Final Year Project Report

Design and Development of an Augmented Reality Learning Experience for Children with Autism

Project Number: A2072-20

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Academic Year: 2020/2021

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Abstract

About one in 160 children worldwide are affected by the Autism Spectrum Disorder (ASD). Although there are special schools and communities available to help these children and provide them with quality learning experience, not all have access to this network. Also, many of them are turned down by regular schools and thus are missing out significantly on their education. It is essential that children with autism have access to quality education, that is catered to their learning styles. In fact, the provision of quality education for all is such an important issue that the United Nations has highlighted it as one of the 17 Sustainable Development Goals to be accomplished by the year 2030.

One of the rising technologies that has been shaking up the landscape in recent years would be Augmented Reality (AR). With the use of AR, consumers are able to superimpose images onto their view of the real world through AR devices or even just a smartphone.

Therefore, by developing an Educational AR application, we are able to provide the children with autism an access to high-quality education that caters to their learning style. This project looks into developing an AR application for iOS devices, *using Unity 3D*, that would introduce an educational game for its users. This application would give an opportunity for its users to have equal access to Quality Education and hopes to break the stigma that surrounds ASD.

Acknowledgements

I would like to express my gratitude to everyone who have helped, encouraged and supported me throughout the course of this project.

Firstly, I would like sincerely thank my project supervisor, Assoc Prof Gwee Bah Hwee for supporting and encouraging me as I took on this project. Thank you for all your insights, advice and feedback provided. I sincerely appreciate your guidance. Thank you for taking the time out of your busy schedule to discuss the project with me.

Secondly, I would like to thank Ms. Sathiyamoorthy Puhaneswari from EEE Outreach for your support and encouragement as well. I deeply appreciate all the help and feedback provided thus far.

Lastly, I would like to thank my family and friends for their consistent love, support and encouragement.

Acronyms

3D	Three-dimensional
API	Application Programming Interface
AR	Augmented Reality
MR	Mixed Reality
OT	Occupational Therapist
SDK	Software Development Kit
UI	User Interface
VR	Virtual Reality
XR	Extended Reality

List of Tables and Figures

Chapter 1 – Introduction

1.1 Background

For many decades now, education is used by society to deliver important knowledge and skills. It helps to reduce poverty, and blur geographical boundaries. In fact the provision of quality education for all is so important that it has been highlighted as one of the 17 Sustainable Development Goals to be accomplished by the year 2030 by the United Nations as shown in Figure 1.

Figure 1: UN's 17 Sustainable Development Goals

This is because there are many children worldwide who are lacking access to basic education. This includes, children living in poverty, children with physical disabilities, and children with mental disorders. Although many organizations are helping children living in poverty and children with physical disabilities, there is not much being done for children with mental disorders and one of the most affected group would be children with the Autism Spectrum Disorder (ASD).

According to the World Health Organization, about one in 160 children worldwide are affected by ASD [1], and many of these children have been denied access to education simply because either they do not have access to special needs school or they have been turned down by regular schools for not having the resources to teach children with ASD [2]. In addition, parents are also struggling to teach their children since they do not have the right resources and skills to deliver the content in an effective way. [3]

1.2 Motivation

Due to this, children with ASD are missing out significantly on their education leading to other problems in the future such as low employment opportunities [4] and a burden on the families to provide for them. Thus, it is essential that these children have access to quality education, that is especially catered to their learning needs/styles. From previous researches, it has been found that children with ASD prefer a more flexible schedule with interactive teaching methods [5]. Although current autism-friendly schools are using basic interactive mediums such as physical games to conduct lessons, they can make use of new technologies to develop a more effective, efficient and personalised learning experience for children with ASD. This would be through the use of Augmented Reality (AR).

AR is one of the rising technologies in recent years. It superimposes computer graphics onto our real world, allowing an individual to interact with the real world in an interesting way [6]. Thus, AR technology has been heavily adapted in various industries including the Educational Sector as shown in Figure 2.

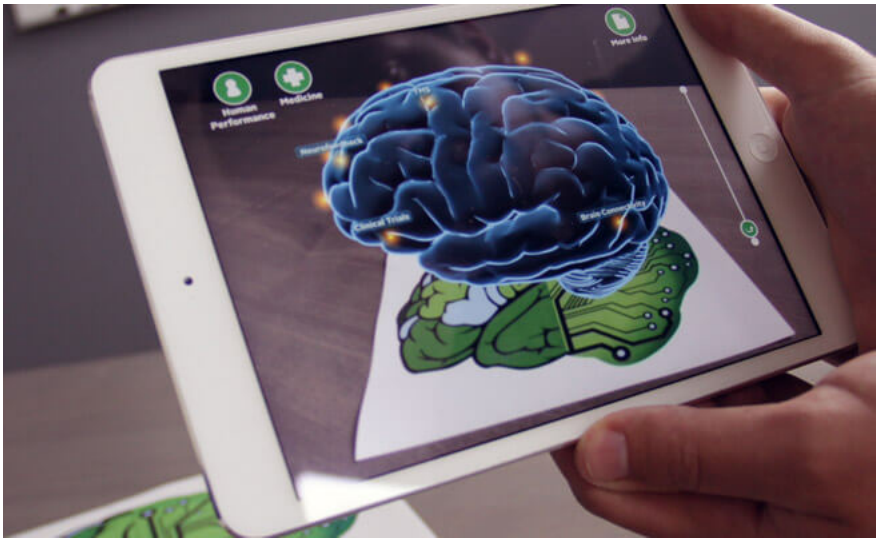


Figure 2: Example of AR being used in the Educational Sector

In previous research conducted, it has been found that the interactive environment created using AR brings about great benefits to students such as increased content understanding and long-term memory retention [7]. Also, with AR one can create a flexible learning schedule that would greatly improve the delivery of content [8].

Although the previous studies have developed an effective framework in analysing the benefits of using AR as an interactive educational medium, they have failed to explore the idea of adapting this AR technology to improve the learning experience of children with mental disorders such as ASD. Thus this project is important since it is able to explore and analyse how an AR educational application can enhance the learning experience of children with ASD.

1.3 Objectives and Scope

The main objective of this project would be to use Unity3D, which is a game development platform, to design and develop an AR educational application for iOS devices that would create a positive learning experience for children with ASD. The scope of this project will be that it will specifically focus on early-stage education for children between the ages of 4 to 6 years old.

1.4 Organisation of the Report

The purpose of this report will be to highlight the progress made on the application thus far, discuss the challenges encountered and outline the future work remaining for the development process. The report is structured as follows:

Chapter 1: Introduction of Background, Motivation, Objective and Scope

Chapter 2: Literature Review consisting current AR Applications, usage of ARKit in Unity 3D and research on the Learning Styles of Children with Autism.

Chapter 3: Overview and Features Implemented in the Colour Identification Topic

Chapter 4: Overview and Features Implemented in the Fruits Identification Topic

Chapter 5: Overview and Features Implemented in the Emotions Identification Topic

Chapter 6: Explanation on Application's Overall Set-Up and Usage

Chapter 7: Conclusion, Challenges Faced and Recommended Future Work

Chapter 2 – Literature Review

2.1 Augmented Reality Applications

In order to better understand the features that can be incorporated in the AR Educational Application, it was important to research on some of the current AR/VR educational and non-education applications that are already available on the market.

2.1.1 EON Reality AR Application

EON Reality is an multinational VR and AR software developer company that was founded in 1999. Some of its well-known products include the 'EON AVR Platform', 'Creator AVR', 'Virtual Trainer', and 'AR Assist'. The company recently released a free XR application called 'EON-XR' that uses VR, AR and MR technologies in order to create an interactive remote education and training experience as shown in Figure 3.

This application provides a variety of features that includes an audio tutorial that goes hand-in-hand with the AR animations of the object. In addition to this, the users can also directly interact with the AR animation to simplify and see the skeleton of the object that is bring presented.

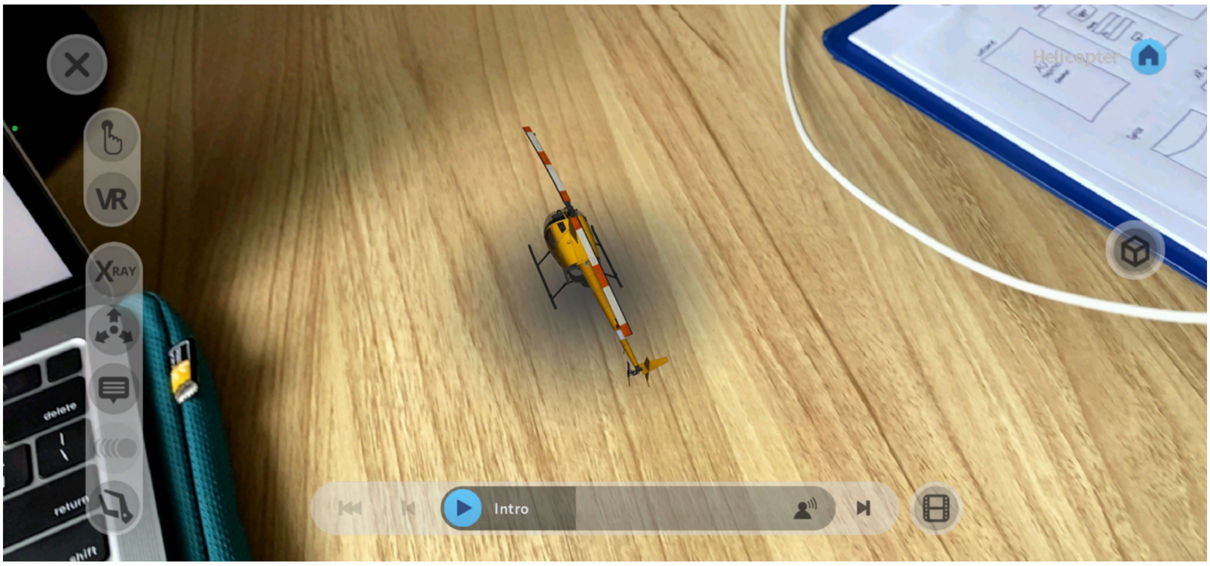


Figure 3: EON Reality's EON-XR Application

2.1.2 InspiritVR Application

InspiritVR is a start-up company that has recently developed and released their Virtual Reality Educational Application. Their application consists of experiments in the core sciences that can be carried out by the users as shown in Figure 4. Although this company mainly uses VR technology instead of AR, some of the features used by InspiritVR can be adapted to the AR Educational Application as well.

Some of these features would include the incorporation of quiz sessions in order to test the content learned by the users and the gamification of the entire learning experience in order to keep to users interested and engaged throughout.

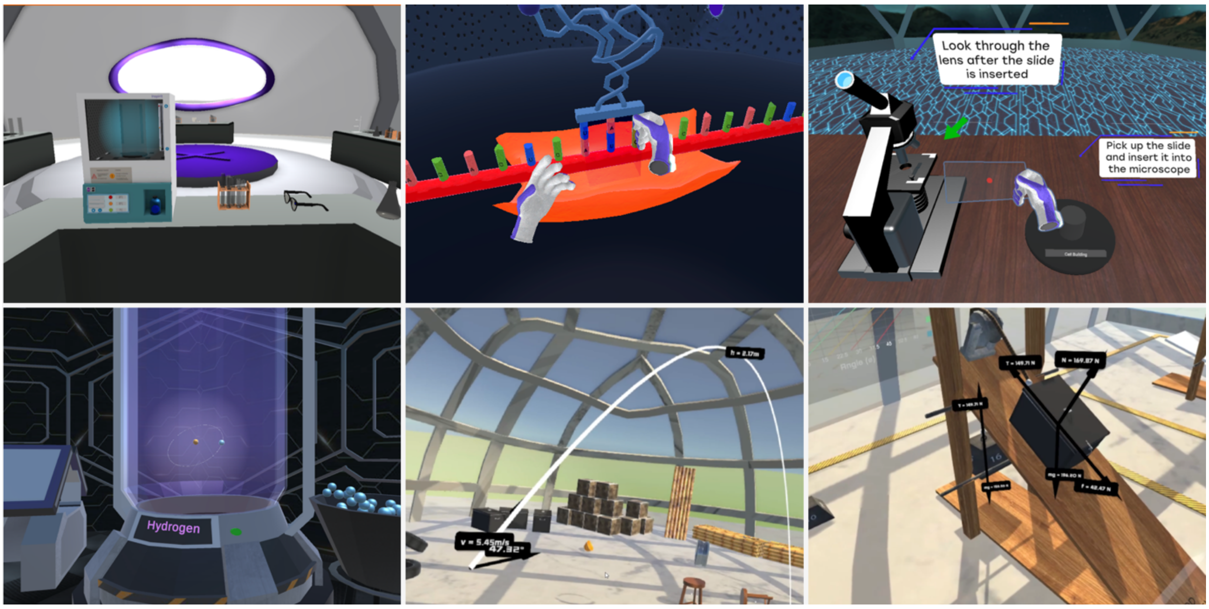


Figure 4: InspiritVR's Educational Application

2.2 ARKit in Unity 3D

One of the most recent software that has been adapted by Unity3D for the development of Augmented Reality games and applications would be the ARKit. ARKit integrates iOS device camera's and motion features in order to produce AR experience for the users. ARKit simplifies the task of building an AR function in Unity3D by offering various features such as device motion tracking, camera scene capture, and advanced scene processing. The ARKit XR Plugin can be installed within Unity3D to activate the features provided by the ARKit.

The most recent version of the ARKit, which would be ARKit XR Plugin 4.1.0, provides a multitude of features which are listed as follows;

- Device localization, and Session Management
- Horizontal and Vertical Plane Detection
- Point Clouds and Pass-through Camera View
- Light Estimates, Anchors, and Hit Testing
- Image, Object and Participant Tracking
- Environment Probes, Meshes and Occlusion

2.3 Research on the Features Needed

Before designing the AR Educational Application, it is important to understand what are the features that should be included in the Application; and to know the features that should be included, it is essential to deeply understand the different learning styles of children with ASD and methods for long-term memory retention.

2.3.1 Different Learning Styles of Children with ASD

Children with ASD have abnormal intellectual and academic skills profile that should be properly analysed and aligned to during the delivery of the curriculum. Although they each have their strengthens, weaknesses and preferences, there are some common learning-style preferences that has been identified among children with ASD. These preferences have been grouped into five main categories which are Environmental, Sociological, Physiological, Emotional and Psychological as shown in Table 1. [9]

Environmental	**Sociological**	**Physiological**	**Emotional**	**Psychological**
Environment with background noises Bright light Warm Temperature Structured environment	Peer collaboration One-to-one Interaction Small group settings	Preference not to snack Learn best at specific times of the day (individual preference) Materials presented in diff. perceptual modalities	Strong need for structure and authority Motivated by others More multi-task persistent Require frequent breaks	More global learners Develop an understanding of the concept than the details

Table 1: Categories of Learning Preferences for Children with Autism

2.3.2 Methods of Long-Term Memory Retention

In addition to the delivery style of the content, long-term memory retention is also an important aspect in education. In order to ensure that the students are able to remember the knowledge that has been taught to them, they should adapt to the various methods of long-term memory retention that would work for them. These methods include reading, audio-visual content delivery, demonstration, discussion, practice and finally teaching others [10]. The average retention rates for the various methods are shown in Figure 5.

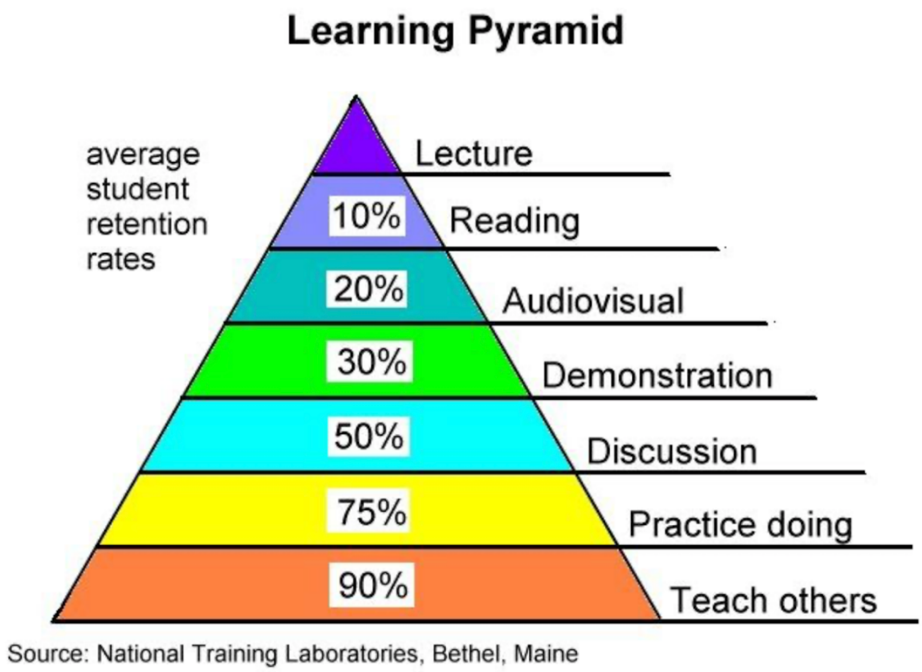


Figure 5: Average Student's Retention Rate Pyramid

2.3.3 Hearing from Autism Caregivers

Apart from online research, it was also extremely important to understand the needs of children with autism directly from their parents or caregivers. Thus one of the main ways used to research out and interact with these individuals was through online communities such as Facebook and Telegram groups. A survey was sent out in these communities to understand if this AR Education Application would be welcomed by parents and caregivers of children with autism and the response to that was mostly positive as shown in Figure 6.

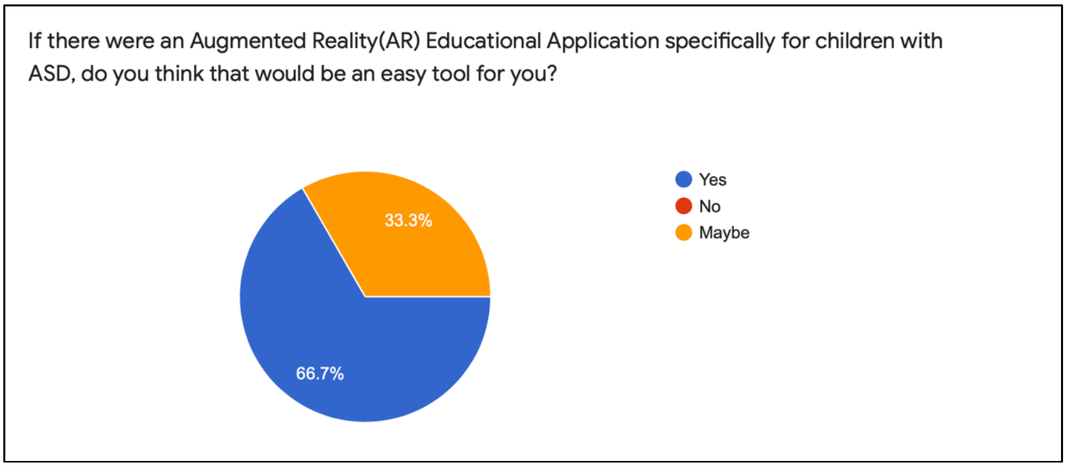


Figure 6: Response from caregivers regarding AR Application

This proofs that the AR Educational Application solves a real problem and that there is a need for such an application among this community. In order to further understand the process of teaching children with autism, an virtual interview was conducted with Ms. Rinnitha Arumugam who works as a teacher in Pathlight. The interview helped in providing a deeper understanding of the teaching methods and the learning styles that can be used for the development of the application (Transcript of Interview included in Appendix). Apart from providing many valuable feedback, Ms. Rinnitha also shared the importance of introducing different emotions to children with autism at a young age which in turn became an inspiration to develop the Emotions Identification Module (explained further in Chapter 5).

2.3.4 Important Features for AR Application

Therefore by researching both on the different learning styles for children with ASD and the various methods of long-term memory retention, the following features would be included in the AR Educational Application. These features would make the application more efficient in tackling the needs of children with ASD and enhancing their overall learning experience.

1. Have a structured learning plan for topics covered
2. Have various mini tasks for each major topic
3. Have a simple and concrete language when communicating
4. Ensure that the concept is presented as a whole rather than the details

2.4 Designing of the Wireframes

After analysing and finalising on the features that is needed to be incorporated in the application, a simple wireframing of the UI of the application was designed using Figma which is an online vector graphics editor and prototyping tool a shown in Figures 7 and 8. The wireframes incorporate some of the important features that should be included in the AR Educational Application.

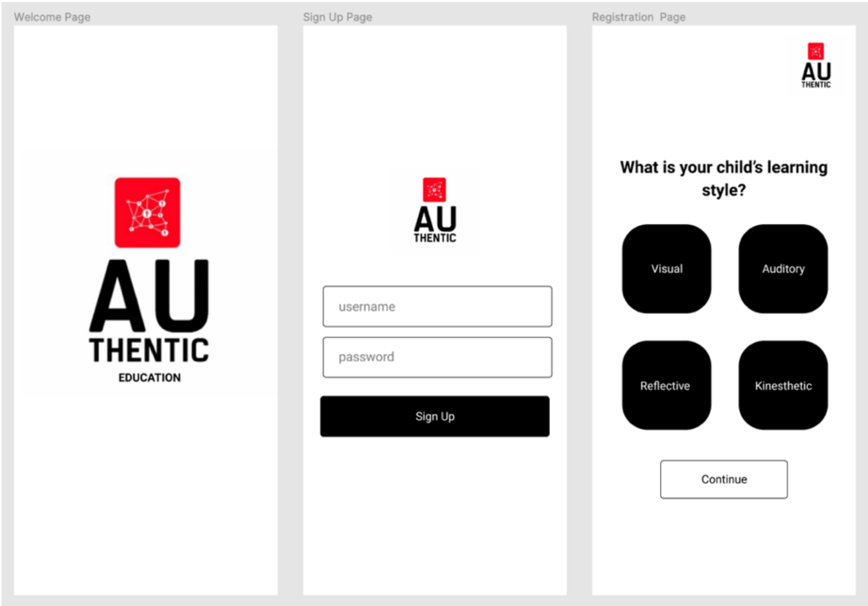


Figure 7: Wireframing of the AR Educational Application - 1

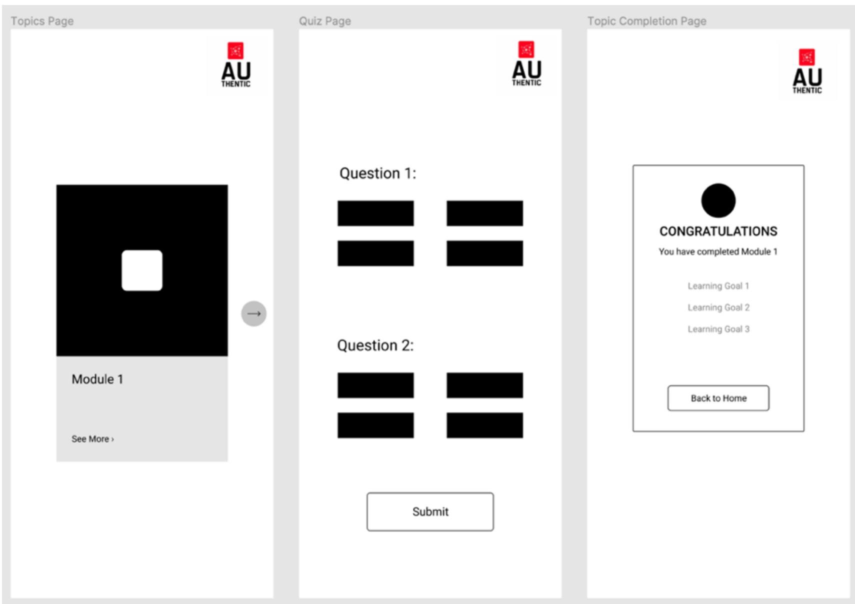


Figure 8: Wireframing of the AR Educational Application - 2

2.5 AR Kit Set-Up

In order to develop an AR application using Unity3D, ARKit must be installed and set up as shown in Figure 10. This can be done by clicking on the top menu bar in Unity3D and selecting Window > Package Manager > ARKit XR Plugin > Install. Once this is completed, the ARKit will be available for use within the Unity3D project as shown in Figure 9.

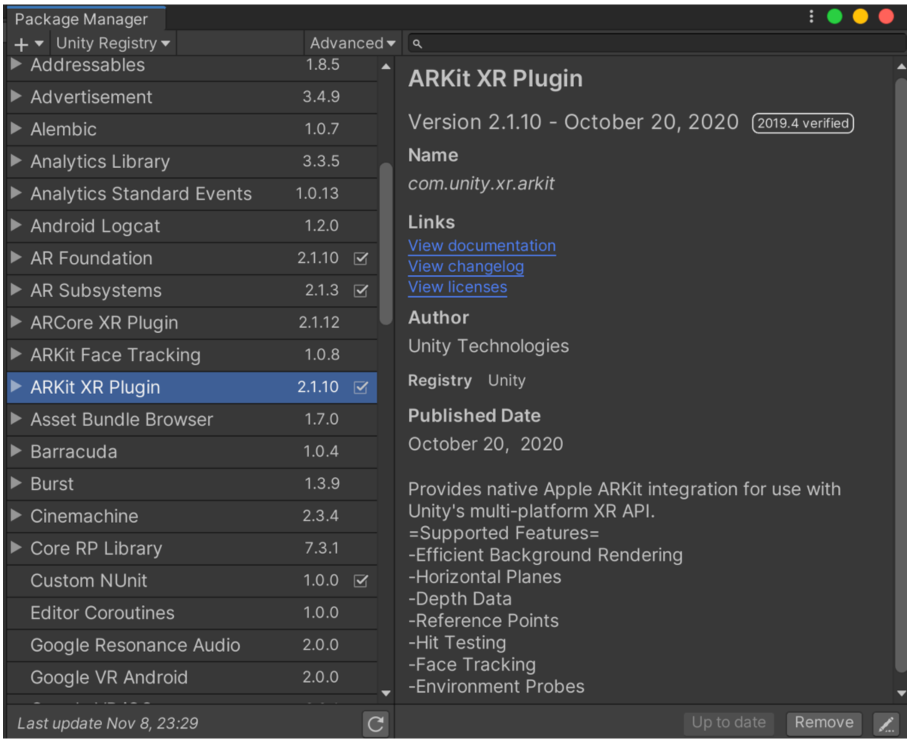


Figure 9: ARKit XR Plugin in Unity3D

Chapter 3: Colours Identification

3.1 Overview

Introducing colours is one of the main concepts under early-stage education for children in general. Thus it is important to teach the identification of various colours for children with autism in a young age as well. Since introducing many different colours at the same time would be extremely confusing for children with autism, it is highly recommended to first start off with the three primary colours: Red, Blue and Yellow.

This is because, colours such as Red and Orange for example are close to each other and it would be difficult for children with autism to identify and distinguish them. Whereas the three primary colours are a lot more distinct from each other which makes it a good starting point [11].

Therefore in order to make the identification of colours more fun and exciting, the activity is integrated with a game where the child will have to shoot balloons of a specific colour as instructed by the caregiver or occupational therapist (OT).

3.2 Spawning Feature Implementation

The first step of the Colour Identification Game would be to allow the balloons to appear in the AR format when launched from an iOS device. Therefore, three 3D models of the balloon prefabs in the colours red, blue and yellow were created for this game as shown in Figure 10. Secondly, three different positions were marked in the game space of the iOS device which is where the prefabs will be spawned upon trigger.

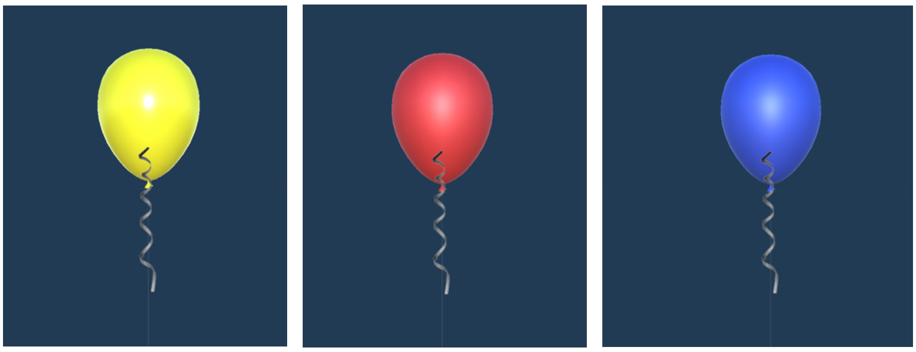


Figure 10: Prefabs of the coloured balloons used

A C# Script, *Spawn Script*, has been written in order to ensure that the balloon prefabs are cloned and spawned in the marked positions continuously. The Spawn Script ensures that the balloon game objects will be spawned continuously every 2 seconds in an random manner on the positions that have been marked previously. This is shown in the Figure 11.

Figure 11: Continuously spawned balloon in the game

3.3 Shooting Feature Implementation

Once the spawning of the balloons are successful, the next step of the game would be to give the user the ability to shoot the AR balloons through the iOS device; thus introducing the shooting feature.

A separate C# Script, *Shoot Script*, has been created to tackle the functionalities of the shooting feature. This script contains the Ray Cast Hit function and Destroy function to mimic the shooting of the balloons. When the Ray Cast Hit position collides with the position of the balloons, the balloon would be destroyed upon clicking on the 'Shoot Button' on the screen.

In addition to this, a Smoke Game Object and a Balloon Pop audio clip were also added to the game to give the user a more wholesome balloon shooting experience as shown in Figure 12.

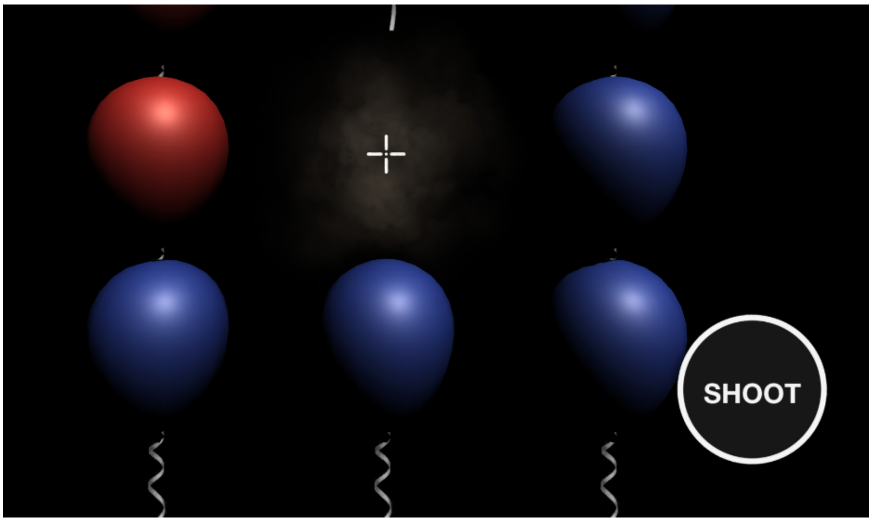


Figure 12: Smoke initiated as the balloon is popped

3.4 Scoreboard and Timer Implementation

A Scoreboard and a Timer Slider were also implemented for an improved gamification experience for the children with autism. The score board keeps track of the points earned as each balloon is shot in the game. The score is cumulative with 2 points allocated to every balloon. The final score will be reflected when the game ends.

Since each game is only 30 seconds, due to the short attention span of children with autism, a Timer Slider is introduced to keep track of the remaining seconds left. As the game approaches the end at the last 3 seconds, the slider turns from green to red into to warn the players. This is shown in Figures 13 and 14.

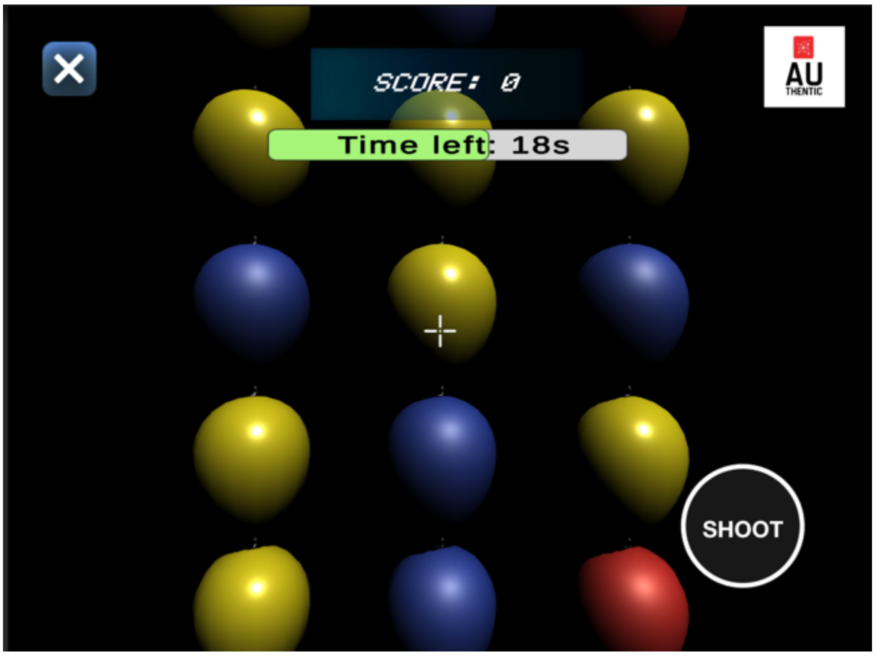


Figure 13: Timer Slider counting down in green

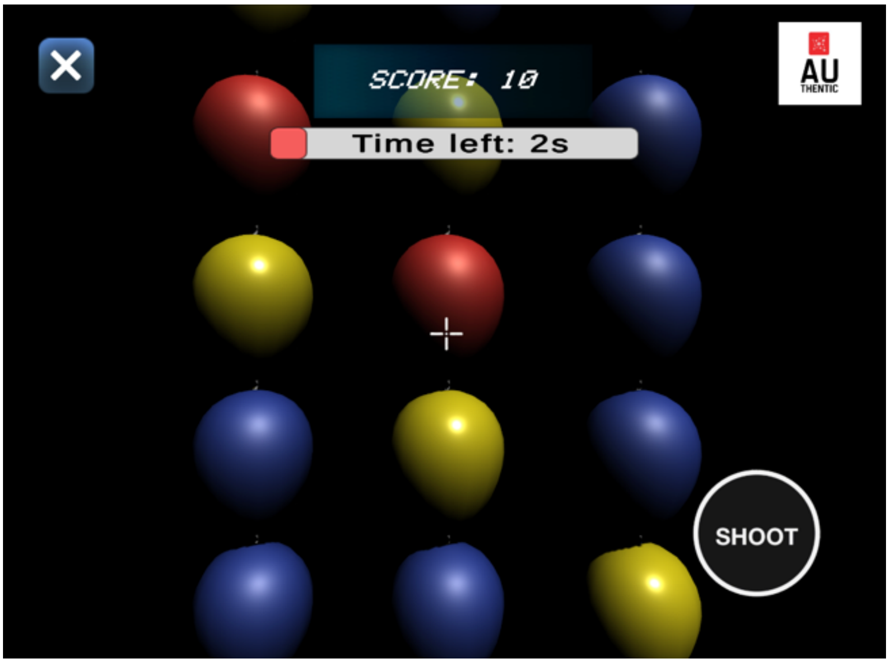


Figure 14: Timer Slider counting down in red

As the game finally approached the end after 30 seconds, a 'Game Over' sign appears across the screen and the spawning of the balloons completely stops in order to prevent the players from scoring any more points as shown in Figure 15.

Figure 15: Game Over sign as timer runs out

Chapter 4: Fruits Identification

4.1 Overview

Another important early-stage education topic would be the introduction to everyday items and objects around us. Children with Autism are traditionally introduced to these items by interacting with the real life objects. In a situation where it is not possible for these children to physically interact with the object due to various reasons like the size or accessibility (i.e. an automobile vehicle), they are introduced in the medium of photos and videos. Although this method works, it is found that the direct interaction with the object leads to a better memory retention rate for the children [12]. Thus, this is where an AR simulation of the 3D model of the objects helps since the children are able to have a closer look at the objects and interact with it directly.

In order to mimic a similar situation, the Fruits Identification Module was developed that allowed the student to interact with a 3D model of the Fruit according to the target image that will be detected by the application.

4.2 Target Image Detection

Before developing the full module, a simple, single image target was used in order to gain a better understanding of how the ARKit works in Unity3D. The first step was to ensure that the application is able to successfully detect the target image and replace it with the 3D model using Augmented Reality. Thus to do this, a target image was first created as shown in Figure 16.

Figure 16: Target Image for Trial AR application

After which, a free 3D model asset, *Low Poly Fruits Pickup, as s*hown in Figure 17, in Unity3D's Asset Store was downloaded to be projected together with the target image.

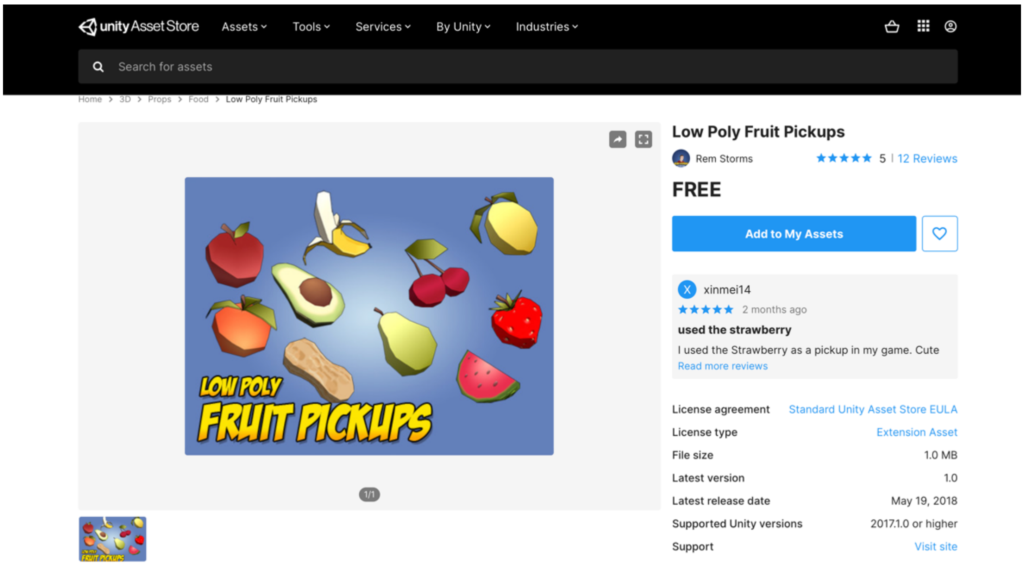


Figure 17: Low Poly Fruits 3D model in Unity Asset Store

The 3D model was incorporated into ARKit and a simple UI design was developed to test run the application. During the test run, the target image was virtually projected on a laptop screen as shown in Figures 18 and 19.

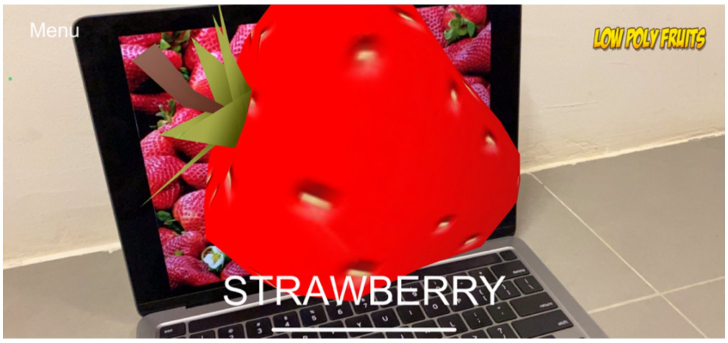


Figure 18: Screenshot of AR Target Image Detection – 1

Figure 19: Screenshot of AR Target Image Detection – 2

Following the success of the test run, the full Fruits Identification Module was then developed which allows multiple target images to be detected. The application was designed to store the target image and prefab information of 7 different types of fruits which includes Apple, Avocado, Banana, Strawberry, Watermelon, Lemon and Peach. The target images of all the 7 fruits were printed out as shown in Figure 20.

Figure 20: Printed Target Images for the Main Application

The target images of all the fruits were stored in a Reference Image library within Unity3D, as shown in Figure 21, and it was ensured that the names of the prefabs of the respective fruits are exactly same as that of the target images since this allows the 3D model to be projected when the target image is detected. In order to ensure that 3D models are correctly triggered based on their specific target image, a special C# Script, *Image Tracking Script*, was written.

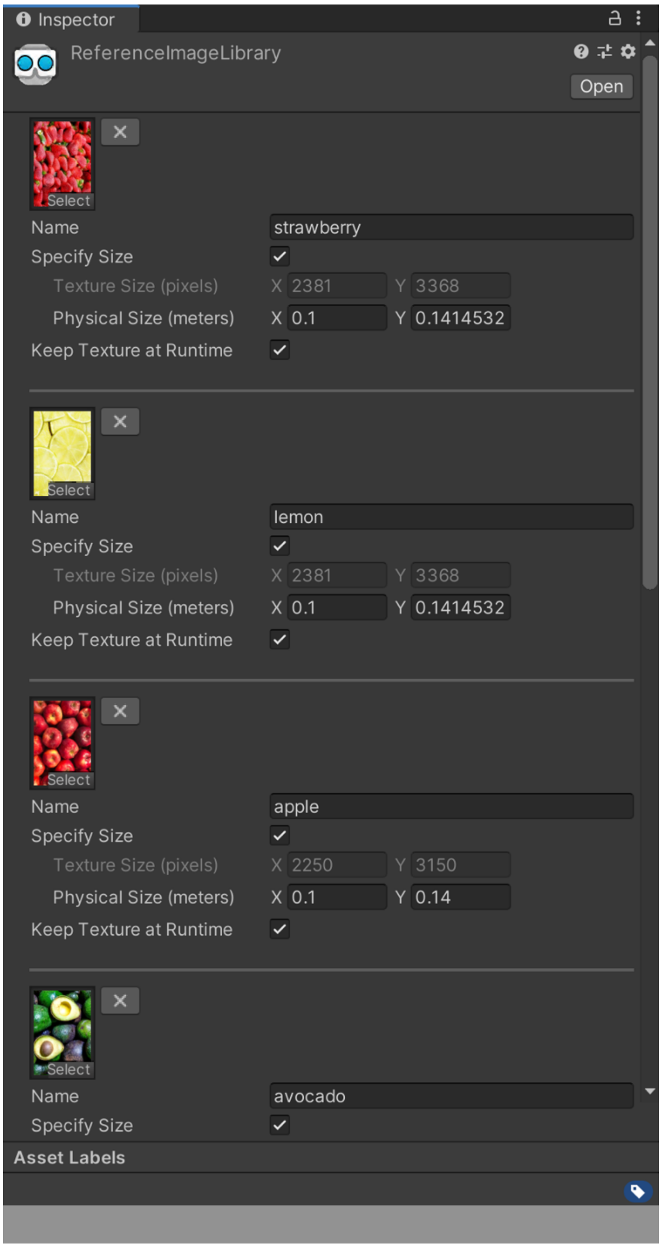


Figure 21: Reference Image Library of Target Images

This allowed all the images to be successfully detected by the application as shown in Figure 22.

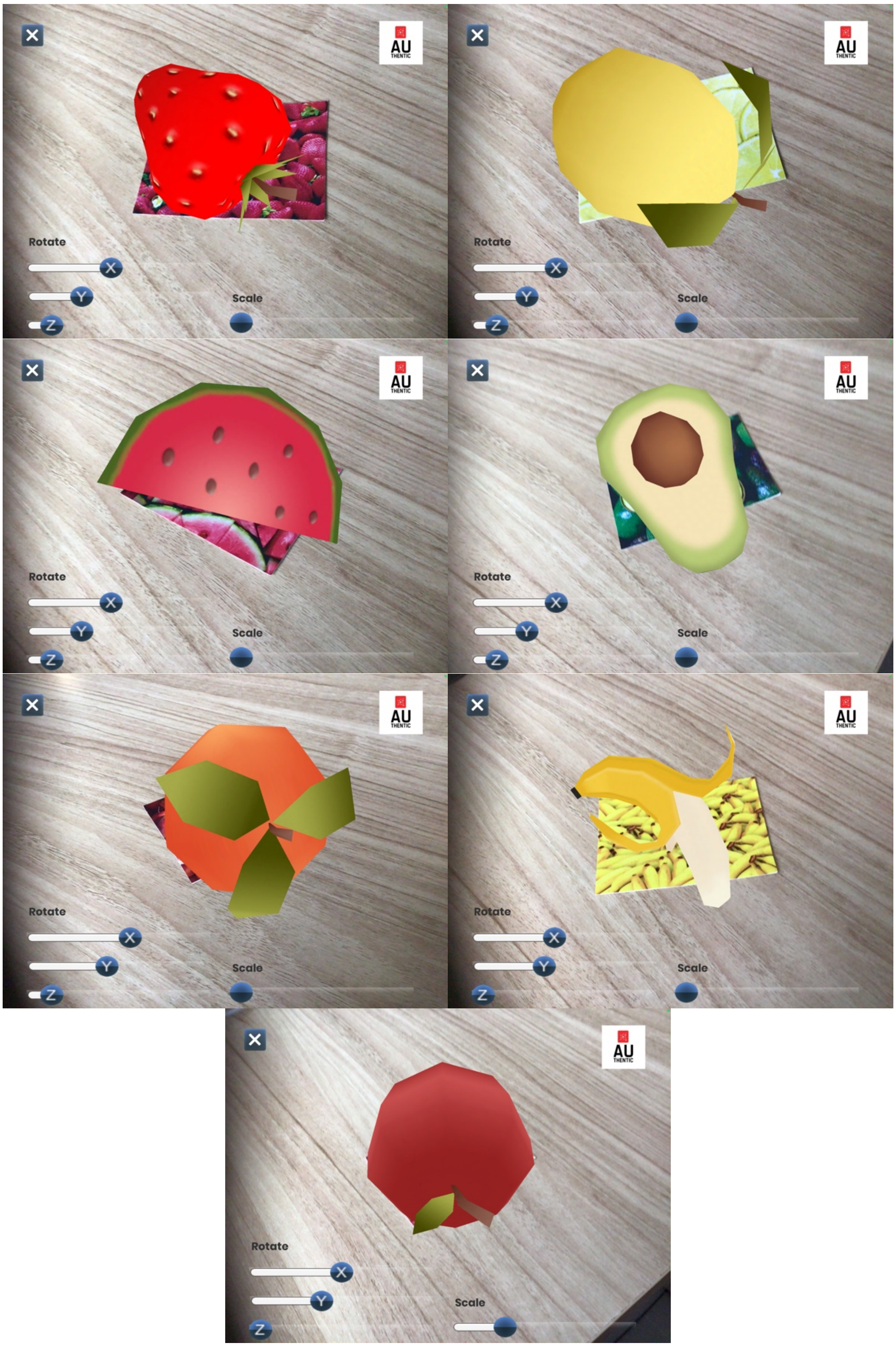


Figure 22: Target Images successfully detected by the Application

4.3 Rotation and Scaling Feature Implementation

Since the images are now successfully detected, the next step would be to allow the students to interact with the AR 3D models directly. Although there are many ways in which an individual can interact with an object using their five senses such as sight, smell, sound, taste and touch, the strongest and most important sense it said to be sight [13].

Therefore by allowing the students to have a closer and better look at the 3D models of the objects, they are able to interact with the objects visually. This is thus achieved by the implementation of both the 3-axis rotation and scaling feature of the 3D model. The *Rotate and Scale C# Script* was written in order to implement this feature.

Firstly the Minimum and Maximum measures for both the rotation and scaling are declared under each prefab. The minimum and maximum for scaling was set to 10 and 15 while for rotation it was set to 0 and 360 degrees for all 3-axis. Secondly, a slider was linked to both the rotation and scaling features that allows the children to control the magnitude of both the functionalities. This is shown below in Figure 23.

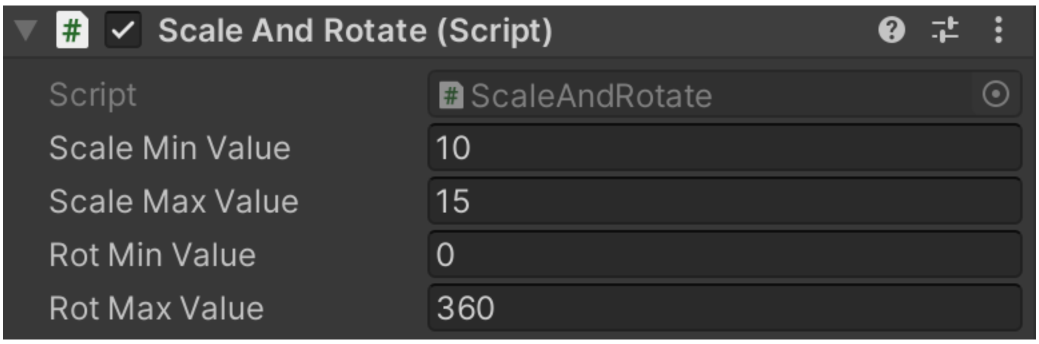


Figure 23: Scaling Measurements that were used for the 3D models

The images of the 3D models being altered according to the Rotation and Scaling Slider are shown in Figure 24. This shows that the implementation of this feature has been successful.

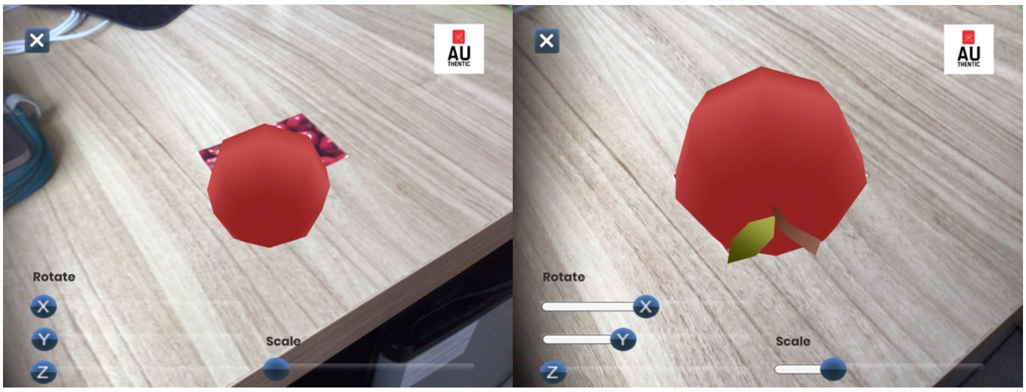


Figure 24: Before and After interacting with the 3D model

Chapter 5: Emotions Identification

5.1 Overview

One of the most important social skills that should be introduced to children with autism in the early-stage would be identifying and labelling emotions. It is found that children with autism who find it difficult to recognise emotions in the early-stage are more likely to struggle with managing their own emotions later on in their lives. In addition to that, they may pay less attention to other peoples' emotional behaviour while negatively influences their social skills [14].

Thus to ensure that children with autism are able to identify, learn and label different emotions accurately, the Emotion Identification Module was designed and developed.

5.2 Gaze Interaction Implementation

Firstly a Gaze Interaction is defined as the point of gaze of the user that is recorded and used in real time as an input in the user-computer interaction [15]. This basically allows the user to move around in their real world space while interacting with an virtual environment through a device. One of the most popular examples of an AR Gaze Interaction game would be 'Pokémon Go' as shown in Figure 25. Thus, this game was used as an inspiration in order to develop the Gaze Interaction Feature in the Emotions Identification Module.

Figure 25: Pokémon Go Game that uses Gaze Interaction

The idea for the module was to place 3D models containing photos of different emotions around the world space, where the name of the emotion would pop up as the virtual Ray Cast collides with the cube enabling the Gaze Interaction. This is so that the students can walk around with the iOS device to learn and identify different emotions.

Therefore to first start off the development of the feature, photos of different emotions exhibited by the same person was used as shown in Figure 26. Out of all these emotions that were shown, only the following five were used; Happy, Shocked, Scared, Angry and Sad.

Figure 26: Photos of the various emotions that were finalised

After which, 3D models of cubes where created and the images of the different emotions where applied on these cubes as materials. These cubes where then placed in different positions in the world space as shown in Figure 27.

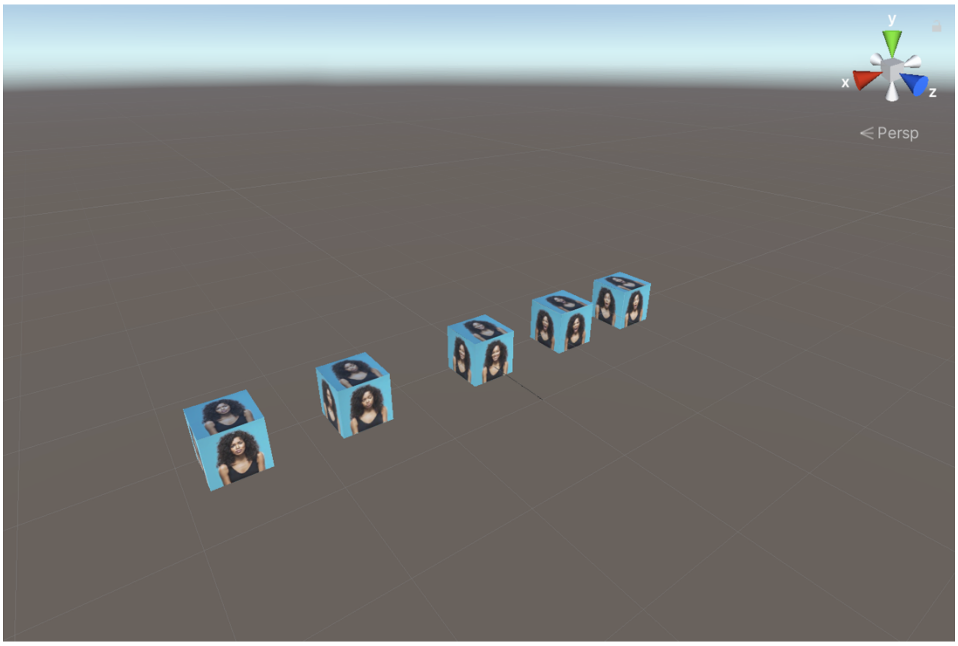


Figure 27: Emotion Cubes placed in World Space in the Game

Following this, an Information Panel containing the name of the different emotions was designed to follow the camera. This functionality was implemented using the C# Script, *Face Camera*. This is shown in Figure 28.

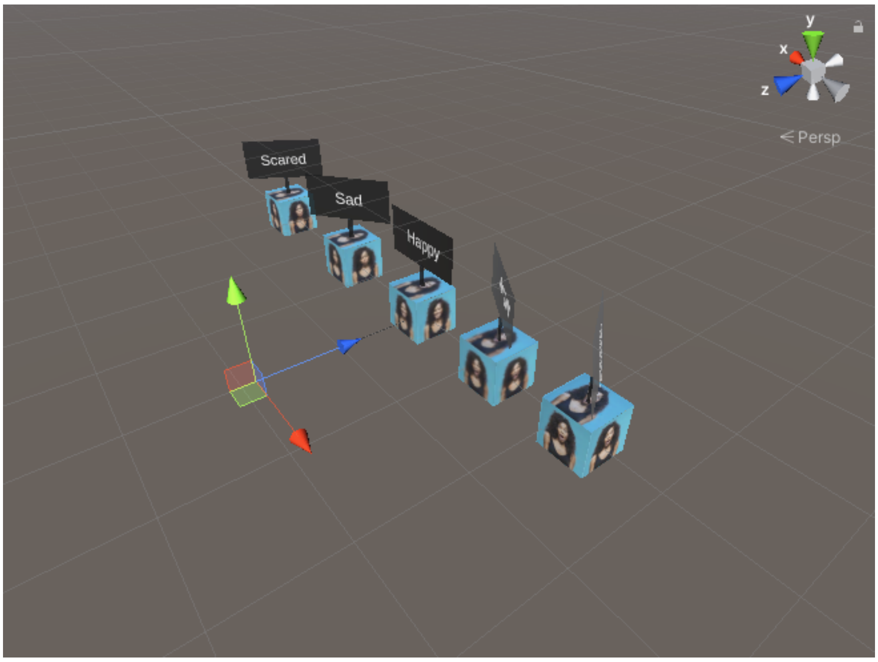


Figure 28: Emotion Cube with Information Panel facing the Camera

Lastly, the Information Panel was programmed to pop up on top of the cube as the Ray Cast collides with the cube using the *InfoBehaviour and Gaze C# Scripts*. This is shown in Figures 29, 30, and 31.

Figure 29: Sad Emotion pops up as Camera faces the Cube

Figure 30: Shocked Emotion pops up as Camera faces the Cube

Figure 31: Happy Emotion pops up as Camera faces the Cube

Chapter 6: Application Set-Up and Usage

6.1 Graphical User Interface Elements

A good UI/UX design is generally said to be an crucial element in customer satisfaction. This is because a good UI/UX designs means that people would willingly want to interact with the content created [16]. Thus, in this case where an Educational Application is designed for children with autism, it is important to ensure that the children are interested and willing to interact with these contents. Therefore the designing of the graphical user interface elements were also an important step in this project.

Since it was found that children with autism prefer a bright light environment with not many stimuli, the main theme colours were finalised to be white and pastel red and the name of the application was also finalised to be 'AUthentic'. With this, the logo of the application was created as shown in Figure 32 and 33.

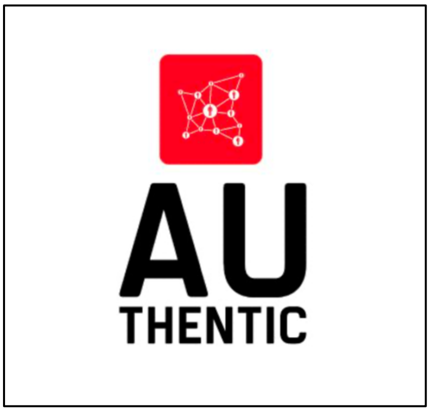
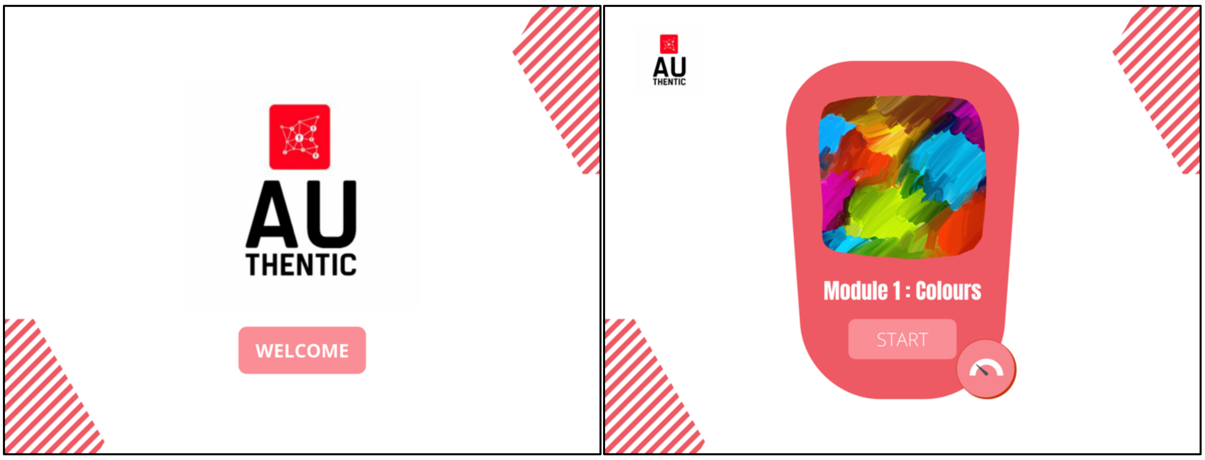


Figure 32: Logo used for the Application

Figure 33: Application as seen in the screen of an iPad

Apart from the Logo, the Home Page and the Modules Menu Page was also designed and created using the online software Canva. In order to ensure that there are not too many stimuli that would make the interaction uncomfortable for children with autism, the background design of all the different pages were consistent and only the colours white and different tones of pastel red was used in the pages. Additional buttons were created within Unity3D. The different designs of all the pages are shown in Figure 34.



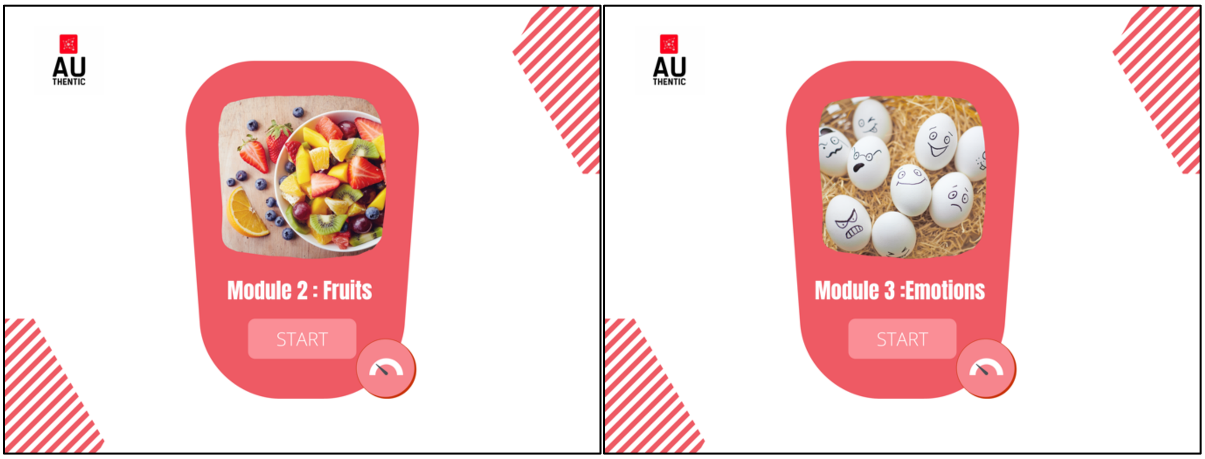


Figure 34: Canva Designs of Home and Menu Pages

Also the modules are placed in the specific chronological order of progressive cognitive ability needed to learn these topics by children with autism. All of these lessons will be conducted together with a Caregiver or an OT since a children with autism have a strong need of authority for an conducive learning environment.

6.2 Module 1 – Colours Identification

In the Colour Identification Module, the caregiver would introduce all three colours to their student and give them a clear and concise instruction such as 'Shoot Blue Balloons'. Following this instruction, the student will have to start the game and shoot the balloon of the specific colour as mentioned by the caregiver. During this process, the caregiver will be able to monitor to see if the student is able to identify the different colours correctly. The point system allows the students to be more interested in the learning process and the timer ensures that each game session is short and thus holding the attention of children with autism for the entire session. Once the student is able to successfully identify all the colours, this module would be completed.

6.3 Module 2 – Fruits Identification

Moving on, for the Fruits Identification Module, the caregiver will be able to use the present the cards of the different fruits to the student one by one. They will introduce the fruit to the student before allowing them to open up the AR camera to detect the target image. After which, the student can interact with the 3D model of the fruit directly. After all the fruits have been introduced to the student, the care giver can check if the student is able to name and identify the different fruits from the target images and the 3D models. Once the student is able to successfully identify all the fruits, this module would be completed.

6.4 Module 3 – Emotions Identification

Lastly, for the Emotion Identification Module, the Caregiver can allow the student to explore the space while guiding and introducing the different emotions to them. Since the Information Banner with the name of each emotion would pop up when the iOS device is focused on the specific emotion cube, the caregivers can use this to test the students of their understanding of the various emotions. Once the student is able to successfully identify all the emotions, this module would be completed.

6.5 Progress Tracker

Another one of the most important process in teaching a child with autism would be to constantly monitor and check on their progress. Having a progress tracker to track the learning ability of a child with autism is a common practice worldwide since it is able to give the caregivers and OTs a better understanding of the child's learning style and speed which would in turn help them when teaching other topics in the future [17].

Therefore in order to ensure that this important process is also included in the Educational Application, a virtual progress tracker for each module has been created as shown in the Figures 35, 36, and 37. These Progress Trackers will include Text Fields that can be edited by the Caregivers and later referred to by the OTs for the children for a better understanding of their learning process.

Module 1 – Colors Identification

Targeted Skill	Date Introduced	Date Mastered
Able to Identify Red		
Able to Identify Blue		
Able to Identify Yellow		

Figure 35: Colours Identification Progress Tracker

Module 2 – Fruits Identification

Targeted Skill	Date Introduced	Date Mastered
Able to Identify Avocado		
Able to Identify Apple		
Able to Identify Peach		
Able to Identify Lemon		
Able to Identify Banana		
Able to Identify Watermelon		
Able to Identify Strawberry		

Figure 36: Fruits Identification Progress Tracker

Module 3 – Emotions Identification

Targeted Skill	Date Introduced	Date Mastered
Able to Identify Happy		
Able to Identify Sad		
Able to Identify Angry		
Able to Identify Shocked		
Able to Identify Scared		

Figure 37: Emotions Identification Progress Tracker

Chapter 7 - Conclusion and Future Work

7.1 Conclusion

To conclude, the goal of this project was to design and develop an AR Educational Application that helps Caregivers and OTs to teach young children with autism some of the basic topics of early-stage education such as identifying and labelling colours, fruits and emotions. This tackles some of the main components under the learning skills and social skills spectrum that are required by an autistic child. The AR Technology was also uniquely adapted for each of the different modules, giving the child an interesting variety of content delivery that helps to further enhance their understanding of the given topics.

The programming language that was used for this application was C# and the software that were used include Unity3D, Microsoft Visual Studio ARKit, XCode and Canva. Unity3D worked hand-in-hand with ARKit which were used mainly to set up the AR Game Scenes while Microsoft Visual Studio was used to programme the C# Scripts. After which, XCode was used to build and install the application into an iOS device. Canva was mainly used for the UI/UX designing of the home and menu pages of the application.

The project has been successful since the goal of the project has been achieved where children with autism would be able to access the application on an iPad and learn from it together with the guidance of their caregivers and OTs. Although the response from the children regarding the application could not be tested out due to the Covid Situation where it was not possible to visit and interact with them, the application was virtually shown to a Caregiver of a Child with Autism who gave a positive response. Thus it can be concluded that the goal of the project has been fulfilled.

7.2 Challenges Encountered

The main challenge encountered for the project was to have a deep understanding of the learning style of children with autism. This is because, each child is different with different sets of strengths and weaknesses, and designing an application that would cater to all of them was an difficult task. Thus it was essential to determine which learning preferences can be developed and incorporated into the project and which learning preferences should be left out. This difficulty was tackled by talking directly to caregivers of children with autism and finding out the most preferred learning methods that would attract the vast majority of the students. By analysing the more common learning preferences among children with ASD and determining which of these features can be implemented in an application setting, the main features of the application were eventually finalised.

Apart from this, another challenge was to adapt the AR Technology in a unique way for the different topics. Although it is well-known that AR/VR/XR/MR are powerful upcoming technologies, it was difficult to get creative with their adaptation due to the limited knowledge on the usage of this technology in the initial stage. This challenge was tackled with extensive research and online tutorials that exhibited the different ways in which AR can be used in game development. This in turn greatly helped in finalising the three methods in which AR was used in this project.

7.3 Recommendation for Future Work

This project has the potential to be expanded to cover various other topics and skillset for children with autism. There are five main skillset categories that are labelled to be important to teach children with autism and these categories includes ‘behavioural skills’, ‘learning skills’, ‘life skills’, ‘social skills’ and lastly ‘play skills’ [18]. The current application only focuses on two of the five categories which are learning skills for Modules 1 and 2, and social skills for Module 3. Therefore for future work, other skillset categories can also be taken into consideration.

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Appendix

Interview Transcript

Nithyasri: Hi, thank you so much for taking the time to attend this zoom call.

Rinnitha: No problem. Glad I can help. How are you doing?

Nithyasri: I am doing well. How are you and what have you been up to?

Rinnitha: I am good too. I am still working with Pathlight and this is my 3rd Year with them. I have been teaching the lower secondary cohort for the first two years and this year I am taking the upper secondary batch and the graduating class.

Nithyasri: N: Oh, wow that really nice! All the very best to you.
Let me just start off by giving you an overview of my FYP project before asking you a few questions relating to the project that would greatly benefit me.

Rinnitha: Yes sure.

Nithyasri: So, my project is about designing and developing an AR educational application for children with autism and the main focus is on early-stage education for 3 to 5 years old children. So, teaching them basic topics such as colors or daily objects or simple life skills. The aim of the AR application would be to work hand-in-hand with a Caregiver or a Parent and not for the children to use in on their own. I am currently in the midst of developing the application and I felt that it would be beneficial to talk to someone who closely works with children with autism such as yourself.

Rinnitha: That's interesting. It's good that this is visual based since for children with autism, the main thing for them is sensory and interaction. For example, when we look at colors, the way we understand colors is not the same way children with autism understand it. So, since this application targets the younger children, it would be good since it will train them from young to memorize the color orange; but it will take them a long time to process and understand the color and in addition to that they will be needing good parental or caregiver support as well.

Nithyasri: Oh, I see. I actually thought of starting it off with the three primary colors first and making it some sort of a game so that the parents can guide their children to understand these three colors first. Would this work well?

Rinnitha: Actually, that is a good idea. Because in terms of attention span, this gamification would definitely capture their attention. Even for myself when I teach my secondary students, they are often more interested when the topic is delivered in a game form and they are more interested to play these games for a longer period of time. In fact, they actually do better with games as well. So, I think this is a good idea, definitely.

Nithyasri: That's great to hear. Then I will focus on that. So, do you think it will be good to have a point system as well?

Rinnitha: Yes, that would work fine. Not only for students with autism but for all students in general, they are more motivated when they see a reward for their work. However, this point system would only work well in an individual setting and not in a group or classroom setting since children with autism can get a bit too competitive at times and this would create classroom tension.

Nithyasri: Oh, I understand. The app mainly focuses on individual learning so I guess that would be alright.

Rinnitha: Yes, if it is just individual it should be fine.

Nithyasri: When it comes to learning styles there are the four main learning styles that all of us are aware of like visual, auditory and stuff. So, does this apply for children with autism as well or do they focus on just one or two specific learning styles?

Rinnitha: Visual. They mainly focus on visual. However, it also depends on different students since autism is a spectrum you see. They each learn in a very different pace. As for my teaching, I mainly use visual, but I also include various prompts like physical and gestures. Audio works for them as well but they do learn better with visuals. Actually, which part of the spectrum are you focusing on since it would be really difficult to target the more severe cases of autism?

Nithyasri: This project focuses on the mild range of autism. This consists of the mid to high functioning children.

Rinnitha: Then visual would be a good learning style to focus on. It would be highly beneficial for the students. Even for Pathlight we work with the same group of students as well.

Nithyasri: Alright so it is mainly visuals that occasionally combines with audio and physical interaction as well, right?

Rinnitha: Yes, that is correct. If you are going to use audio, you definitely need visual support with that.

Nithyasri: Got it, got it! I also wanted to talk to you about life skills. So, what are some of the more important life skills that children with autism should be learning at a young age?

Rinnitha: So, for 3- to 5-year-olds, it would be better to focus on their emotions. Like controlling emotions or even being able to identify them first. For example, angry. What does it mean to be angry or what do I do when I am feeling angry? These are some skills that should know at a young age since if this is not taught properly, as they grow up, they can become more aggressive, or they would not be able to regulate themselves even for small things. So, identifying emotions or classifying like what can you do when feeling an emotion is crucial.

Nithyasri: Oh, that is interesting. I didn't think of that and didn't realize the importance of teaching emotions. That is definitely something I can consider and see what I can do about it in AR.

Rinnitha: Yeah sure. The most important thing is the emotions' part. It would be great if you can find a way to include it in your project because children with autism really have difficulty identifying emotions. It is something you can explore to teach at a younger age. Maybe just the basic emotions like happy, sad and angry would be more than enough for 3- to 5- years old.

Nithyasri: Yes, sure this is a really interesting point. I will definitely focus on emotions as well then. Well, I have most of my questions answered already. Thank you so much for your time once again. I really appreciate it.

Rinnitha: No worries. It is heartening to see you work on this for children with autism. Hope your project is successful and wishing you all the very best. See you!

Nithyasri: Thank you so much! See you too! Goodbye!

Colour Identification Codes

Balloon Script

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class BalloonScript : MonoBehaviour
{


    // Update is called once per frame
    void Update()
    {
        transform.Translate(Vector3.up * Time.deltaTime * 0.2f);
    }
}
```

Spawn Script

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class SpawnScript : MonoBehaviour
{
```

```
    public Transform[] spawnPoints;
    public GameObject[] balloons;


    void Start()
    {

        StartCoroutine(StartSpawning());

    }

    IEnumerator StartSpawning()
    {

        yield return new WaitForSeconds(2);

            for (int i = 0; i < 3; i++)
            {
                Instantiate(balloons[Random.Range(0, 3)], spawnPoints[i].position,
Quaternion.identity);
            }

        StartCoroutine(StartSpawning());

    }

}
```

Shoot Script

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;

public class ShootScript : MonoBehaviour
{
    public GameObject arCamera;
    public GameObject smoke;
    public GameObject scoreToSpawn;

    public void Shoot()
    {
        RaycastHit hit;

        if (Physics.Raycast(arCamera.transform.position, arCamera.transform.forward, out hit))
        {

            if (hit.transform.name == "balloon1(Clone)" || hit.transform.name ==
"balloon2(Clone)" || hit.transform.name == "balloon3(Clone)")
```

```
            {
                Destroy(hit.transform.gameObject);
                Scoring.score += 2;
                Instantiate(smoke, hit.point, Quaternion.LookRotation(hit.normal));
            }
        }
    }

}
```

Timer Slider Script

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;
using TMPro;

public class TimerSlider : MonoBehaviour
{
    Slider timerSlider;
    TextMeshProUGUI timerText;

    public float gameTime = 30.0f;

    Image fillImage;
    public Color32 normalFillColor;
    public Color32 warningFillColor;
    public float warningLimit;  // as a percentage

    public bool stopTimer;

    TextMeshProUGUI gameOverText;

    void Start()
    {
        stopTimer = false;
        gameObject.GetComponent<ShootScript>().enabled = true;

        gameOverText =
GameObject.FindGameObjectWithTag("GameOverText").GetComponent<TextMeshProUG
UI>();
        gameOverText.gameObject.SetActive(false);

        timerSlider =
GameObject.FindGameObjectWithTag("TimerSlider").GetComponent<Slider>();
        timerText =
GameObject.FindGameObjectWithTag("TimerText").GetComponent<TextMeshProUGUI>()
;
```

```
        fillImage =
GameObject.FindGameObjectWithTag("SliderFill").GetComponent<Image>();

        timerSlider.maxValue = gameTime;
        timerSlider.value = gameTime;
        fillImage.color = normalFillColor;
    }


    void Update()
    {
        gameTime -= Time.deltaTime;

        string textTime = "Time left: " + gameTime.ToString("f0") + "s";

        if (stopTimer == false)
        {
            timerText.text = textTime;
            timerSlider.value = gameTime;
        }

        if (timerSlider.value < ((warningLimit / 100) * timerSlider.maxValue))
        {
            fillImage.color = warningFillColor;
        }

        if (gameTime <= 0 && stopTimer == false)  // On Game over
        {

            stopTimer = true;
            gameObject.GetComponent<ShootScript>().enabled = false;
            Destroy(timerSlider.gameObject);
            gameOverText.gameObject.SetActive(true);
        }

        if (gameTime <= 0)  // On Game over
        {

            var balloon = GameObject.FindGameObjectsWithTag("balloons");

            foreach (var balloons in balloon)
            {
                Destroy(balloons);
            }

        }
    }
}
```

Scoring Script

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using TMPro;

public class Scoring : MonoBehaviour
{
    public TextMeshProUGUI scoreText;
    public GameObject scoreBoardUI;
    public static int score;

    private void Start()
    {
        gameObject.GetComponent<ShootScript>().enabled = true;
        scoreBoardUI = GameObject.FindGameObjectWithTag("ScorePanel");
        scoreText =
GameObject.FindGameObjectWithTag("ScoreOnBanner").GetComponent<TextMeshProUG
UI>();
    }

    private void Update()
    {
        scoreText.text = "Score: " + score.ToString();
    }
}
```

Fruits Identification Codes

Image Tracking Script

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.XR;
using UnityEngine.XR.ARFoundation;
using UnityEngine.XR.ARKit;

[RequireComponent(typeof(ARTrackedImageManager))]
public class ImageTracking : MonoBehaviour
{

    [SerializeField]
    private GameObject[] placeablePrefabs;

    private Dictionary<string, GameObject> spawnedPrefabs = new Dictionary<string,
GameObject>();
    private ARTrackedImageManager trackedImageManager;
```

```
private void Awake()
{
   trackedImageManager = FindObjectOfType<ARTrackedImageManager>();

   foreach(GameObject prefab in placeablePrefabs)
   {
      GameObject newPrefab = Instantiate(prefab, Vector3.zero, Quaternion.identity);
      newPrefab.name = prefab.name;
      spawnedPrefabs.Add(prefab.name, newPrefab);
   }
}

private void OnEnable()
{
   trackedImageManager.trackedImagesChanged += ImageChanged;
}

private void OnDisable()
{
   trackedImageManager.trackedImagesChanged -= ImageChanged;
}

private void ImageChanged(ARTrackedImagesChangedEventArgs eventArgs)
{
   foreach(ARTrackedImage trackedImage in eventArgs.added)
   {
      UpdateImage(trackedImage);
   }
   foreach (ARTrackedImage trackedImage in eventArgs.updated)
   {
      UpdateImage(trackedImage);
   }
   foreach (ARTrackedImage trackedImage in eventArgs.removed)
   {
      spawnedPrefabs[trackedImage.name].SetActive(false);
   }
}

private void UpdateImage(ARTrackedImage trackedImage)
{
   string name = trackedImage.referenceImage.name;
   Vector3 position = trackedImage.transform.position;

   GameObject prefab = spawnedPrefabs[name];
   prefab.transform.position = position;
   prefab.SetActive(true);

   foreach(GameObject go in spawnedPrefabs.Values)
   {
      if(go.name != name)
```

```
            {
                go.SetActive(false);
            }
        }
    }
}
```

Scale and Rotation Script

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;

public class ScaleAndRotate : MonoBehaviour
{

    private Slider scaleSlider;
    private Slider rotateSliderX;
    private Slider rotateSliderY;
    private Slider rotateSliderZ;
    public float scaleMinValue;
    public float scaleMaxValue;
    public float rotMinValue;
    public float rotMaxValue;
    void Start()
    {
        scaleSlider = GameObject.Find("ScaleSlider").GetComponent<Slider>();
        scaleSlider.minValue = scaleMinValue;
        scaleSlider.maxValue = scaleMaxValue;
        scaleSlider.onValueChanged.AddListener(ScaleSliderUpdate);

        rotateSliderX = GameObject.Find("RotateSliderX").GetComponent<Slider>();
        rotateSliderX.minValue = rotMinValue;
        rotateSliderX.maxValue = rotMaxValue;
        rotateSliderX.onValueChanged.AddListener(RotateSliderXUpdate);

        rotateSliderY = GameObject.Find("RotateSliderY").GetComponent<Slider>();
        rotateSliderY.minValue = rotMinValue;
        rotateSliderY.maxValue = rotMaxValue;
        rotateSliderY.onValueChanged.AddListener(RotateSliderYUpdate);

        rotateSliderZ = GameObject.Find("RotateSliderZ").GetComponent<Slider>();
        rotateSliderZ.minValue = rotMinValue;
        rotateSliderZ.maxValue = rotMaxValue;
        rotateSliderZ.onValueChanged.AddListener(RotateSliderZUpdate);
    }


    void ScaleSliderUpdate(float value)
```

```
    {
        transform.localScale = new Vector3(value, value, value);
    }

    void RotateSliderXUpdate(float value)
    {
        transform.localEulerAngles = new Vector3(value, transform.rotation.y,
transform.rotation.z);
    }

    void RotateSliderYUpdate(float value)
    {
        transform.localEulerAngles = new Vector3(transform.rotation.x, value,
transform.rotation.z);
    }

    void RotateSliderZUpdate(float value)
    {
        transform.localEulerAngles = new Vector3(transform.rotation.x, transform.rotation.y,
value);
    }
}
```

Emotions Identification Codes

Face Camera Script

```
using UnityEngine;

[ExecuteInEditMode]
public class FaceCamera : MonoBehaviour
{
    Transform cam;
    Vector3 targetAngle = Vector3.zero;

    void Start()
    {
        cam = Camera.main.transform;
    }

     void Update()
    {
        transform.LookAt(cam);
        targetAngle = transform.localEulerAngles;
        targetAngle.x = 0;
        targetAngle.z = 0;
        transform.localEulerAngles = targetAngle;
    }
}
```

InfoBehaviour Script

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class InfoBehaviour : MonoBehaviour


{
    const float SPEED = 6f;

    [SerializeField]
    Transform SectionInfo;

    Vector3 desiredScale = Vector3.zero;

    // Update is called once per frame
    void Update()
    {
        SectionInfo.localScale = Vector3.Lerp(SectionInfo.localScale, desiredScale,
Time.deltaTime * SPEED);
    }

    public void OpenInfo()
    {
        desiredScale = Vector3.one;
    }

    public void CloseInfo()
    {
        desiredScale = Vector3.zero;
    }
}
```

Gaze Script

```
using System.Collections;
using System.Collections.Generic;
using System.Linq;
using UnityEngine;

public class Gaze : MonoBehaviour
{
    List<InfoBehaviour> infos = new List<InfoBehaviour>();

    private void Start()
    {
        infos = FindObjectsOfType<InfoBehaviour>().ToList();
    }
```

```
    private void Update()
    {
        if (Physics.Raycast(transform.position,transform.forward, out RaycastHit hit))
        {
            GameObject go = hit.collider.gameObject;
            if (go.CompareTag("hasinfo"))
            {
                OpenInfo(go.GetComponent<InfoBehaviour>());
            }
        } else
        {
            CloseAll();
        }
    }

    void OpenInfo(InfoBehaviour desiredInfo)
    {
        foreach (InfoBehaviour info in infos)
        {
            if (info == desiredInfo)
            {
                info.OpenInfo();
            }

            else
            {
                info.CloseInfo();
            }
        }
    }

    void CloseAll()
    {
        foreach (InfoBehaviour info in infos)
        {
            info.CloseInfo();
        }
    }
}
```

Place Content Script

```
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.XR.ARSubsystems;
using UnityEngine.XR.ARFoundation;
using UnityEngine.EventSystems;
using UnityEngine.UI;
```

```
public class PlaceContent : MonoBehaviour {

   public ARRaycastManager raycastManager;
   public GraphicRaycaster raycaster;

   private void Update() {

      if (Input.GetMouseButtonDown(0) && !IsClickOverUI()) {

         List<ARRaycastHit> hitPoints = new List<ARRaycastHit>();
         raycastManager.Raycast(Input.mousePosition, hitPoints, TrackableType.Planes);

         if (hitPoints.Count > 0) {
            Pose pose = hitPoints[0].pose;
            transform.rotation = pose.rotation;
            transform.position = pose.position;
         }
      }
   }

   bool IsClickOverUI() {
      //dont place content if pointer is over ui element
      PointerEventData data = new PointerEventData(EventSystem.current) {
         position = Input.mousePosition
      };
      List<RaycastResult> results = new List<RaycastResult>();
      raycaster.Raycast(data, results);
      return results.Count > 0;
   }
}
```

Toggle AR Script

```
using UnityEngine;
using UnityEngine.XR.ARFoundation;

public class ToggleAR : MonoBehaviour {

   public ARPlaneManager planeManager;
   public ARPointCloudManager pointCloudManager;

   public void OnValueChanged(bool isOn) {
      VisualizePlanes(isOn);
      VisualizePoints(isOn);
   }

   void VisualizePlanes(bool active) {
      planeManager.enabled = active;
      foreach (ARPlane plane in planeManager.trackables) {
         plane.gameObject.SetActive(active);
```

```
        }
    }

    void VisualizePoints(bool active) {
        pointCloudManager.enabled = active;
        foreach (ARPointCloud pointCLoud in pointCloudManager.trackables) {
            pointCLoud.gameObject.SetActive(active);
        }
    }
}
```