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***“Digital Booklet for teenagers  
that uses Augmented Reality”:  
AR Game for AMR***

**BSc (Hons.) Computer Science**

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## Chapter 1: Introduction

The aim of my project is to enhance the public understanding of microbe spread and resistances by creating an augmented reality application. The target audience for my application is 12-16-year old's.

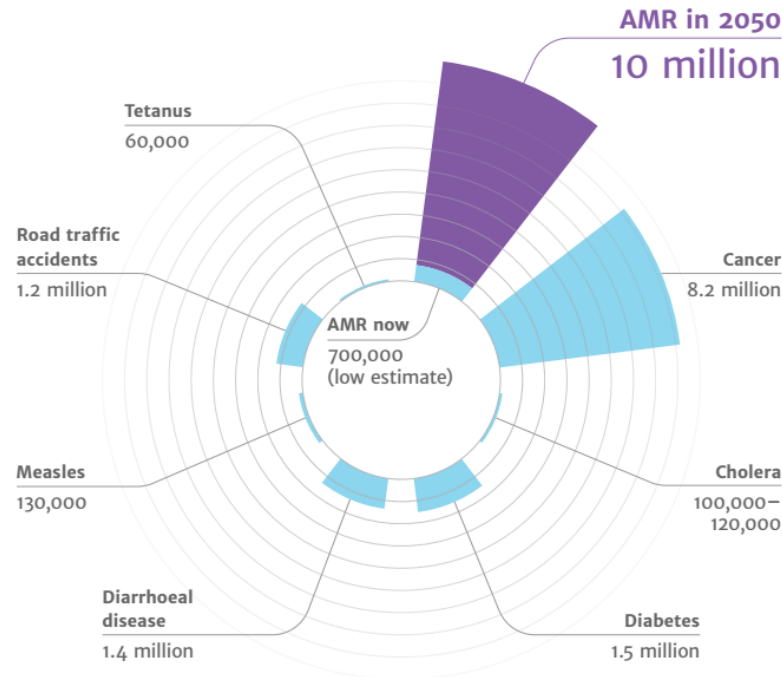


Figure [1] 1.1 - Deaths from Antimicrobial Resistances every year

Figure 1.1 shows that the amount of deaths every year from antimicrobial resistances are rapidly rising and so it's important that the public are made aware of how microbes spread and why and how bacteria is becoming resistant to antibiotics. In the case of my project, it will help teenagers ages 12-16 understand what bacteria is, how bacteria spreads, how to prevent the spread of bacteria and what antibacterial resistance is, in the form of a handheld and digital booklet that has augmentable images inside it to provide a more interactive learning experience. As of right now, many people won't know what AMR is, and so my project aims to teach AMR to the generation that it will most likely affect. I will utilize augmented reality to try and engage users that want to find out more information about AMR and bacteria.

Ultimately, the aims of my project are to:

- Improve teenager's general understanding about microbes and how they spread
- Introduce and explain the concepts of antibacterial resistances
- Help in teaching teenagers how to prevent the spread of bacteria
- Enhance the interactivity of learning by using augmented reality
- Create a booklet with information about antibacterial resistances and bacteria with augmentable images inside

## Chapter 2: Background

I needed to do quite a lot of background research for the project to gain an understanding of AMR and bacteria spread so that I could then teach relevant material to the target audience. This chapter contains all the findings of my research into augmented reality, bacteria, antimicrobial resistance, digital game based learning, existing AMR software, projects I considered by reading academic papers and finally my ideas for the project.

### 2.1 Augmented Reality

Augmented Reality is a vital part of my project, and therefore I felt that it was necessary to research more about it. In this section, I will discuss what augmented reality is, current augmented reality applications being used in education, applications of augmented reality in games and software development kits/libraries that allow you to create your own augmented reality experiences.

#### 2.1.1 What is Augmented Reality?

Augmented reality enables graphics, videos and 3D models to be overlaid over real world locations or objects using a smart phone application, in real-time. It usually works by using a 2D image as a target in which to augment on, but many modern SDKs allow 3D models to be used as targets also and some are even starting to no longer need markers at all. It can be used for education, marketing, commerce and games and provides a more interactive and fun approach than traditional approaches in many of these areas. Figure 2.1 shows an example of augmented reality, in which locations and attractions around the user's real-world location are overlaid on relevant real-world attractions and objects through use of the smartphones camera, thus allowing them to gain access to information about their surroundings that otherwise would have been harder to attain.



Figure [2] 2.1 – Example of augmented reality

### 2.1.2 Augmented Reality in Education

Augmented reality is already being heavily used in education to provide a more interactive, fun and pleasant experience for students. The effectiveness of augmented reality in education has been questioned for years along with many other emerging and growing technologies. There is a wide variation of projects that have been carried out when it comes to augmented reality in education, some of which include:

- Aurasma
- Star Walk
- AR Liver Viewer

Aurasma allows users to create their own augmented reality experiences. It's currently being used in high schools by teachers and students alike.

Star Walk is a mobile application that allows you to point your phone camera to the sky and receive information about any stars and constellations that you see.



Figure [3] 2.2 Star Walk Demonstration

AR Liver Viewer [4] is an example of an educational augmented reality application that can provide *“real-time 3D medical education and patient communication tools, featuring incredibly detailed anatomical models.”* This software can be used to train medical staff about livers and potentially even other anatomy. The augmented reality aspect of the software enables the user to overlay a virtual liver over a marker. They can then rotate this marker to explore the organ in more depth.

There are of course many more applications available that use augmented reality to enhance the learning experience but this is an example of some of them. It is however clear that augmented reality can be a helpful addition to educational applications for many different professions and ages.

### 2.1.3 Augmented Reality in Games

A common use of augmented reality is in games. The most well-known and most recent example of a game that utilizes augmented reality is Pokémon Go. Pokémon Go uses GPS positioning to



overlay 3D models of Pokémon into real-world locations around the player. The player must travel around the real world and catch as many Pokémon as they can in the game. When the game released, it was met with a huge influx of players and the augmented reality aspect of the game contributed towards this along with the health benefits. It also got people to socialize more, as whilst playing you would see many other people playing also. Exercise is a major plus of Pokémon Go and is one of the main health benefits, as it encouraged players to travel around by foot and gave some people motivation to travel to other places.



Figure [5] 2.2 – The augmented reality aspect of Pokémon Go

Figure 2.2 shows the augmented reality aspect of Pokémon Go, with a Pikachu augmented into the road. Augmented reality added extra interactivity and fun to the game than it would have had without it, however this only lasted for a few months, as many players started to turn the augmented reality off to save phone battery and because the novelty had worn off. The fact that many players began turning off the augmented reality feature in the game begs the question of if augmented reality has the capability of keeping users engaged long-term. However, battery life could have been the main contributor to why so many players turned the augmented reality off.

There are other games that have utilized augmented reality to success also, such as the predecessor game to Pokémon Go, known as “Ingress”. This shows that augmented reality can help in making games more fun and engaging, as both games were considered very successful.

Augmented Reality in games has room to grow and in a few years, it could be a vital part of many mobile games. There are issues that need to be solved however, such as the drain of battery life.

#### **2.1.4 Augmented Reality SDKs**

For the project, I will need to use an existing library or SDK that enables me to create augmented experiences for the users of my booklet. I decided to research some AR libraries and decide which one would be best for my project.

Some AR libraries include:

- Vuforia
- Wikitude

- ARLab

Vuforia is an SDK that provides everything needed to create augmented reality experiences. It also provides a package for Unity which is ideal as I will likely also be using Unity in the project. A benefit that Vuforia has over the other AR toolkits is the capability of augmenting videos as well as images and animations.

Wikitude is another AR SDK that provides a lot of features that are required to make AR experiences. The only downside of Wikitude is it doesn't allow videos to be augmented, which sadly is a major focus point of my booklet.

ARLab is an SDK that I didn't research as much as the others because I was already set on using either Vuforia or Wikitude. ARLab however, also provides many features.

As I wanted the capability of augmenting videos, I chose Vuforia over Wikitude. Videos are important in the booklet as they can provide a fun and more engaging way for children to learn, as children in the modern age are always using technology and commonly use websites like YouTube to watch videos. Vuforia and Wikitude also have free licenses available, whereas ARLab requires a purchase.

## **2.2 Bacteria**

### **2.2.1 What is bacteria?**

It is important to understand properly what bacteria is if I am to teach others about it.

LiveScience [6] define bacteria as *“microscopic single-celled organisms that thrive in diverse environments. They can live within soil, in the ocean and inside the human gut. Humans' relationship with bacteria is complex. Sometimes they lend a helping hand, by curdling milk into yogurt, or helping with our digestion. At other times, they are destructive, causing diseases like pneumonia and MRSA.”* This mentions that there are also good bacteria which can be helpful to us, which I want to consider when teaching the target audience about bacteria.

### **2.2.2 How does bacteria spread?**

It is also important for me to fully understand how bacteria spreads so that I can fully explain the relevant information to my target audience. Bacteria can spread in many ways. Some of these ways include:

- Through the air
- Contact with animals
- Food that is contaminated
- Touching other people
- Through water

Sneezing or coughing can cause bacteria to spread in the air, therefore if somebody else is to breathe in these bacteria then they can potentially become ill.

As for animals, a common example is the mosquito, which can carry the bacteria which causes malaria. If bitten or scratched by a mosquito, there is a chance of getting malaria.

Food can have bacteria in it that can cause food poisoning, this is mostly in food such as meat that isn't cooked properly. Cooking meat thoroughly can kill any bacteria.

Someone may have bacteria on their hand, and then touch somebody else with that hand and these bacteria could then spread to the other person. Another way that touch can spread bacteria, is through objects, for example a person with bacteria on their hand touches a door handle and then the other person touches the door handle after and the bacteria on the door handle then spreads to the other person's hand. Regularly washing your hands can help in preventing bacteria from spreading in this way.

Contaminated water is mostly a problem in third world countries. This is because the water isn't usually filtered due to poor living conditions, poor sanitation and many other problems. Therefore, it's important in these countries to boil water to kill most of the bacteria.

There are also many other ways in which bacteria can spread, but these are some of the most common ways.

## **2.3 Antimicrobial Resistance**

AMR is a big part of my project so I decided to research it in more depth, so that I could teach most of the concepts to my target audience.

### **2.3.1 What is AMR?**

AMR stands for antimicrobial resistance and in the case of bacteria, is when antibiotics that kill bacteria are no longer as effective in killing them, don't kill them at all or are also no longer effective at preventing the growth of them. Resistance is accelerated by misuse of antibiotics and other antimicrobials. Many people misuse antibiotics by using them for illnesses that are caused by viruses, such as the common cold and flu, when antibiotics are ineffective against viruses.

The World Health Organization (WHO) [7] states that antimicrobial resistant-microbes *"are found in people, animals, food, and the environment (in water, soil and air). They can spread between people and animals, and from person to person. Poor infection control, inadequate sanitary conditions and inappropriate food-handling encourage the spread of antimicrobial resistance."*

AMR is a growing problem in the world, but not many people are aware of it and still commonly misuse antibiotics.

### **2.3.2 Why is AMR a problem?**

The WHO [7] states that *"New resistance mechanisms are emerging and spreading globally, threatening our ability to treat common infectious diseases, resulting in prolonged illness, disability, and death."* It is obvious that AMR is a growing threat in the modern world, and as of right now the only people that properly know about and understand the issue is health care professionals, academics and researchers. The lack of awareness is one issue, but another is that

antibiotics are currently being misused by the public for illnesses such as colds and the flu which are not in most cases caused by bacteria.

Per the World Health Organization [7], AMR is a big problem because “*without effective antimicrobials for prevention and treatment of infections, medical procedures such as organ transplantation, cancer chemotherapy, diabetes management and major surgery (for example, caesarean sections or hip replacements) become very high risk.*” There are also other issues such as longer hospital stays, as patients will potentially be very ill. Another problem is AMR has the potential to take us back to a time before antibiotics existed again, which is a very scary thought.

The WHO [7] also mention that “*Globally, 480,000 people develop multi-drug resistant TB each year, and drug resistance is starting to complicate the fight against HIV and malaria, as well.*” Data shows that this number is on the rise and if nothing is done about the current crisis, it will only get worse. Therefore, it’s important that AMR is tackled and sooner rather than later.

## **2.4 Digital Game Based Learning**

### **2.4.1 What is Digital Game Based Learning?**

Digital Game Based Learning (DGBL) is an approach to finding a more engaging, fun and interesting way for children to learn, using digital games. Children learn by playing games that have learning elements incorporated into them. Marc Prensky [8] was a big promoter of DGBL and described it as being “*precisely about fun and engagement, and the coming together of and serious learning and interactive entertainment into a newly emerging and highly exciting medium — Digital Learning Games.*”

Prensky [8] discusses how “*learners have changed in some fundamentally important ways — the bulk of the people who are learning and being trained today, people who in the year 2000 are roughly under the age of 36 (the median age of the US corporate worker), are, in a very real intellectual sense, not the same as those of the past.*” It is emphasized that children today and children of the past not only learn, but think and process information in different ways.

Digital Game Based Learning is a great approach to learning, as many students find current education archaic and boring. This can in turn, affect how some students perform in educational settings. I want to try and take Digital Game Based Learning into account throughout my project.

## **2.5 Current Software Solutions to the AMR crisis**

There are already plans in place for tackling the AMR crisis, with the World Health Organization leading the way. In this part, however, I will look mostly at software solutions to the AMR crisis as it relates to my project.

### **2.5.1 Superbugs**

Superbugs is an attempt at creating a game that teaches about AMR. The player must kill bacteria that are inside a petri dish using antibiotics. Over time, the antibiotic you originally used will no longer be effective on the bacteria and so you must wait until a new antibiotic is “discovered”. Figure 2.3 shows the bacteria inside the petri dish in Superbugs.



Figure [9] 2.3 Superbugs Game

Initially, the bacteria can be killed with normal drugs just by tapping on the bacteria, but over a period some bacteria that is resistant to the normal drugs will not be killed by them. You must activate the antibiotic which makes these bacteria killable again. To get another antibiotic you must clear a few levels and have some time go by. If the invincible bacteria fill up the whole petri dish, then it's game over.

I do like how the game has attempted to teach about AMR, but I personally didn't find that the game kept me engaged for a long time which in some cases could mean that people don't play it long enough to understand what the learning objective was. The actual learning objective of the game isn't directly mentioned anywhere whilst playing the game either, and you must go out of your way to find it from the main menu. In my project, I would aim for it to be engaging, interactive and fun, but also teach about how bacteria spreads and about AMR. The learning objective of my project will be clear and transferred effectively.

## 2.6 Original Project Ideas

I've had many different ideas for mobile applications during the project that all vary quite drastically from one another. These ideas all contributed to coming up with the final idea for the project.

### 2.6.1 Kitchen Augmented Reality Game

One of my original ideas in the first few weeks of my project was to create a game that could be used in the Lancaster University campus accommodation kitchens. The idea was to augment 3D models of common microbes and have animations displaying how they spread around kitchen surfaces. The flaws of this idea became apparent whilst I was researching augmented reality toolkits, as many of the freely available toolkits didn't provide as many features as I had hoped to achieve this idea.

### 2.6.2 Tower Defense AMR Game

Another initial idea that I had was a tower defense game that would integrate AMR as the focus. This idea wasn't explored as much as the previous idea mentioned above, but the idea was to make augmented reality a big focus point whilst also getting the message across about AMR.

### **2.6.3 Hand AMR Game**

This idea was to have the target audience as children and to teach them about AMR, what bacteria is and how it spreads with a reasonably simple approach. The idea was that the users hand would be the “marker” in which objects would be augmented onto. It would then be possible to show common bacteria that is found on the hand to the user. The idea also included the plan to show videos and animations of exactly how bacteria spreads and how the user could prevent it or at least reduce spread.

### **2.6.4 GPS-based AMR Game**

This idea was heavily inspired by Pokémon Go. The plan was to have the user find and kill bacteria that would be augmented in the world using their GPS location. They would use antibiotics as their weapon and if the antibiotics were used incorrectly, like for example on viruses, then some future bacteria would be a higher level.

### **2.6.5 Final Idea**

The final idea was to create a booklet for 12-16-year old’s that would be engaging, fun and interactive, but most importantly, still provide some necessary information about bacteria and AMR. Augmented reality is a great aid to make the booklet fun, as it allows more information to be provided to the curious learner, can be used for interactive experiences, can be used for videos and much more, all of which I plan to put in the booklet.

## **Chapter 3: Design**

This chapter looks at the major design decisions that I made when designing the booklet. It will include useful diagrams of initial sketches of the booklet and its pages and any necessary class diagrams. Diagrams of the overall architecture will also be shown, along with an explanation of each of the components. I will also look at game design principles which I followed to make the booklet more enjoyable and user friendly.

### **3.1 Game Design Principles**

Even though the booklet will not necessarily have any games in it, many of these game design principles could be applied to the booklet itself and so I will use some of them whilst designing the booklet. The booklet will mostly feature augmented visualizations and videos but some of these principles still apply and are helpful in designing a good booklet.

#### **3.1.1 Accommodate all skill levels**

The booklet should and will accommodate all skill levels of the target audience that the project is being designed for. The content will display information in a way that is easy for anybody between the ages of 12-16 (and above) to comprehend. It is important to not exclude certain individuals from being able to use the booklet and so the language used and the presentation of the information will be conveyed effectively.

#### **3.1.2 Minimize user's confusion**

The user should never be confused whilst using the booklet, and therefore I ensured that I follow this game design principle. At the beginning of the booklet, there will be a few simple instructions such as how to turn the page of the booklet using the arrow keys or by a mouse click. Any buttons that are augmented will have text on them specifying exactly what it does so that the user doesn't have to click it to find out.

#### **3.1.3 Avoiding Repetition**

In the booklet, I should avoid using content that is repetitive. As I will be using videos and interactions mostly in the form of augmented reality, this principle should be simple to meet. Videos can be played and paused as much as the user wants, this ensures that they don't have to wait too long for an action to be completed and if the user wants to, then they can skip certain videos.

#### **3.1.3 Simplicity**

Ultimately, the booklet will be simple but effective in teaching the audience about how bacteria spreads and about antimicrobial resistances as a global threat. Each page is unique in terms of topic, meaning the user will not get confused between pages. Simplicity is key for my project, as too much information at once could overwhelm my target audience and will also make it less fun to use.

#### **3.1.4 Colour**

Colour is a very important part of design and one that I will importantly consider when creating the booklet. The booklet will follow a red, white and blue colour scheme throughout for the pages but the images in the booklet will vary in colour. The augmented objects will all vary as

videos will vary in colour quite a bit. Colour can surprisingly help in keeping children engaged and interested in something and so is something I wanted to focus on.

### 3.2 Nielsen's Heuristics

Jakob Nielsen created 10 usability heuristics that are essential to consider when creating user interfaces. I will follow some of the usability heuristics suggested by Nielsen to make the booklet easy to use for users. In the evaluation section of the report, I will discuss whether these heuristics have been met effectively or not.

#### 3.2.1 Visibility of System Status

For this principle, Nielsen [10] states *"The system should always keep users informed about what is going on, through appropriate feedback within reasonable time."*

I plan to make the booklet in a way in which the user always knows what is going on. This can be done in many ways. Each 2 pages in the booklet will be related (e.g. Page 1 and Page 2 are both topically connected) and the second page will be used as a marker for the augmented reality. This will continue throughout the booklet, with the AR marker being on the right-hand side of a pair of pages.

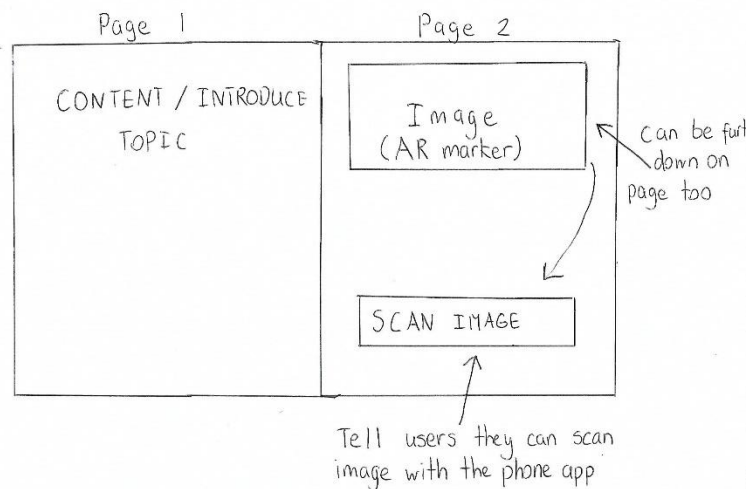


Figure 3.1 Page Designs

Figure 3.1 shows an original plan for the pages. The image on the right-hand side will be able to be positioned in different places, but will always stay on the right-hand side. The design of the pages will be discussed in more depth in chapter 3.4.

#### 3.2.2 Match between system and the real world

For this principle, Nielsen [10] states *"the system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order."*



All the content in the booklet will be appropriately presented in a way in which the target audience will understand. For example, instead of just instantly discussing “AMR” without expanding upon what it means, I would first describe that AMR stands for antimicrobial resistances. This would make it so that people who haven’t come across this term before would also be able to easily follow what is being said.

### **3.2.3 User Control and Freedom**

This principle is all about users being able to recover from mistakes. Nielsen [10] states “*Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.*”

This is important as if there is no obvious or easy way for the user to recover from, for example, pressing a button accidentally, then they may get frustrated with the product they are using and no longer want to use it.

I hope to incorporate this principle into my project by allowing easy navigation between pages in the booklet with use of keyboard arrow keys and on-screen buttons. If you accidentally click to go to the next page, you’ll be able to recover from this by clicking a “Previous” button.

In the case of the augmented reality, I will utilize videos that can be paused and played repeatedly, so if the user accidentally plays a video they will be able to undo this by pausing it.

### **3.3.4 Consistency and standards**

Nielsen [10] states “*Users should not have to wonder whether different words, situations, or actions mean the same thing.*”

The principle is important in my design because any confusion caused whilst a user is reading my booklet would mean that I have failed in my objective to effectively teach them about bacteria spread and antimicrobial resistance. Pages and the wording of content will be consistent throughout to ensure that the user is not left confused about anything.

## **3.3 Software Design & Development**

In this section I will be discussing the software design aspects of my project. This will include the user requirements and briefly touch on software used.

### **3.3.1 User Requirements**

User requirements are an integral part of software design and can help in understanding what features the user would want out of the product. It also can be helpful to me when designing the booklet as it gives a guideline of what features need to be implemented.

A digital form of the booklet is most important, but a physical version would be beneficial to users and would make the augmenting of objects make a lot more sense. Due to this, if possible, I would like to create a physical version of the booklet.

The booklet must catch the attention of the target audience, and so must be interactive and engaging. I plan to do this using augmented reality. Augmented Reality has shown to be useful in improving the interactivity and engagement of software.

Although the booklet must be fun to use, interactive and engaging, it must still provide the relevant information about AMR and how bacteria spreads to the target audience, otherwise the goal of my project will not have been met. To make it interactive and engaging, the user will be able to watch augmented videos, view infographics and maybe even play games or interact with virtual buttons. Games would be helpful; however, I will more be focusing on playful visualizations.

The digital booklet will be easy to navigate, using on-screen buttons along with the keyboard arrow keys, and the content discussing AMR and bacteria will be written in a way in which the target audience fully understands what is being communicated.

Ultimately, the booklet must still focus on teaching the target audience about AMR and bacteria spread.

The user requirements will be referenced throughout the report in chapters such as the evaluation and testing to ensure that these requirements have been met. Table 3.1 shows the user requirements.

User Requirements	
1	The booklet <b>SHALL</b> have a digital form
	The booklet <b>SHOULD</b> have a physical form
2	The booklet <b>SHALL</b> be interactive and engaging
3	The booklet <b>SHALL</b> provide relevant and helpful AMR information
4	The booklet <b>SHOULD</b> have a few games in
5	The booklet <b>SHALL</b> be easy to use and navigate
6	The booklet <b>SHALL</b> be easy to exit
7	The booklet <b>SHALL</b> use language that will be easy for the target audience to understand
8	The booklet <b>SHALL</b> be enjoyable to use
9	The booklet <b>SHALL</b> teach users about bacteria and how it spreads
10	The booklet <b>SHALL</b> augment at least one animation, video or image every 2 pages

Table 3.1 Booklet User Requirements

### 3.3.2 Software

I will be using a lot of different software for the project to ensure that the booklet turns out to be as good as it can be.

Unity will be used to create the booklet in, Adobe InDesign, Inkscape and Paint.net will be used to create any graphics. Software will be discussed more in-depth in chapter 4.

### 3.4 User Interface/Page Design

The user interface for my project is vital as this is what the user will always see. The booklet won't necessarily have a main menu, but the user will be able to navigate through pages.

#### 3.4.1 Booklet Instructions

The first page of the booklet will act as the front cover and will provide instructions to the user on how to use the booklet properly. It should provide a link to download the augmented reality application and should tell them how to use it. The instructions should all be simple and to the

point so that the user can remember them. Figure 3.2 shows the initial layout of an instruction page.

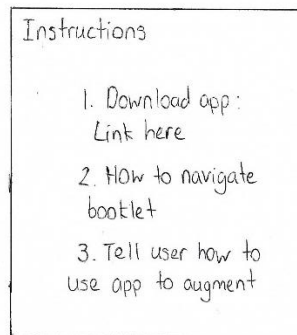


Figure 3.2 Instruction Page Design

### 3.4.2 Booklet Navigation

The navigation of the booklet will be simple but effective. In the case of a physical booklet, you could simply flip the pages but in the digital version I will add buttons next to each side of the booklet, one represents going back to the previous page and the second represents going to the next page. Figure 3.2 shows this. As shown in the figure, it will be possible for the user to either click on the buttons with the mouse, or by using the arrow keys.

To make the interface better, when the user is on the first page, the “previous” button will disappear so that they can only move to the next page. Similarly, when the user is on the last page, the “next” button will disappear so that they can only move back through the booklet. This will prevent confusion to the user. The user will be able to move back and forth through pages as

much as they want. These buttons will be black by default but when the user hovers over them with the mouse, they will turn white to indicate that it's a button that can be interacted with.

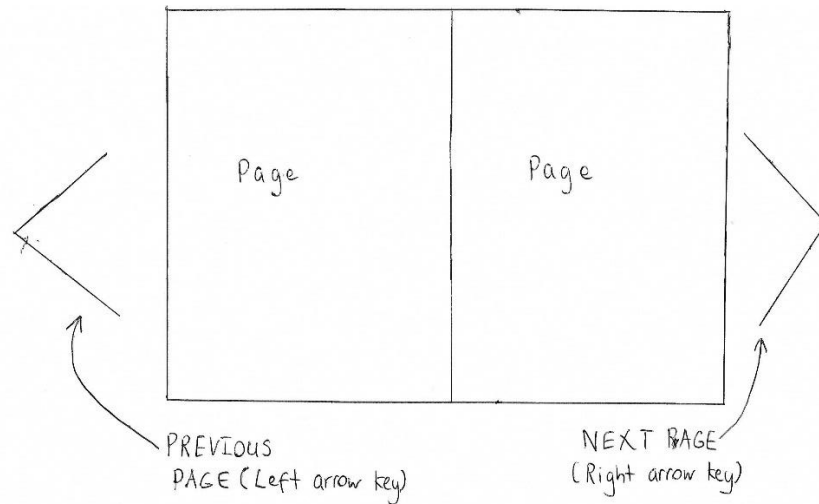


Figure 3.3 Navigation Example

Each first page of a pair of pages (Page 1, Page 3, Page 5 etc) will have an appropriate title that is representative of the content for 2 pages. The title will be placed consistently over different pages so that the user always knows where to look for it, and can easily find out what the page is about. The marker and information is also in consistent places over every page. Figure 3.3 shows the consistency between pages.

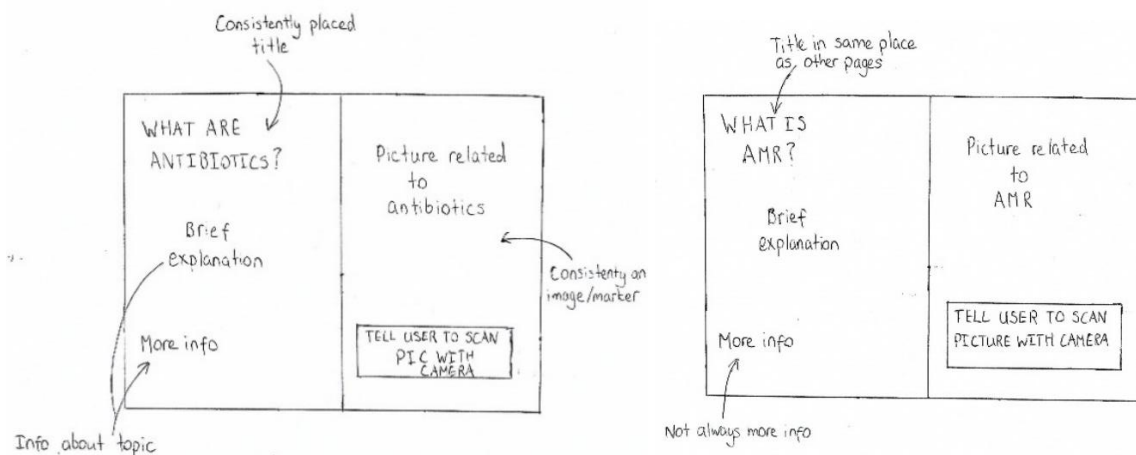


Figure 3.4 Content and Title Consistency

### 3.4.3 Augmented Reality Application

The augmented reality application I will develop will use the user's smartphone camera to augment above the booklet when the user points the camera at the pictures on the right-hand side page.

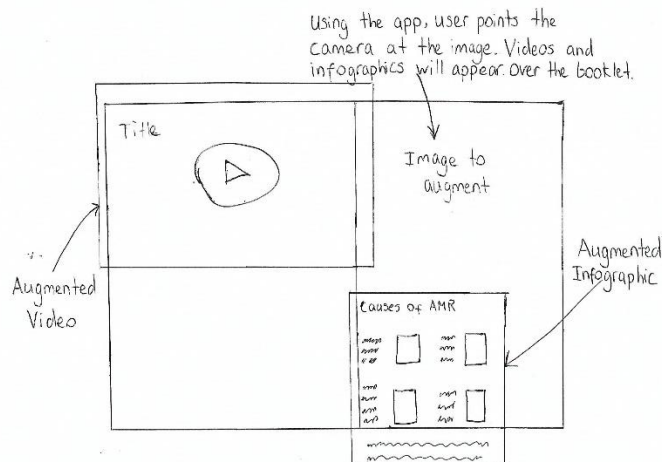


Figure 3.5 Augmented Multimedia

As can be seen in Figure 3.4, videos and infographics will be augmented above the booklet when the user places the camera over them. I think it is important that the augmented content is well laid out and enough information is presented. The amount of content being augmented on every 2 pages will be a maximum of four objects, this is so that the user will not be overwhelmed and to ensure that the augmented experience is as good as it can be.

Other pages will also augment video and infographics, but also potentially interactive sprites and games.

### 3.5 Learning Objectives

The whole aim of my project is ultimately to teach the target audience about antibacterial resistances and bacteria spread. It is important to discuss how each page of the booklet will help me in achieving this goal.

#### 3.5.1 Pages 1 and 2 Design – What are antibiotics?

Page 1 and Page 2 of the booklet will both be focusing on teaching what antibiotics are, what they're used for and what they should not be used for. Teaching about what antibiotics are I think is quite important, as many people still try and use antibiotics for viral infections. The lack of antibiotics due to antibiotic resistances is also most likely to affect the younger generation, and so teaching about current misuse will hopefully encourage users to use antibiotics only if necessary. The augmented reality will show relevant videos about antibiotics to the users.

For my diagrams, I think it is important to show the ideal design of both the pages themselves as if you were looking at them physically but also show the design of the augmented view and what the users would see when using the augmented reality application. Figure 3.5 shows the potential design that I will use for pages 1 and 2.

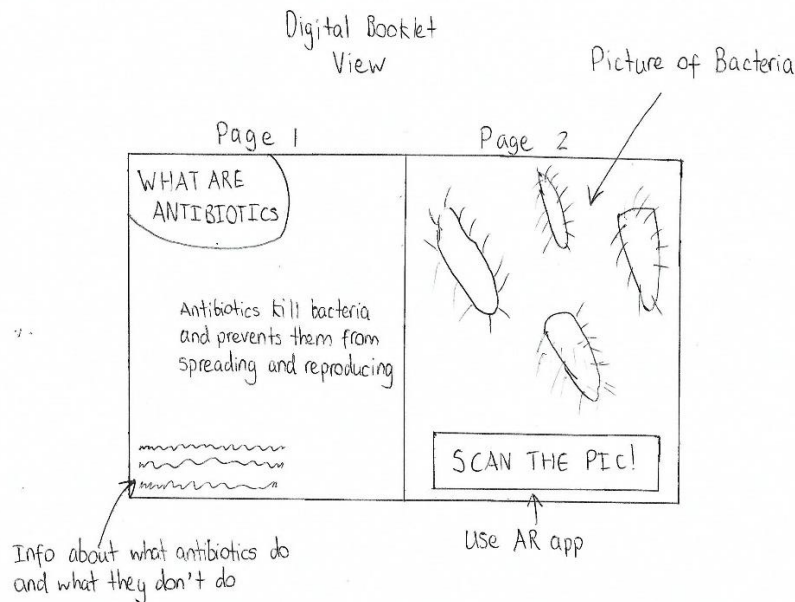


Figure 3.6 Page 1 and Page 2 Digital Booklet Design

The augmented view will likely display two videos to the users, which they can play and pause as much as they want. These videos will be fun but also actually help backup the information already presented in the physical view of the booklet. It will reinforce what has already been learnt. Figure 3.6 shows the ideal design of the augmented view of pages 1 and 2.

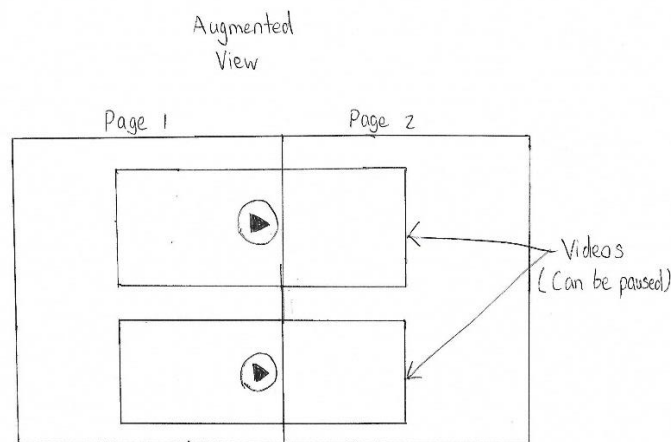


Figure 3.7 Page 1 and Page 2 Augmented View Design

### 3.5.2 Pages 3 and 4 Design – What is AMR?

Pages 3 and 4 of the booklet will focus on explaining what antimicrobial resistances are and what exactly it is that causes AMR. It will also describe why AMR is a big problem in the modern world, and why it is important that it is tackled. Quality of information over quantity is the approach that I will take with this page but also the others as well. Too much information could overwhelm or even confuse my target audience. From these pages, I would like users to gain a general understanding of AMR and what exactly they can do themselves to help prevent it.

As with the previous pages, I drew designs for the physical view of the booklet and the augmented view. Figure 3.7 shows the potential physical view of the digital booklet.

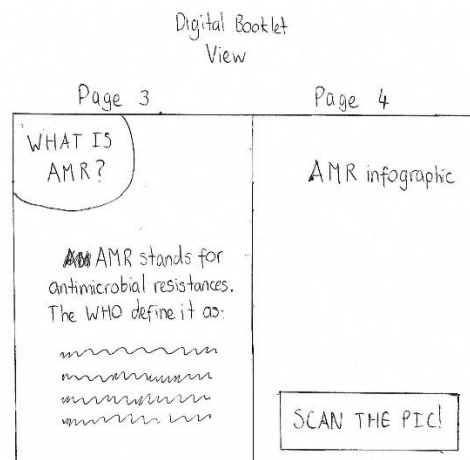


Figure 3.8 Page 3 and 4 Digital Booklet Design

The augmented view of pages 3 and 4 can be seen in Figure 3.8. There will likely be two videos and two infographics that provide more information about AMR and the problems with it. The videos and infographics will be relevant for the ages of the target audience and easy to understand. Like in pages 1 and 2, reinforcing what the user has already learnt is the approach.

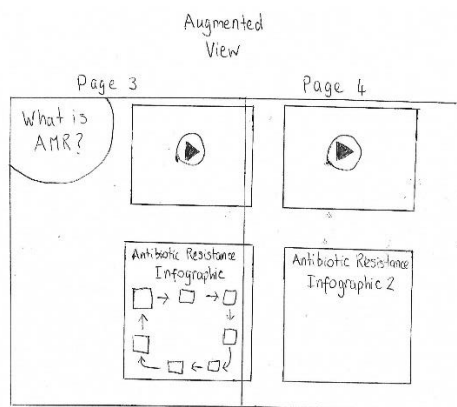


Figure 3.9 Page 3 and 4 Augmented View Design

### 3.5.3 Pages 5 and 6 Design – Spread of Bacteria

Pages 5 and 6 will focus on explaining how bacteria spreads and how the spread of bacteria can be prevented. This is a main goal of my project specification. Currently, many people don't wash their hands regularly when they should, and it isn't just children that don't. After reading these pages and viewing the augmented multimedia, the target audience should know what steps they can take to prevent themselves from spreading bacteria and reducing their chances of becoming ill.

Figure 3.9 shows the ideal view for pages 5 and 6. Page 5 will be quite information heavy compared to some of the other pages but this is due to the importance of the information. This information will also be laid out in a way which still makes it easy to read and follow for the target audience.

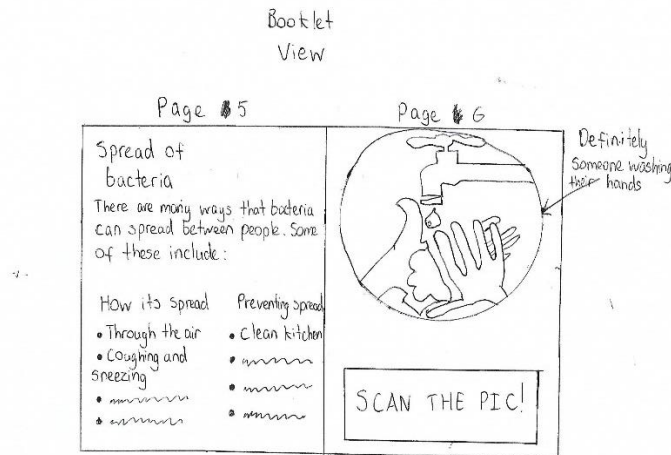


Figure 3.10 Page 5 and 6 Digital Booklet Design

Figure 3.10 shows the expected design of the augmented reality view for pages 5 and 6. The video will explain how bacteria spreads by showing a real-life example in a test lab. It will also show the bacteria mutating over time and becoming more resistant to the antibiotic being used. The bacteria spread infographic will provide more information about bacteria in general and will reinforce what the user has already learnt by reading the digital booklet.

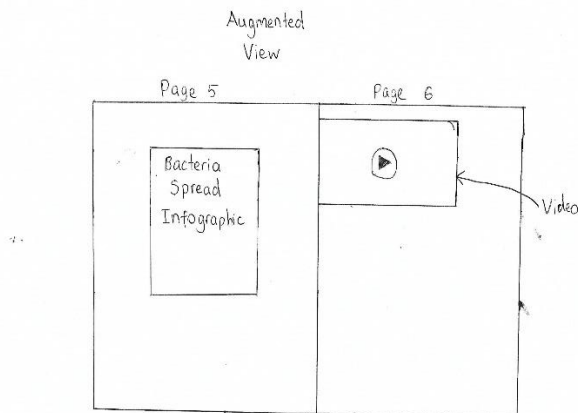


Figure 3.11 Page 5 and 6 Augmented View Design



### 3.5.4 Pages 7 and 8 Design – Good Bacteria

Page 7 and 8 will discuss good bacteria. I think this is an important topic to include in the booklet as whenever bacteria are discussed and taught to people, they are mostly discussed in a negative way. These pages will aim to give the target audience an understanding that not all bacteria are bad and that some microorganisms are important for our bodies to digest food and to create foods such as yoghurt and cheese.

Figure 3.11 shows the expected design of the digital booklet. The layout of this page will vary a little bit from the others due to the picture that I plan to use on it. There is also a little bit more information that I think is quite important to add.

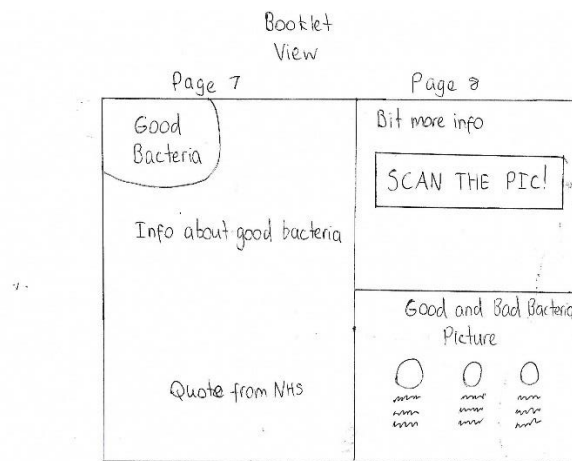


Figure 3.12 Page 7 and 8 Digital Booklet Design

With this page and inside the augmented view I decided that I would try and add a take on noughts and crosses using sprites of bacteria instead of the usual sprites. The user will be presented with a grid and when they touch a square in the grid with their finger inside the camera view, an invisible button will trigger and the user's sprite will be added to the square they pressed. Figure 3.12 shows the grid view that the user will be presented with, and a sprite that has been added to the grid. On the left-hand page, a video about good bacteria will be augmented.

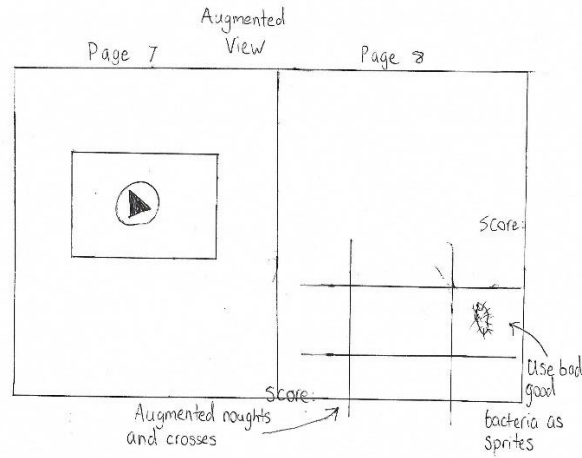


Figure 3.12 Page 7 and 8 Augmented View Design

This game would be a fun addition to the booklet, but could be harder to implement than initially thought.

## Chapter 4: Implementation

In this chapter, I will discuss how the booklet was implemented and will look at the creation of the booklet pages. The booklet has been created considering the user requirements and following Nielsen's Heuristics as much as possible.

### 4.1 Software Used

In this sub-chapter, I will discuss in more detail the software used throughout the project that helped me create the page designs, augmented view and any sprites.

#### 4.1.1 Sprites

To create the sprites seen in the noughts and crosses game, Inkscape was used. I decided to use Inkscape for sprites as I wanted them to look cartoony to suit the target audience but also be scalable and a vector graphics editor was perfect for this. I used some existing knowledge of Inkscape to create these, but also had to learn more about how to use it throughout the project. Inkscape provides all the features that I needed to create the sprites. The three sprites are inspired by and took ideas from a resource that I found online [11].

The first sprite that I created is the bad bacteria, I used the colour red for this sprite. The reason why I decided to make it red is because this colour is usually associated with “evil” and so the hope was that by distinguishing each sprite with colours, the target audience would know just by appearance whether the bacteria is good or bad. Figure 4.1 shows the bad bacteria.

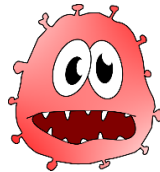


Figure [11] 4.1 Bad Bacteria

The second sprite is the good bacteria, and I decided to make this sprite like the bad bacteria but again, used colour to try and distinguish between the good and bad bacteria. For this sprite, I used a blue colour as this is usually related to “good” or “hero” (Ref tvtropes). Figure 4.2 shows the good bacteria.

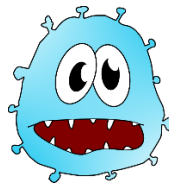


Figure [11] 4.2 Good Bacteria

The last sprite that I created which may or may not be used is the virus. I customized this sprite quite a bit in comparison to the bad and good bacteria sprites. I decided to create the virus with an orange colour to distinguish it from the other sprites. Figure 4.3 shows the virus sprite that I created.

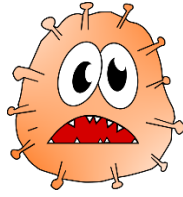


Figure [11] 4.3 Virus

### 4.1.2 Digital Booklet and Augmented Reality Application

Unity was the main program used for the development of my project. For the digital booklet and augmented reality application, I decided to use two different Unity applications.

The first application has the digital booklet and the second application has the markers and augmented content in. The reason for this is because I wanted the augmented reality application to be separate and for Android phones. The digital booklet is a windows executable. I also used a website called “Issuu” that can create an animated digital booklet if you provide a PDF of the different pages. This is just to give the user a different option as animation of pages was too hard to implement in Unity.

Unity provides all the tools necessary to create either 3D or 2D games. As I thought I would have games in the booklet, this was also a reason as to why I chose Unity. Although I chose Unity, as I got further into implementing the project I started noticing flaws with using it for a digital booklet but at that point it was too late in the development process. I will discuss these flaws more in-depth in chapter 7 and 8. Figure 4.4 shows me using Unity to create the booklet.

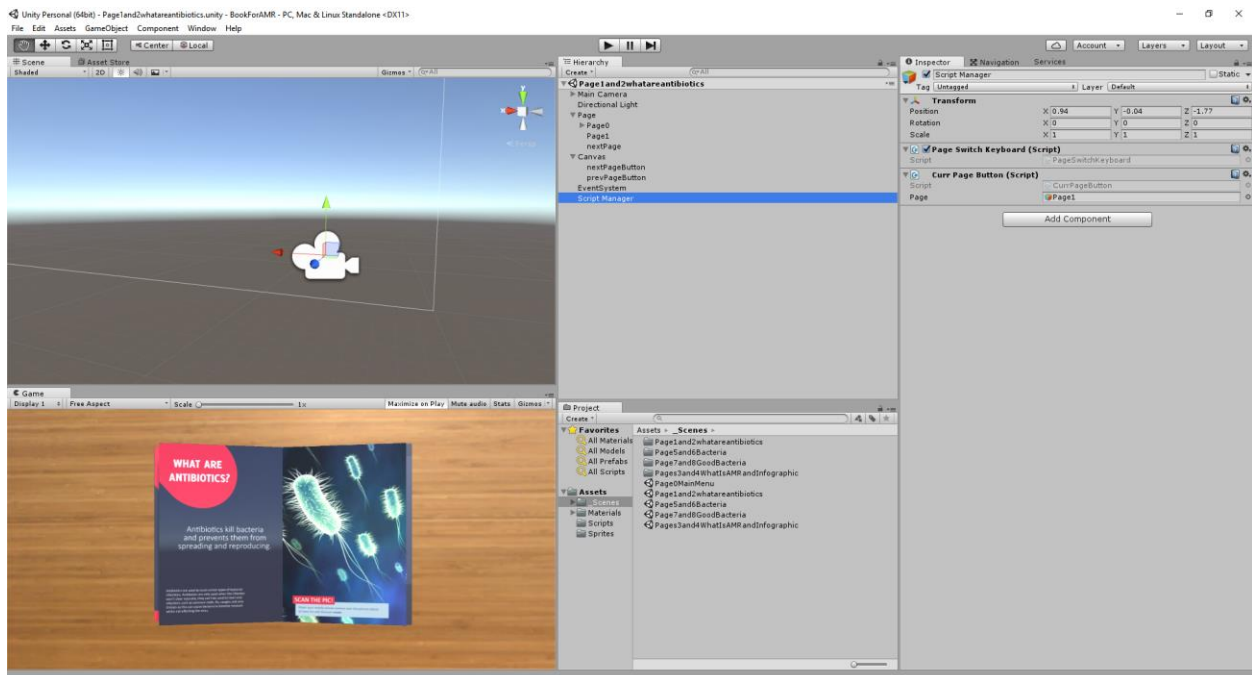


Figure 4.4 Using Unity to develop the booklet

The designs for each page was created using Adobe InDesign. This software was mostly chosen as I already had knowledge of how to use it in comparison to other similar software. Figure 4.5 shows me designing a page for the booklet in InDesign. The rest of the pages are designed in a similar way.

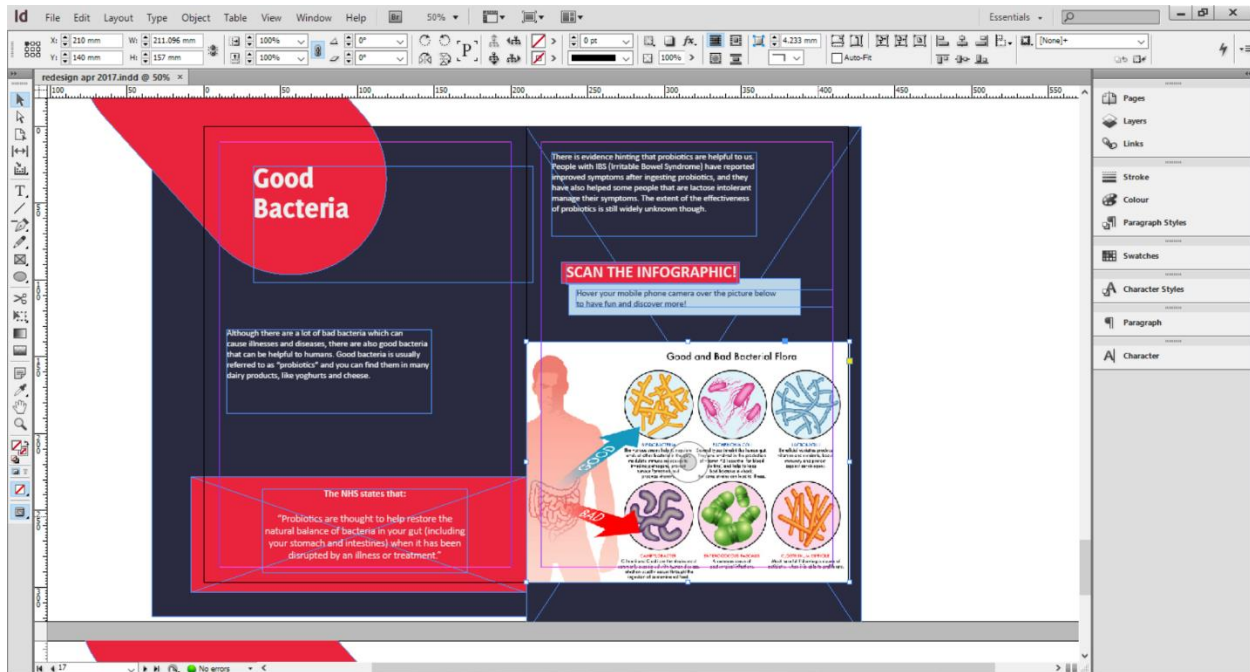


Figure 4.5 Using Adobe InDesign to design the pages

## 4.2 Developing the Booklet

In this section, I will go through each part of the booklet and explain how it was implemented and any problems that I encountered. Many of the pages of the booklet followed a similar implementation approach to look consistent and to try and make the augmented reality a focal point in backing up information.

### 4.2.1 Digital Booklet Navigation

I closely followed the originally planned design for the navigation in the booklet and this kept it simple and easy to use. In the case of the augmented reality application, I ensured that the user doesn't have to "change" to the next page in the Android application to be able to use the augmented reality. All they must do is progress through the booklet using the arrows on the computer and then the new augmented objects will appear above their appropriate marker, if they have the camera pointed at it. The navigation will be on screen always on the digital booklet, as shown in Figure 4.4.

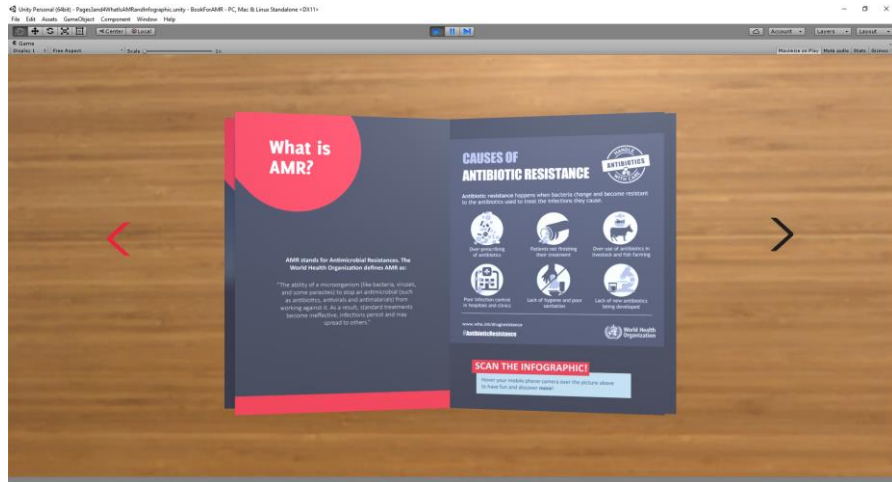


Figure 4.6 Simple User Navigation

The left arrow will disappear when the user is on the first page, and the right arrow will disappear when the user has got to the last page. This is to avoid confusion and to indicate that the user has gone as far left as they can. Figure 4.5 shows that when on the first page, the left arrow has disappeared.

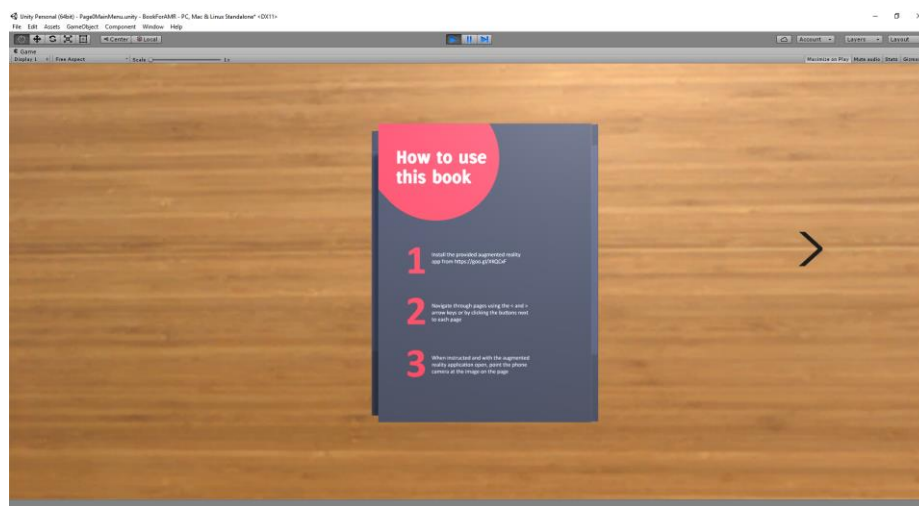


Figure 4.7 Mitigating user confusion in user interface

As planned in my original design, the user can use the keyboard arrow keys and mouse buttons to navigate through the booklet. An animation between pages is unfortunately lacking, however, as the limitations of working on 2D objects in a 3D environment made such a thing extremely difficult. Any scripts written are in C# in Unity, but I will mostly include pseudocode in the report. The script for navigating to different pages of the booklet is shown below, in pseudocode.

**changePage.cs**

method for nextPage() {

```

    Load the next page by getting the current scenes
    (Each scene is 2 pages, with exception of instruction page) position in the final build and
    adding 1

    (e.g Scene 3 will go to scene 4)
}

method for prevPage() {

    Load the previous page by getting current scenes
    position in final build and subtracting 1

    (e.g Scene 3 will go to scene 2)
}

Update method() {

    If (user pressing left arrow key) {

        Call prevPage method;

    }

    Else if (user pressing right arrow key) {

        Call nextPage method;

    }

}

```

I ensured that I kept the navigation code in one C# script file to try and lower the amount of scripts I end up with. When the user reaches the first or last page, the relevant navigation arrows are disabled in the Unity editor rather than in the script. It could have been done in the same script shown above, but was much easier doing it in the editor. Figure 4.8 shows the prevPageButton is disabled in the first scene. If the user went to scene 2, it would be enabled again.

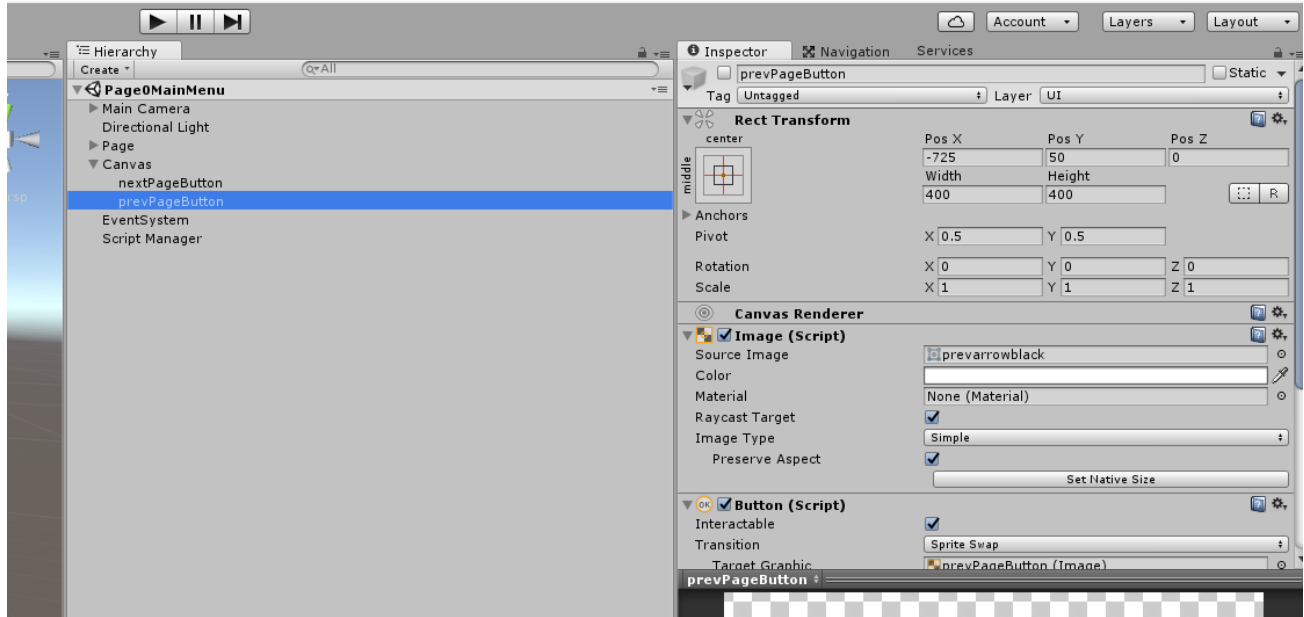


Figure 4.8 Disabled Previous Page Button

#### 4.2.2 Page 0 Implementation – Booklet Cover

The booklet cover is just a simple instructions page for the user and provides a download link for the application. I think this page is important so that users know what it is that they are doing.

Figure 4.9 shows the cover page of the booklet that I have implemented in Unity.



Figure 4.9 Instruction Page Implementation



This page was simple to implement, and just required me to create a material in Unity and apply this graphics file to the material. I used a 3D object known as a “Quad” in Unity to represent the pages and applied the material to this 3D object, which resulted in Figure 4.9.

#### 4.2.2 Page 1 and Page 2 Implementation – What are antibiotics?

Page 1 and page 2 also follow the initial design idea closely, and provide information to the user about what antibiotics are. The way this page was implemented is like every other page. However, unlike the first page, the quads are rotated at each side on angles by a small amount to make the pages look more like part of a booklet, as you can also see a bit of the next and previous pages sticking out. This will apply to every other page also apart from the first page.

Figure 4.10 shows the antibiotics page of the digital booklet. I am happy with how it turned out as I think it provides enough brief information on the left-hand side and leaves room for more information to be presented to the user with augmented reality.

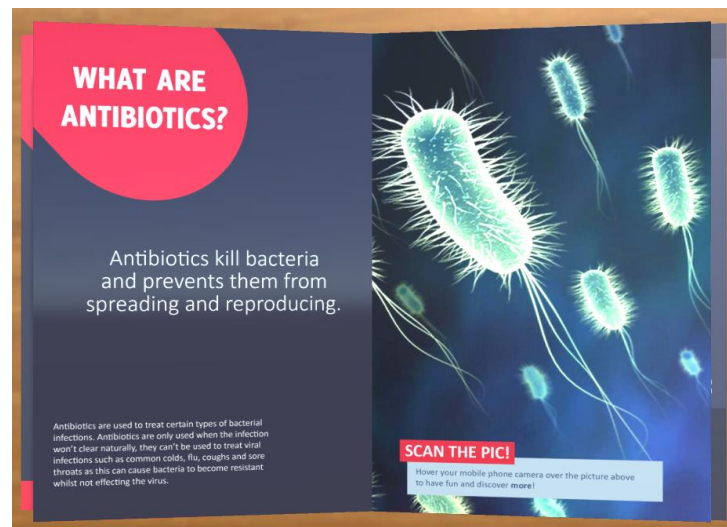


Figure 4.10 What are Antibiotics Page Implementation

Using the augmented reality application that the user can download, they can point the camera at the picture on the right-hand page like originally planned to augment videos and images. The augmented reality application is implemented using the Vuforia SDK. It provides most of the scripts and objects needed to create augmented experiences and so I didn’t have to add much extra functionality in terms of scripts, as they would have just been added for the sake of it.

Vuforia makes use of Unity prefabs, which is an asset type that can be used to store GameObjects that have different properties and components to them already. Vuforia uses a lot of prefabs for different objects, and it made development much easier. An important Vuforia prefab for my project is called the “ImageTarget”. This prefab is vital to every page in my booklet.

The ImageTarget prefab provides an object that already has some scripts attached to it. Some of the variables of these scripts are public and so can be changed in the Unity inspector on the object. In this case, I changed the public variables of the “Image Target Behaviour” script to the

actual marker that I want to augment my content on. Figure 4.11 shows that I have now created my first marker, which is the same picture seen on page 2.

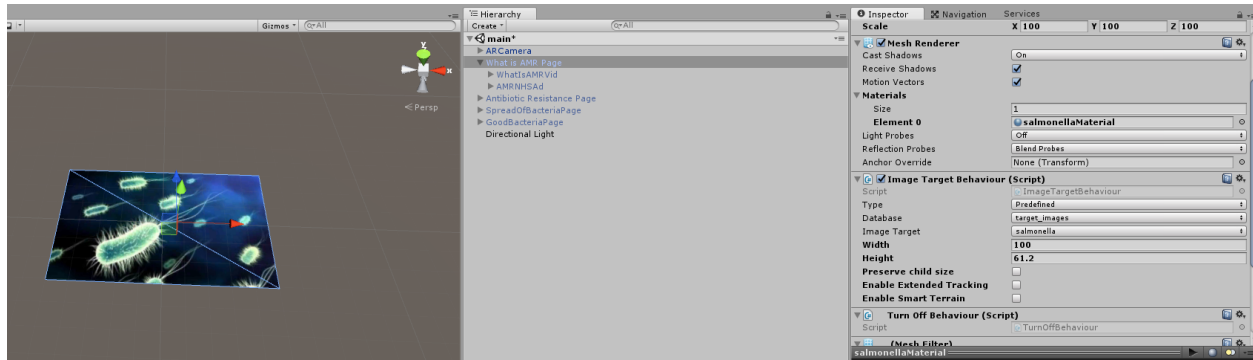


Figure 4.11 Implementing the marker for augmented reality

Now all that was left to do was to add objects above this marker. This is where another important prefab provided by Vuforia, called “Video”, came in handy. This prefab comes with video playback scripts already on them, I had to change the public variable for the video name on them to the name of the video that I have stored in a “StreamingAssets” folder. This was a little bit more awkward to implement, as at first I couldn’t get the video player to work in the augmented view. I fixed this by reading helpful documentation on Vuforia’s website and by changing a bit of the code. I added two videos above this marker which can be played by the user when they put the camera over the image in the booklet on page 2.

After this, I could run the augmented reality application on my Android device, and point the camera at page 2 on the digital booklet. Figure 4.12 shows the result of this. I can play the videos and pause them as much as I want. The videos have been carefully selected to ensure that they will keep the target audience engaged whilst still teaching them about the necessary material.

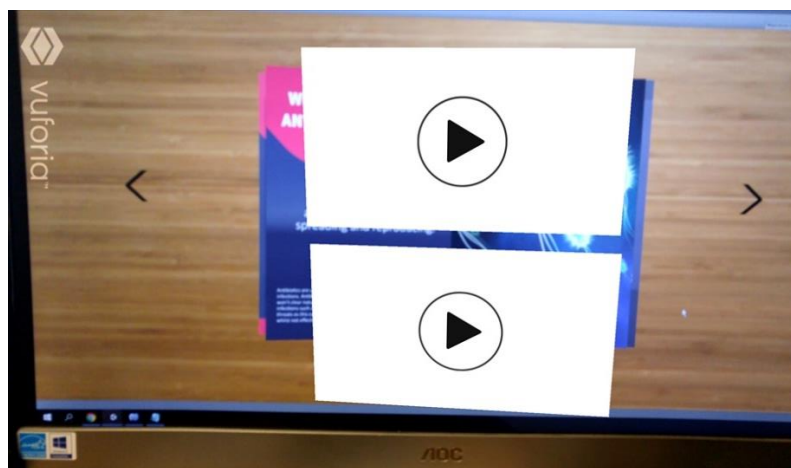


Figure 4.12 Augmenting Video

#### 4.2.3 Page 3 and Page 4 Implementation – What is AMR?

For page 3 and page 4 I have also followed the original design ideas quite closely. On the left-hand side, I felt like a quote from the World Health Organization was the best way to go about

giving a definition of AMR to my audience because they are a leading combatant of AMR. To avoid confusion, I mention to the reader what AMR stands for before giving them the definition. Figure 4.13 shows the implementation of pages 3 and 4. As mentioned in the previous implementation chapter for pages 1 and 2, this is implemented in pretty much the same way.

On the right-hand side, an infographic is used as the marker for the augmented reality and the user is told to scan it with their smartphone camera.



Figure 4.13 What is AMR Pages Implementation

As mentioned in the previous sub-chapter, ImageTargets are used on every page for the augmented reality application. The only difference between the ImageTarget between pages is the image chosen as the marker. On this marker, I have augmented videos (using the Video prefab) and more infographics to try and reinforce what the user has learnt and already knows about AMR. Figure 4.14 shows the augmented view over this page.

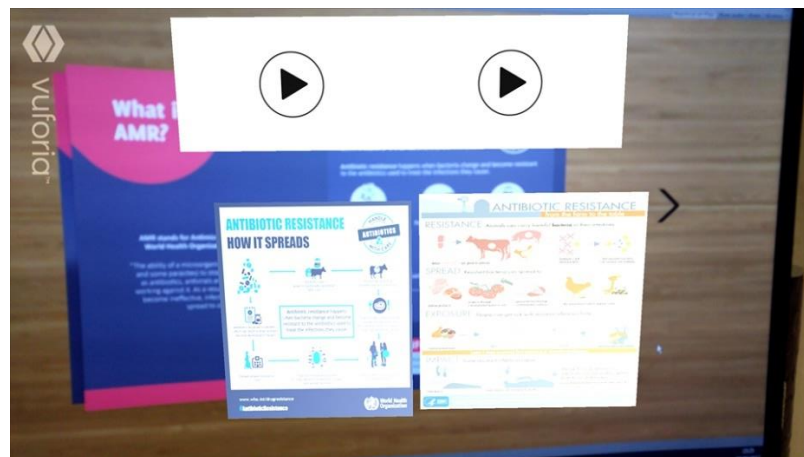


Figure 4.14 Augmenting Video – Page 3 and 4

It is possible for the user to move in a bit closer with the camera view to be able to read properly what is on the infographics. Figure 4.15 shows a closer view of one of the augmented infographics.

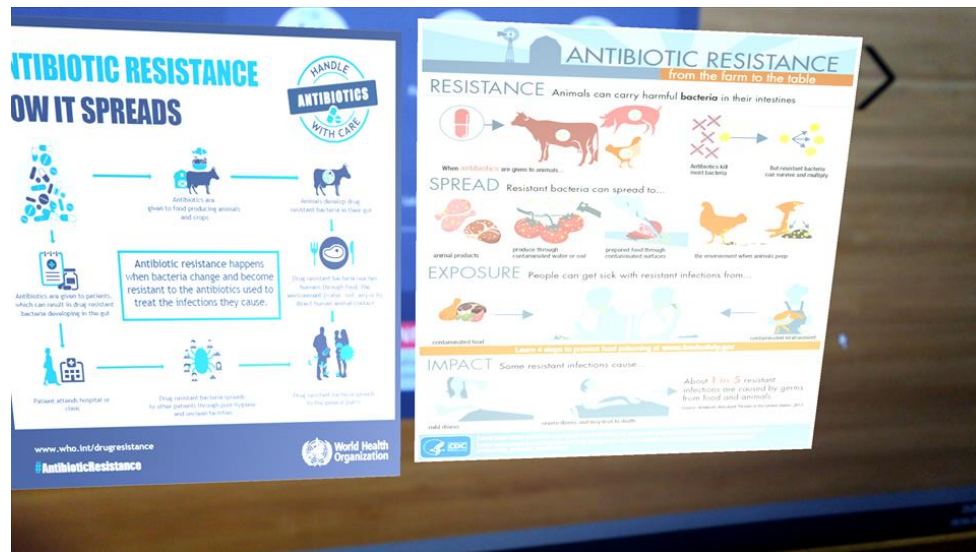


Figure 4.15 Close view of infographics

#### 4.2.4 Page 5 and Page 6 Implementation – Spread of Bacteria

Yet again I have stuck to the original designs that I came up with for these 2 pages. I think the amount of information on the left-hand side is just the ideal amount for the target audience. With helping improve the target audiences understanding of bacteria spread being a major focus point, it was important to have a bit more information on than some other pages. These pages were implemented in the same way as the previous pages. Figure 4.16 shows the implemented pages 5 and 6. The image of somebody washing their hands was a good choice for the marker for these pages as it is one of the most common causes of bacteria spread.



Figure 4.16 Spread of Bacteria Pages Implementation



As with the other pages, the augmented reality is implemented in the same way for pages 5 and 6 too. On this page, I have augmented quite an important video that demonstrates how bacteria can become resistant to antibiotics. I have also augmented another infographic that provides statistics about bacteria spread in an office environment. Figure 4.17 shows the augmented view of pages 5 and 6.



Figure 4.17 Augmenting bacterial spread content

#### 4.2.5 Page 7 and Page 8 Implementation – Good Bacteria

This page explains the information that I wanted it to when I originally decided to add it. I thought that young audiences already always get told about bad bacteria quite a lot in school and so thought good bacteria may be something they haven't even heard of or considered. Figure 4.18 shows the implementation of pages 7 and 8 in Unity.



Figure 4.18 Good Bacteria Pages Implementation

For this pages augmented reality, I attempted to add a noughts and crosses game. Although the concept was simple and in other mediums would be fairly easy to program, I ran into constant

problems. One of the main problems was with the “VirtualButtons” provided by Vuforia. These buttons are basically prefabs which act as buttons in the camera view of the augmented reality application. They are transparent so the user can’t see them but by putting their finger inside the camera view and tapping where they are then an event can be triggered. These VirtualButtons must be placed over “features” of the image, this is basically how Vuforia detects the markers. Figure 4.19 below shows the features that Vuforia found on the marker from page 8.

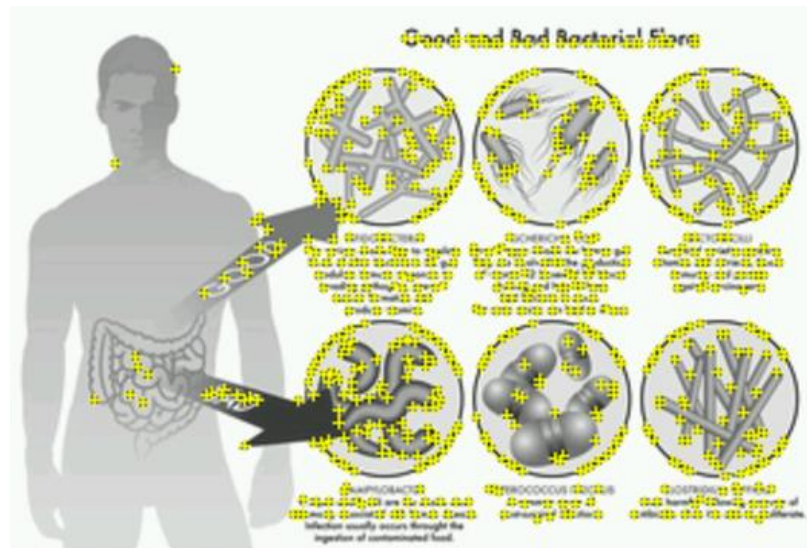


Figure 4.20 Features in the page 8 marker

Each of the bacteria pictures within the image should logically be good positions to put VirtualButtons as they have a good number of features, but when I tried pressing these buttons that I had placed over the bacteria pictures, some of the VirtualButtons would just not register my clicks. This unfortunately means that I didn’t manage to fully implement the noughts and crosses game that I had spent quite a while on. Figure 4.21 shows the idea I tried to implement.

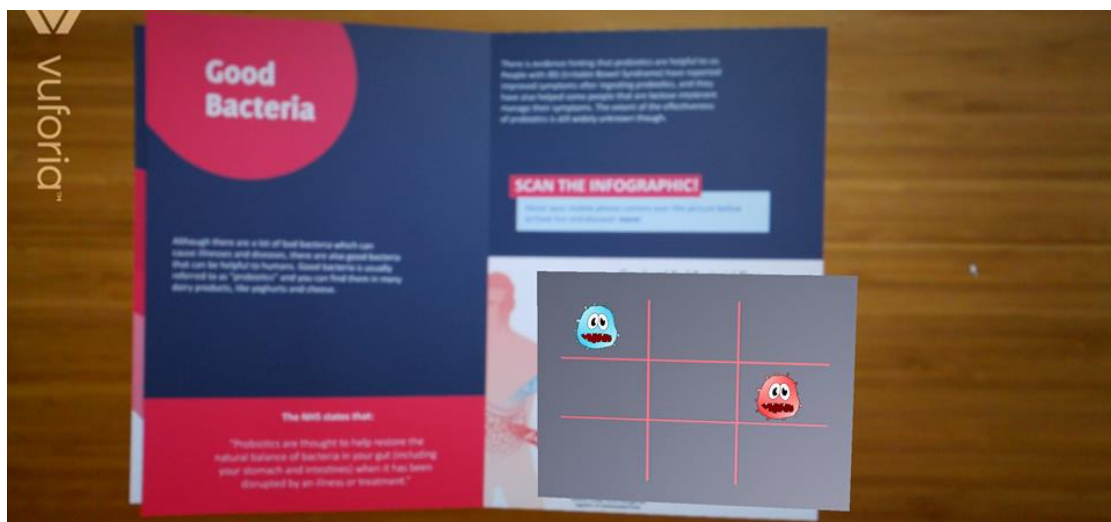


Figure 4.21 Attempted noughts and crosses game

## Chapter 5: The System in Operation

In this chapter, I will be discussing what the system is like to use.

### 5.1 Front Page



Figure 5.1 User's First View

Figure 5.1 shows what the user will see when they first load the executable file. The user is presented with simple instructions on how to use the booklet. The user must install the augmented reality application from the URL provided in step 1.

The user can then click on the arrow at the right-hand side of the screen to move onto the second page. Alternatively, they could quit the program.

### 5.2 Page 1 and Page 2

After clicking on the next page arrow on the front page, the user will arrive at page 1 and page 2 as seen in figure 5.2.



Figure 5.2 Page 1 and Page 2 of the Booklet

From here, the user can decide what to do. They can either skip the page, read the page and then move on, or fully engage with the page and read it and then use the augmented reality application and point it at the image on page 2. For the walkthrough, I will use the augmented reality application on the image on the right-hand side.

The user will have the augmented reality application open whilst navigating through the booklet. The user will then scan the picture with the camera on their smartphone and the augmentations will appear over the booklet as shown in figure 5.3.



Figure 5.3 Augmenting on Page 2

The user may then choose to watch these videos. They can pause them at any point. After watching the videos, they can then move on to the next page or if they choose to do so, watch the videos again. Alternatively, yet again, the user can choose to quit if they would like to.

### 5.3 Page 3 and Page 4

The next pages that the user will arrive on is page 3 and 4 which is all about what AMR is. Like the last pages, the user has a few options but again in this case the user will decide to use the augmented reality for demo purposes. Figure 5.4 shows the current view of the user.

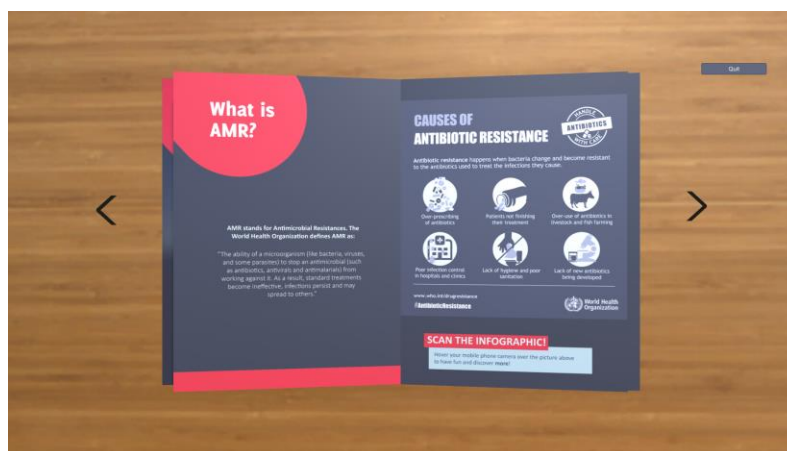


Figure 5.4 Page 3 and Page 4 of the booklet



They can then use the augmented reality application to augment objects above the infographic seen on page 4. Figure 5.5 and 5.6 shows the augmented content.



Figure 5.5 User's augmented view

Figure 5.6 Augmented Infographics

The user can choose to read the infographics and watch the videos. After that they can move on to the next pages.

## 5.4 Page 5 and Page 6

The user will arrive on page 5 and 6 which is about the spread of bacteria. The user can yet again decide what they want to do on this page, whether it be skip it or read it. Figure 5.7 shows the current view of the user.



Figure 5.7 Page 5 and Page 6 of the Booklet

The augmenting is similar on these pages to previous pages, and will display videos and infographics to the user which they can respectively interact with and view. Figure 5.8 shows the users view whilst using the augmented reality application.

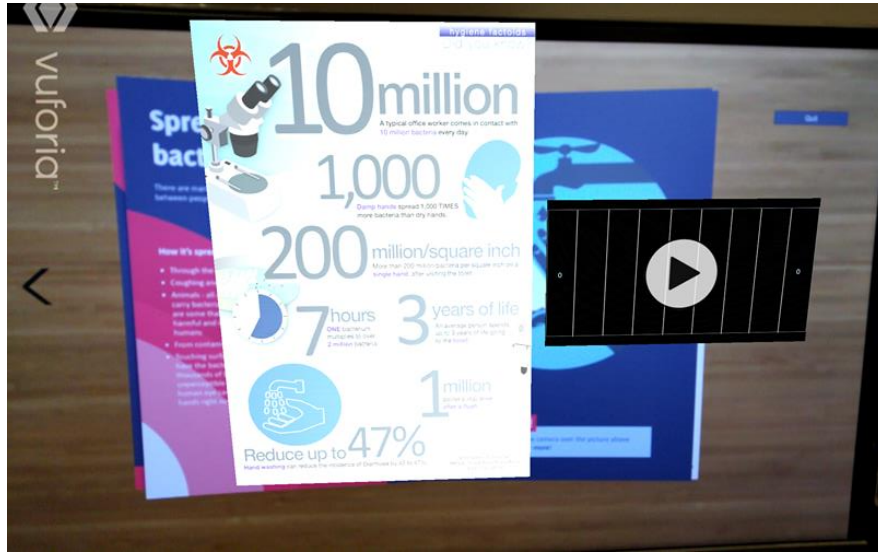


Figure 5.8 Page 5 and Page 6 Augmented Reality

The user can then move on to the next page, go back to the previous page, stay on the same page or quit the application if they would like to.

### 5.5 Page 7 and Page 8

When moving on to page 7 and page 8, the user will be presented with the pages about good bacteria. These are the last pages of the booklet. Figure 5.9 shows the current view of the user.



The user could then augment the image on the right-hand side page again if they wanted to, this time to be presented with a game. Sadly, as mentioned in the implementation section of the report, I encountered problems with Vuforia that prevented the game from fully working. These problems will be discussed in more depth in the testing and evaluation chapters. Figure 5.10 shows the augmented view that the user has.

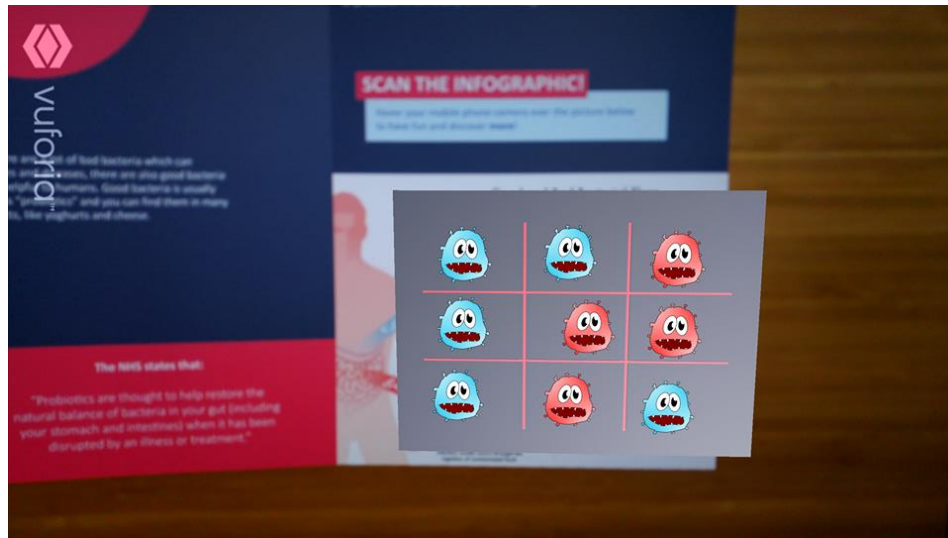


Figure 5.10 AR Noughts & Crosses Page 7 and Page 8

After this, the user can either quit the application or navigate back through the booklet by clicking the previous button arrow or by using the left arrow keys. The whole idea of the booklet is to introduce my target audience to AMR and teach them about bacteria spread without overwhelming them with too much information.

## Chapter 6: Testing and Evaluation

After having designed and implemented the project, it is important to test each part thoroughly to make sure that it works properly. I also actively tested everything regularly as I developed it, however, it's always best to check for edge cases that may not have been originally noticed. I will also test the performance of the windows executable for the digital booklet and the Android application.

Evaluation also goes somewhat hand in hand with testing and so I will also be evaluating choices that I have made throughout the creation of the digital booklet and augmented reality application.

### 6.1 User Interface and Navigation

It is vital in my booklet that the user interface and navigation buttons work properly, otherwise the user would not be able to progress through the booklet. I went through every page multiple times to ensure that no bugs occur either graphically or programmatically. By doing this, I did find that for the previous button on the last scene, I had forgotten to add the script to it to change pages, which I promptly fixed but could have missed if I hadn't tested. Figure 6.1 shows the button found with no script in its On Click() event.

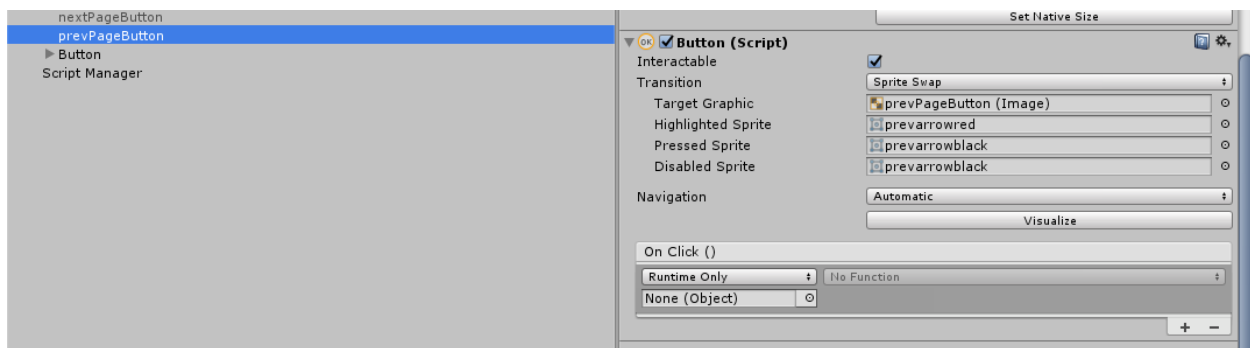


Figure 6.1 Previous button with no script attached

This was a simple fix and was simply a mistake rather than a major bug. Even though it was a mistake, this could have essentially made the booklet unusable once the user reached the last page, yet again showing why testing is very important. Figure 6.2 shows the simple fix.

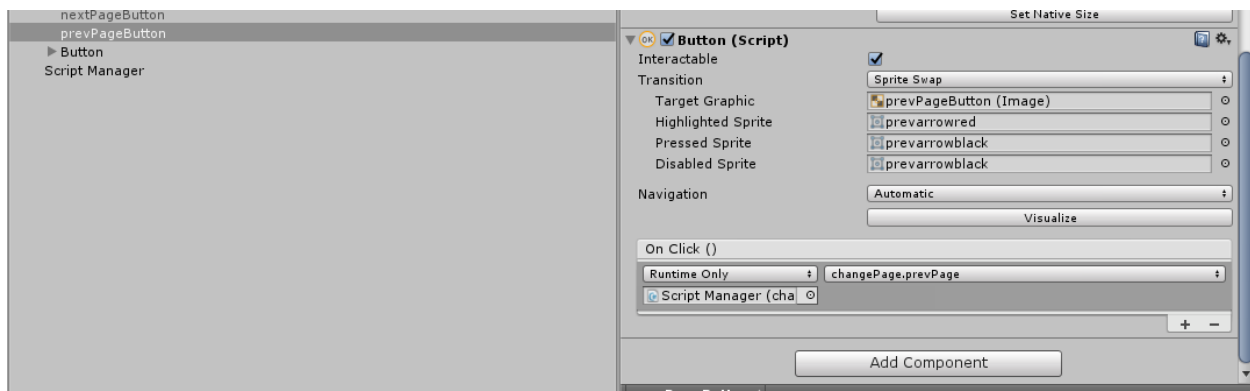


Figure 6.2 Previous button with script attached

Although the navigation and user interface is very simple, there isn't much need for a complex user interface for this kind of application and so I do think that the user interface for my booklet does achieve its aim of being easy to use and not confusing to the users. I think the buttons to change page are a reasonable size and that it is clear as to what they do. Simplicity is sometimes the best approach, and in this case I think it is.

The simple navigation also helped me in providing the user with control and freedom, which is one of Nielsen's Heuristics. At each point in the program, the user can decide what they want to do next, and if they accidentally make a mistake by going to the next scene, then they can undo this by pressing the previous button to go back.

I also had to test the quit button that is in the top-right hand corner of the game screen. The only issue that could have arisen with this button is yet again not having applied the script to it. After thoroughly testing the button, no problems were found with it and you can quit the application from any page. I think that the addition of a quit button was a good idea as in my user requirements, I mentioned that the user should be able to exit the application easily and at any point.

## **6.2 Booklet Pages**

As the booklet pages are all implemented the same way, I decided to put them all together when discussing the testing of them.

The most important testing method I used on the pages in the booklet was a form of testing known as "Alpha Testing" (Reftutorialspoint).

I checked for spelling and grammatical mistakes on the pages, as this could cause huge problems for my aim of teaching the user about bacteria spread and AMR. If there are spelling or grammatical errors throughout the pages, the user could either get confused or some may even lose trust in what it is that they are reading.

After testing the pages thoroughly, no spelling mistakes or grammatical errors were found on any page.

All the augmented objects apart from the noughts & crosses game work properly. After extensive testing with the positioning of the VirtualButtons, unfortunately no solution could be found for this as it is a limitation of the Vuforia libraries VirtualButton prefab.

Overall I am pleased with how the pages turned out. In the design chapter I discussed how I wanted to use Nielsen's Heuristics in certain ways to achieve a good user experience for my booklet. I think with the consistent design of the pages I managed to provide the users with feedback about what is going on, based on the content of the pages. I also met another one of Nielsen's Heuristics, which is to always speak the user's language. The information on each page should be easy enough for my target audience to understand.

Lastly, taking into consideration the user requirements that I set out in the design phase, even without the game fully working on page 7 and page 8, the booklet still meets nearly all of the user requirements set out in that chapter.

## **6.4 Performance Testing**

In this section I will discuss the performance of the windows executable and the Android application.

### **6.4.1 Booklet Performance**

The booklet performance is generally quite good. Navigating between pages is very smooth and is almost instantaneous. The only thing lacking is an animation of the pages, which I think could have enhanced the feel of this being presented as a booklet. The initial opening of the executable for the booklet only takes around 3-5 seconds to get to the first page of the booklet, and this is partly due to the Unity splash screen.

### **6.4.2 Android Application Performance**

The Android application performance is also relatively good. When tapping the app on my smartphone, it takes around 4-5 seconds to load up. I have tested it on two different devices also that are not as good as my main smartphone and it was also around 4-5 seconds on them. In terms of the augmented reality, the quality of augmentations mostly depend on the marker and its features but when you hover the camera over every page, the marker is recognized very quickly and almost instantaneously the augmented objects appear.

By testing it on multiple devices and it performing just as well, I think it will also work on many other Android devices too.

## Chapter 7: Conclusion

### 7.1 Review of Aims

In the introduction of my report, I created some aims that I wanted to meet with the creation of my digital booklet. These aims were:

- Improve teenager's general understanding about bacteria and how they spread
- Introduce and explain the concepts of antibacterial resistances
- Help in teaching teenagers how to prevent the spread of bacteria
- Enhance the interactivity of learning by using augmented reality
- Create a booklet with information about antibacterial resistances and bacteria with augmentable images inside

The whole project has been focused on ensuring that these aims are met as best as they possibly can be. I themed the pages of the booklet in a way in which I could simply introduce topics such as bacteria, how it spreads, how to prevent spread and AMR but then could provide more information using augmented reality. The augmented videos and content is meant to be a reinforced way of learning, backing up what the user has read on the pages. Overall, I do feel that my project has met all of the original aims that I had intended to as all the content in the booklet is related directly to my aims. The only aim that I would want to provide a better solution to, is the interactivity aim, as I wasn't able to add a game that worked well.

If I did the project again, I think I would try and do something different completely. Augmented Reality has been hard to work with, as it still very much feels like it is in its infancy, or at least the freely available libraries do. This isn't necessarily a bad thing though, as I can see the potential that augmented reality has, and think it can be a great tool in education in the future.

### 7.3 Problems Encountered

I encountered many problems throughout the development of my project and most of them were based around one of the most important aspects; the augmented reality.

I tried many different augmented reality libraries but all of them had limitations that could not be overcome. One of my biggest disappointments was that I could not add an augmented reality game that worked to the booklet as I originally wanted to, as any idea that I came up with always had to have its gameplay scaled down greatly to the point where it wouldn't be fun for the user. Like mentioned in previous chapters, even a noughts & crosses game couldn't be implemented because the VirtualButton object provided by Vuforia was temperamental and in a few cases, unresponsive.

Another problem that I encountered was with Unity. As I got further along into the development of the booklet, I started to realize that for my type of project, there were probably better alternatives than Unity that would have made it easier to create a booklet and probably even add animation. Simple websites like "Issuu" just need you to upload a PDF of images and it will create an animated booklet for you. At the same time, however, I did like the challenges that Unity provided.

## **7.4 Future Work**

I don't think I would change much when it comes to the design of the pages themselves, but I would try and mess with the noughts & crosses game a bit more to try and find a solution to it. I think the only solutions though would have been to find a new marker for the page so that I could spread out the VirtualButtons more, or use a different augmented reality library which would be a major decision to make. I would also love to try and add other games that use augmented reality.

Additionally, in terms of the augmented reality aspect of my project, I would have loved to implement augmentations of 3D models and would try to incorporate that if I had more time. I did briefly try to do this but learning to use Blender or Cinema 4D isn't something that can be done quickly.

Future work would also allow me to add more pages to the booklet. An example idea for a page that I could add would be one that is focused on a specific type of bacteria.

## **7.5 Lessons Learned**

During the project, I learnt a lot of lessons. I'm glad I did the project for this reason as even though I was disappointed with not being able to implement a game, I feel like I learnt more about the current limits of augmented reality, which helped me when it came to the other augmentations.

I also improved my C# skills and general Unity skills. Before the project, I had never done C# before and had only used Unity briefly in the past and so the project gave me the opportunity to learn new skills that I can use in the future.

Time management was also tough for me to get right at the beginning of my project, but I feel that as time went on I had a good balance going between doing the project and doing other work from other modules.

I have also learnt a lot about bacteria, AMR and bacteria spread and prevention, which I am thankful for as it is another interest area of mine and so mixing computer science and biology together was the perfect project for me.

With all that said, and with all my problems of being ill throughout the second term aside, I genuinely feel like I have gained a lot out of doing this project. Delving into the world of augmented reality and being able to develop augmented experiences was an amazing experience and extremely fun. I think with the skills I have gained from my project; I will approach any future projects with excitement and confidence.



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