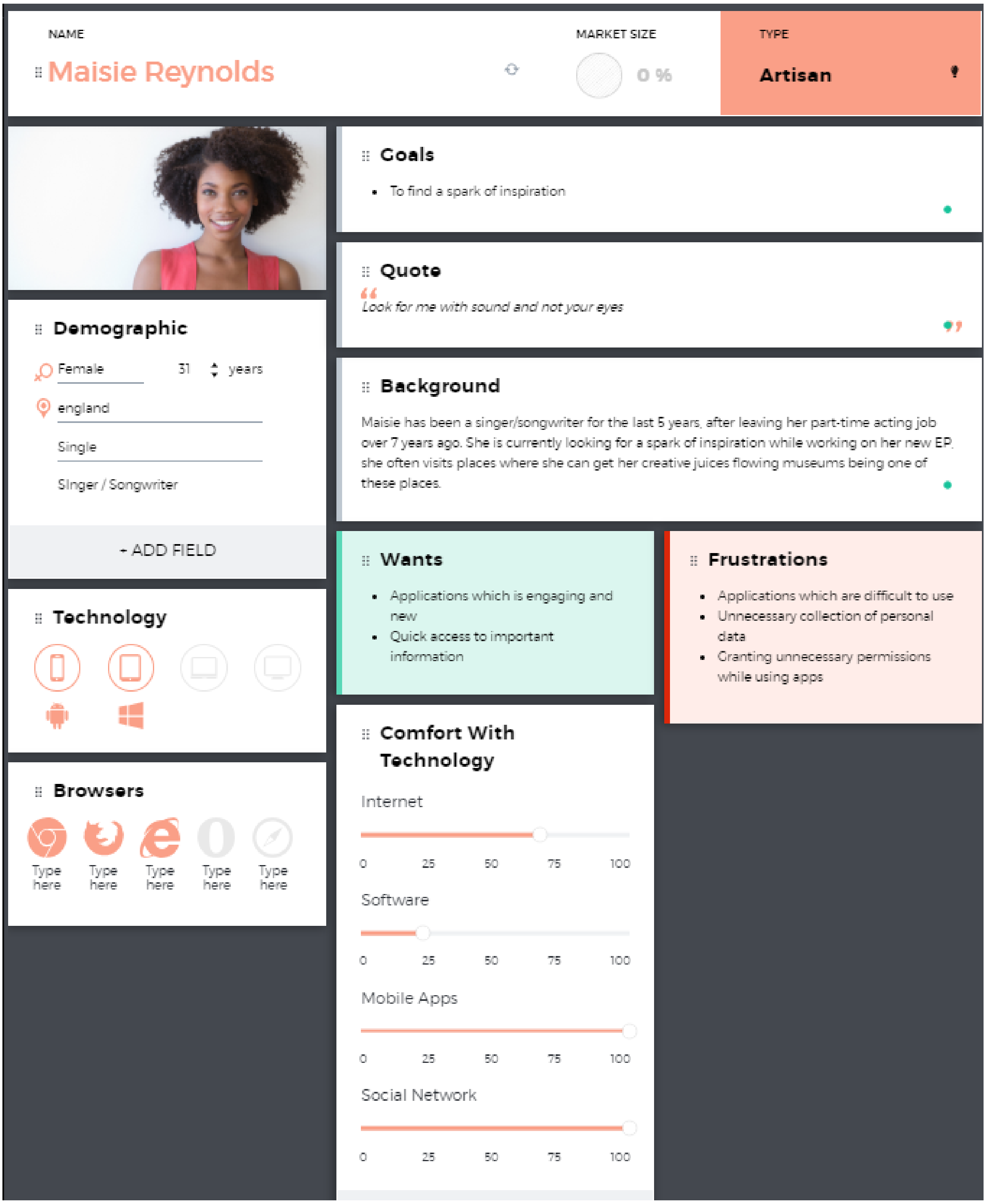

Figure 47: Maisie Reynolds (Persona)

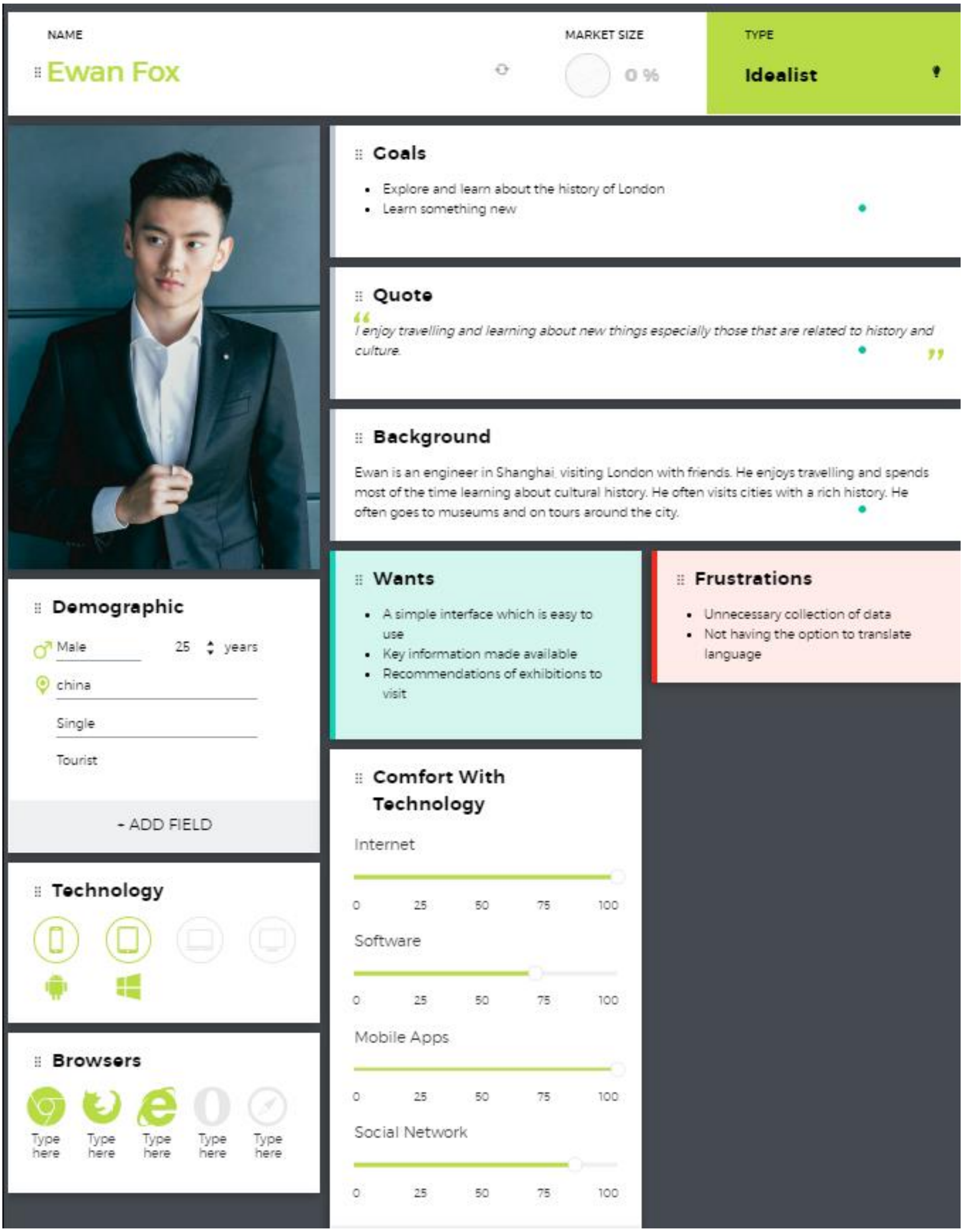

Figure 48: Ewan Fox (Persona)

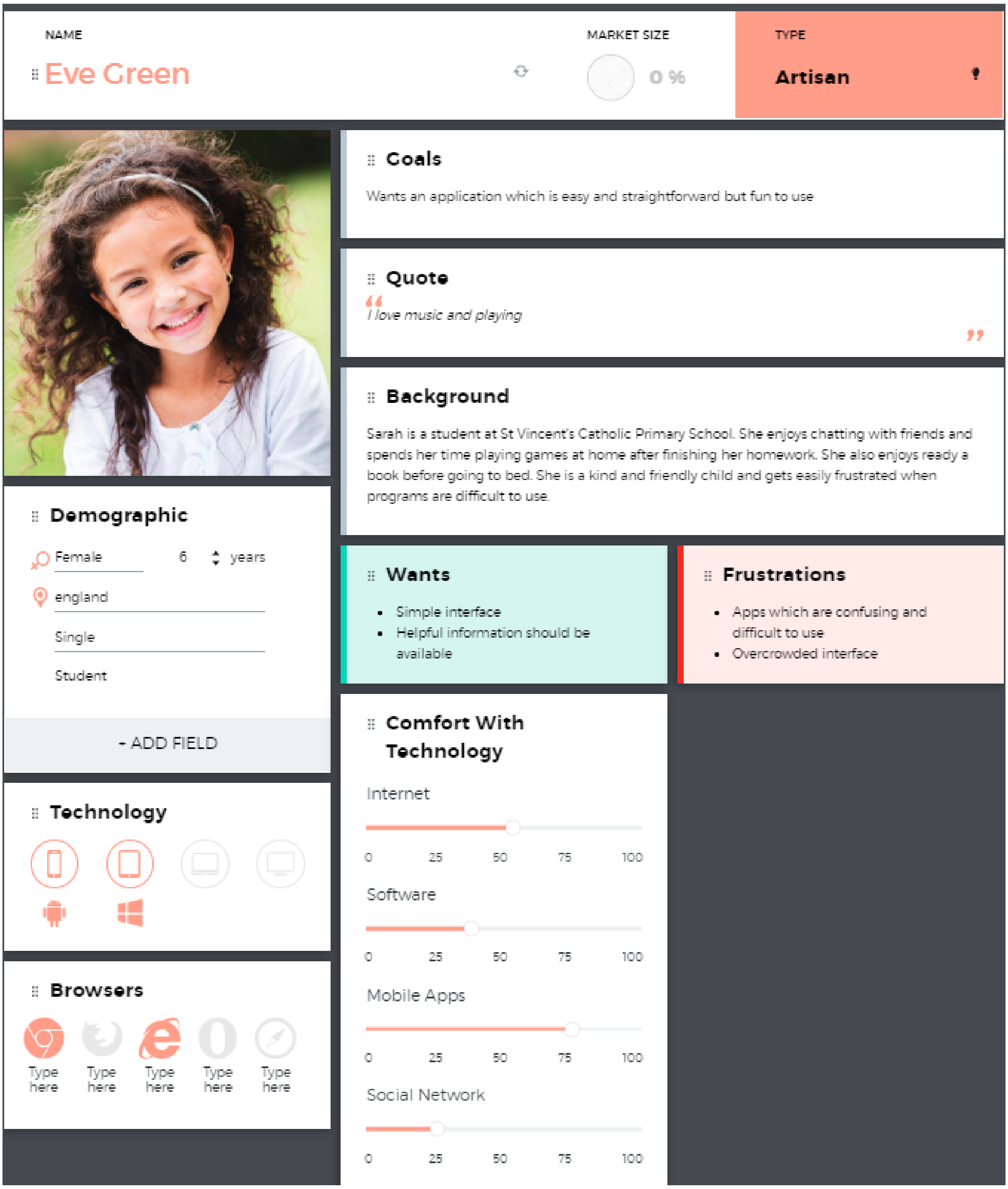

Figure 49: Eve Green (Persona)

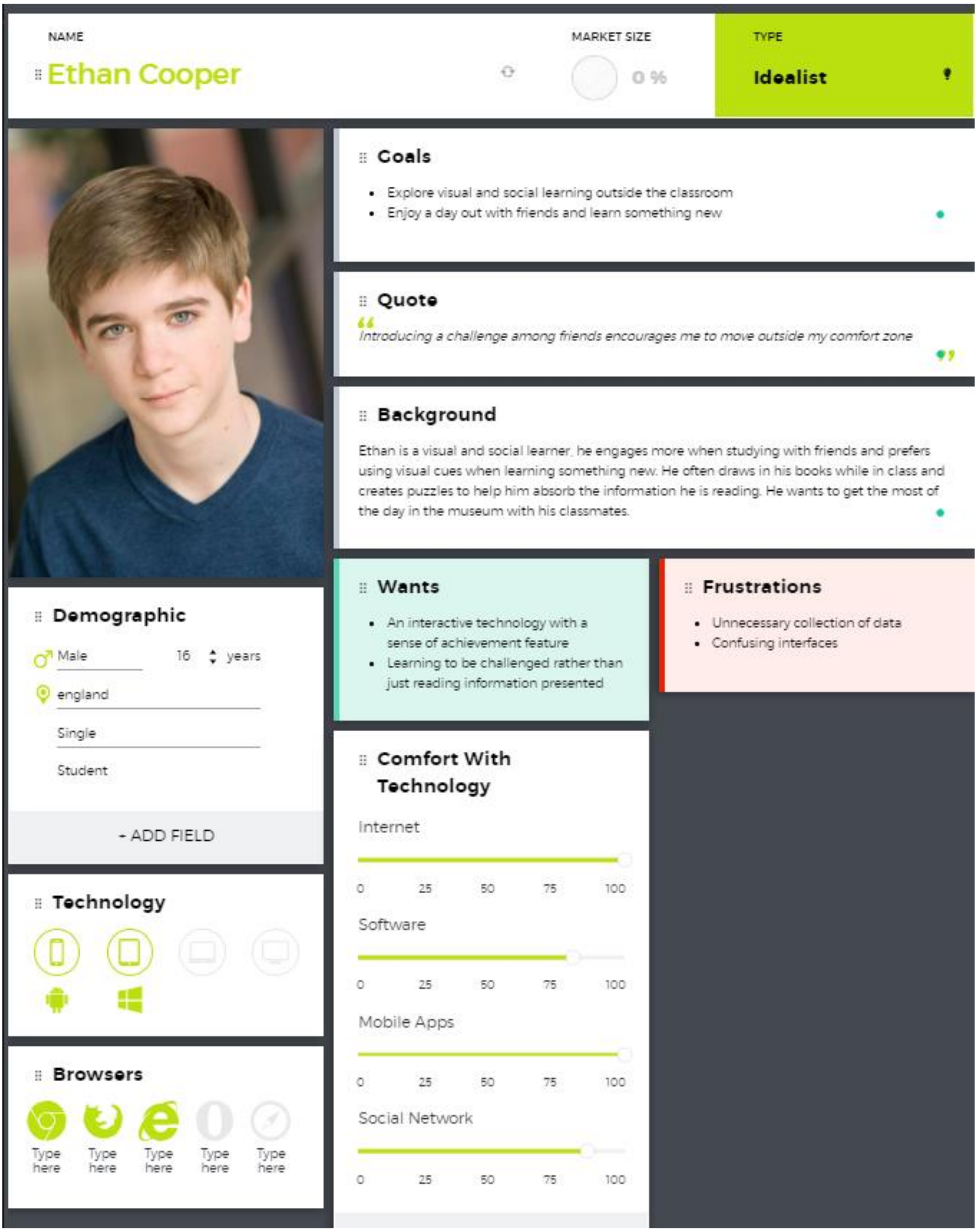

Figure 50: Ethan Cooper (Persona)

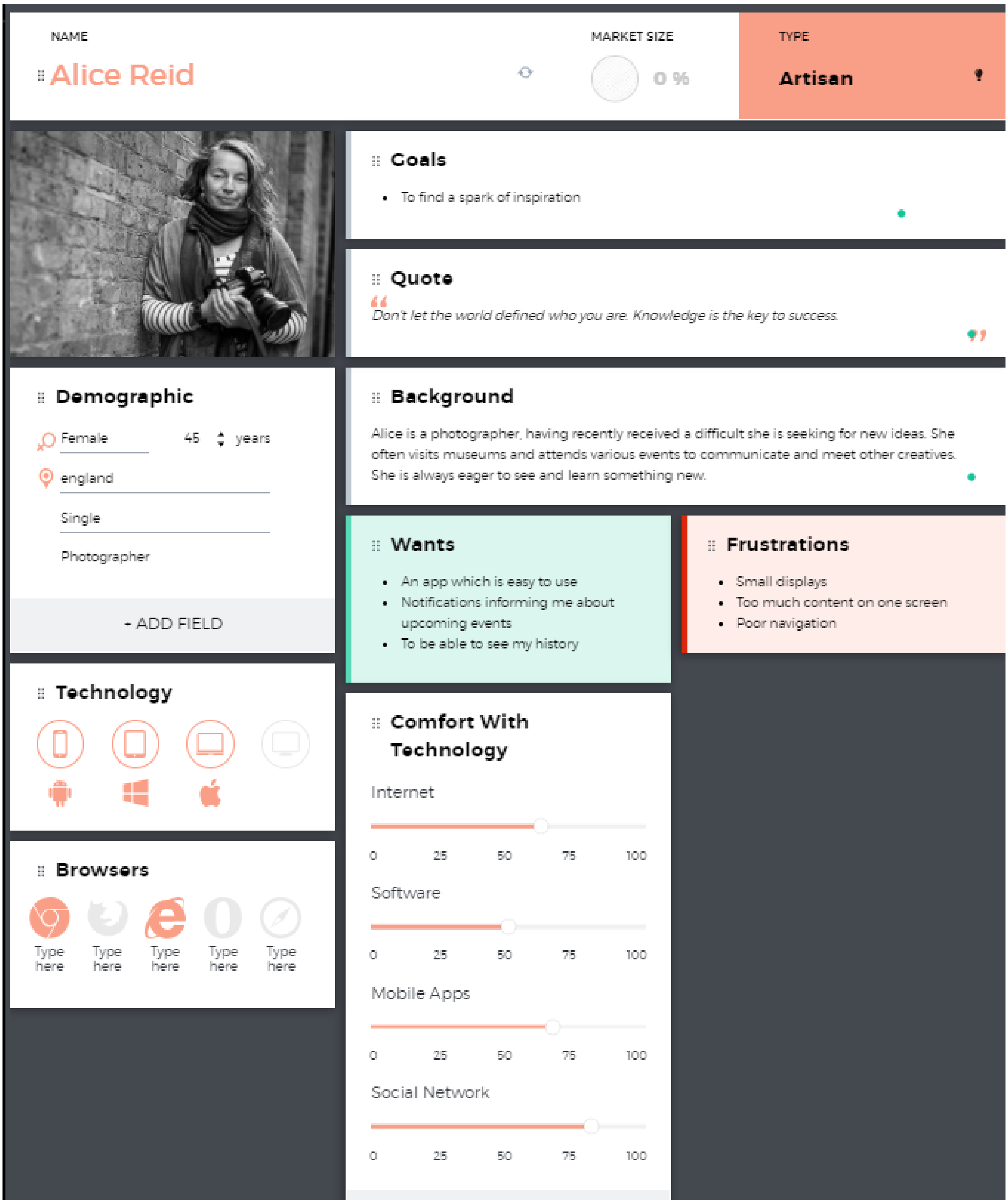

Figure 51: Alice Reid (Persona)

Appendix D Ethics Approval

Below are email exchanges in regards to ethical approval.

Seron Constance [Staff]
Thu 28/02/2019 11:32
Alecsandria Missangu

Dear Alecsandria,

I am reviewing your BREO application and you have selected that your research does not involve human participants or their data.

Could you please justify why your research does not require the use of human participants. For example, are you using purely secondary data analysis? Are you using information that can be found online and is already anonymised? Or are you designing a product or service where you will be the only participant required to test it?

I look forward to your response.

Kind regards,

Seron.
Seron Constance
Governance and Compliance Administrator (for Research Ethics)
T (0)18952 65631 | E Seron.Constance@brunel.ac.uk (Usually Mon-Fri 08:00 – 16:00)
Directorate of Governance, Legal, Academic and Student Services (GLASS)

Alecsandria Missangu
Sun 17/03/2019 22:03

Hi Seron,

The app I'm developing does not require human participants because I'll be generating random data to test the solution.
Would I need to amend my ethics form or is this response okay?

Kind Regards,
Alecsandria.

Seron Constance [Staff]
Mon 18/03/2019 09:34

Hi Alecsandria,

Many thanks for your reply. The justification you have provided is okay and In that case you do not need to amend your BREO form.

You can carry on with your research.

Kind regards,

Seron.

Alecsandria Missangu
Fri 29/03/2019 14:59

Hi Seron,

I have received my letter of approval which I need to add into my dissertation, do I need to complete anything else?

Kind Regards,
Alecsandria.

Seron Constance [Staff]
Fri 29/03/2019 15:03

Dear Alecsandria,

No you only need to include your approval letter in your dissertation.

Kind regards,

Seron.

Appendix E Affectiva SDK

Increase Positive Likelihood	Increase Negative Likelihood
Smile Cheek Raise	Inner Brow Raise Brow Furrow Nose Wrinkle Upper Lip Raise Lip Corner Depressor Chin Raise Lip Press Lip Suck

Figure 52: Mapping Valence Likehood

Emotion	Increase Likelihood	Decrease Likelihood
Joy	Smile	Brow Raise Brow Furrow
Anger	Brow furrow Lid Tighten Eye Widen Chin Raise Mouth Open Lip Suck	Inner Brow Raise Brow Raise Smile
Disgust	Nose Wrinkle Upper Lip Raise	Lip Suck Smile
Surprise	Inner Brow Raise Brow Raise Eye Widen Jaw Drop	Brow Furrow
Fear	Inner Brow Raise Brow Furrow Eye Widen Lip Stretch	Brow Raise Lip Corner Depressor Jaw Drop Smile
Sadness	Inner Brow Raise Brow Furrow Lip Corner Depressor	Brow Raise Eye Widen Lip Press Mouth Open Lip Suck Smile
Contempt	Brow Furrow Smirk	Smile

Figure 53: Mapping Emotions to Expressions