ISSN 2278-3091
Volume 9, No.3, May - June 2020
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse180932020.pdf
https://doi.org/10.30534/ijatcse/2020/180932020

GoonAR: A Bilingual Children Storybook through Augmented Reality Technology Using Unity with Vuforia Framework

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ABSTRACT

This paper aims to apply the augmented reality (AR) technology in storytelling to enhance and give a more motivating and fun reading experience to children. The primary objective of this study is to develop a bilingual AR children storybook mobile application called GoonAR. GoonAR is an android smartphone application that uses augmented reality technology to display 3D characters and environments in the story. The app offers auditory, kinesthetic, and visual learners a fun experience as they are immersed in learning activities. An original story was developed, and a pseudo-book is created. The pseudo-book incorporates the AR technology that displays 3D assets. Grade 1 students under 6 – 7 years of age are the target users for this application, as children at this age start to learn reading. The users are able to understand the story by (1) the aid of a narrator that speaks both English and Filipino language or (2) by reading it themselves on the phone and view displayed 3D objects that were made possible through the use of Unity with Vuforia framework.

Key words: 3D and 2D technology, augmented reality, mobile application, pseudo book, storybook

1. INTRODUCTION

In the history of humans, envisioning the invisible has been one of the most intriguing phenomena. With the emergence of computers and other forms of technologies, this became possible. There are increasing demands to adopt technology in education due to the rapid growth of information technology, to influence students to motivate them to gain an active learning process and learn actively. There lies the challenge as to how to integrate technology into the learning experience. With augmented reality (AR) technology, it is presently possible to utilize smartphones because of progress in mobile technology and the usefulness of a mobile platform in the present time.

Augmented reality (AR) is a term that depicts advances that allow the combination of what is virtual and real. AR can be characterized as computer-generated objects that are overlapped in the real-world environment. This technology is a different approach to creating a more interactive experience. These practical features are usually visuals and sounds. On technical aspects, AR is generally identified with wearable technologies (PCs and overhead screens). Before, it is usually determined to be costly as it is used in military and medical purposes. Now, people can witness a more varied assortment of AR usage through the use of a camera or one's mobile device.

Augmented reality (AR) applications demonstrate significant potential in providing children with more meaningful, dynamic, and productive learning processes. It makes the learning process more stimulating, and it is more convenient for demonstration and instructions.

In most cases, children learn to read by 6 or 7 years of age. Some children learn at 4 or 5 years of age, and others struggle for years. Children having a hard time teaching are confronted with the challenge of reading without visuals where they need control over their learning effectively and catch their attention. According to the American Federation of Teachers, these kids having difficulty in reading are considers late bloomers. In this case, proponents and educators alike believed that the idea of "late bloomer" is the endearing term for a child who was slower than his peers in learning to read. Also, it is considered that these individuals would do it a bit later than their peers. The problem is known as the development lag theory; it was a reasonable basis for teachers' patience with students who didn't catch on to reading quickly—and it justified the common practice of delaying the diagnosis of reading problems until they were quite severe.

To address children's reading difficulties, it is proposed that children should handle learning with the guidance of their parents and at their own pace with the help of the GoonAR; thus, this study. Instead of being passive recipients, the children are given the freedom to interact with the reading experience leading to better understanding and a high level of motivation towards learning and reading for children.

Generally, this study aims to create a bilingual pseudo-book with interactive AR characters and the environment through AR technology using Unity and Vuforia framework.

2. RELATED SYSTEMS

2.1 iDinosaurAR

iDinosaur is developed by Red Frog Digital Limited; it is an Android app that is designed to work correctly with the iDinosaur book. The application requires a rear-facing camera to unleash augmented reality dinosaurs with the iDinosaur book. Each page shows images of different dinosaurs. To see the dinosaur animations in action, the user needs to find the yellow Augmented Reality boxes in the page that serves as markers to show the realistic 3D model dinosaur. By launching the app and point their device's camera at the book while it is open flat on the floor or a table, users can now watch the dinosaurs come to life. These dinosaurs are put inside a crate where the user has to tap the crate in order to release the dinosaur and let it roam freely.

The users may move their mobile devices around to get a 360-degree view of each dinosaur. Moreover, they can control the dinosaur with the onscreen joystick control. With just a tap, users can make dinosaur roar or shut them safely back into their crates. Users are able to take photos of themselves with each dinosaur, ready to print or share [1].

2.2 Benefits of Augmented Reality in Educational Environments - A Systematic Literature Review

This study describes several possibilities of using Augmented Reality in educational settings. By augmenting the real-world with virtual info, Augmented Reality (AR) provides new options for education. Although AR is frequently applied in educational environments, the value of AR applications in these environments is not yet investigated in its entirety. Additionally, educators face different directions of AR applications, which may differ regarding their potential benefits. The findings of the study indicate that the specific instructions of AR applications are more likely to lead to certain benefits such as increased motivation. Future research is needed to investigate the causality between the benefits and directions of AR in more detail [2].

2.3 3D AR and VR TOTO Storytelling Scanning Book

This study introduced an interactive AR, VR, and MR application developed by Victoria Productions Inc. TOTO is a book series, and the stories are crafted for children and parents. It is an application built to cultivate a child's logic and critical thinking abilities. The graphics of the app is created in a 3D view for augmented reality but display as a 2D animated illustration. It has a printed book cover, and each page shows the 2D animation. Furthermore, parents can personalize the book for their children by using the custom voice-recording feature [3].

2.4 A Case Study of Augmented Reality Simulation System Application in a Chemistry Course

The study discussed the comprehension of micro-worlds and the challenge of chemistry learning. It is noted that junior high school students have artistic abilities that are not yet mature. In the study, the researchers targeted "the composition of substances" segment of junior high school chemistry classes and, furthermore, involved the design and development of a set of inquiry-based augmented reality (AR) learning tools. Students could control, combine, and interact with a 3D model of micro-particles using markers and conduct a series of inquiry-based experiments. The AR tool was tested in practice at a junior high school in Shenzhen, China [4].

2.5 Storybooks alive™ - Amos Alligator Arrives at the Airport

Storybooks alive™ is an application for Amos Alligator Arrives at the Airport storybook developed by Alive Studios, LLC. It is an augmented reality book that helps children learn some facts about the alligators, practice 29 sight words, play the airplane letter/word game, enrich listening vocabulary, and enjoy the story. To use the app and see the 3D models of the storybook, users must install the Storybooks alive™ App. Similar to all AR storybooks, it also needs scanning, and once done, users can now entertain themselves [5].

2.6 Educational Magic Toys Developed With Augmented Reality Technology for Early Childhood Education

This study shows how augmented reality applies to children's toys that helped these kids develop their cognitive skills. It aims to reveal teachers' and children's opinions on educational magic toys (EMT), to determine children's behavioral patterns and their cognitive attainment, and the relationship between them while playing EMT. The study revealed that teachers and children liked EMT activity. The children interactively played with these toys but not had high cognitive attainment. Hence, the researchers of this study concluded that these toys could be effectively used in early childhood education. However, collaborative and interactive learning with these toys should be provided. Moreover, this study provided an important contribution to the proponent's system to fully understand the use of AR technology in children's learning [6].

2.7 Peronio Pop-up Book

Peronio Pop-Up Book is an application developed by Ovni Studios it is a game app that can be played in two platforms, it is either Virtual Reality or Augmented R. The story of Peronio is about the adventures of a boy who cannot decide what he wants to be when he grows up. During Peronio's journey, the users will explore different challenges and mini-games. Playing Peronio can be on Augmented Reality and Virtual Reality both give different immersion. To use the augmented reality of Peronio, the users have to access the markers in Peronio.

To realize, the user may use two options. The first option is to print the Peronio target, open the app, and scan the markers on the printed area, and the 3D objects will show up. So the other option is to access a URL of Peronio, open the app, and then scan the markers, then the users can start playing the game on their phone. For Virtual Reality, the user has to use a virtual reality glass technology to be immersed in the game. The game will function with every low-cost VR glasses like Google Cardboard [7].

3. METHODOLOGY

3.1 Data Gathering

In the gathering of data, most of the information collected was from teachers, students, and artists at the University of Mindanao, Davao City, Philippines. Grade school teachers and parents who have children ages 6 to 7 years old, were asked to evaluate the written story.

3.2 Conceptual Framework

The methodology for development used in this study is the Agile Development and are in forms of the sprint to wit: information gathering, design analysis, development, testing, and deployment. Figure 1 illustrates the conceptual framework of the AR project. In using GoonAR, the mobile device hovers over the pseudo-book with markers, as shown in Figure 2.

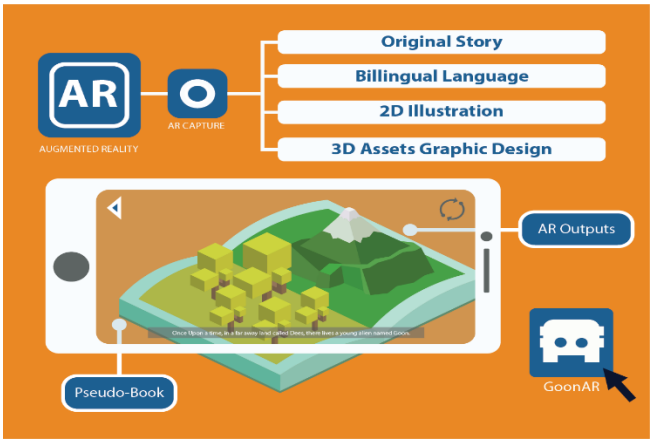

Figure 1: Conceptual framework of GoonAR

Figure 2: AR display sample

Additionally, the story is written for the younger reader. With the AR technology, 3D models appear before the user's eyes. These 3D models are viewed through any angle, such as in front and sides. Furthermore, the system has two features; the AR Camera and Kids Prompt. The AR Camera is a feature that lets the user take images of the 3D objects with them. An original 2D illustration and 3D graphic design are creatively made, with a bilingual language in the system using the English and Filipino languages.

3.2.1 GoonAR Pseudo-book

A GoonAR pseudo-book is handmade using vellum board for the story, illustrations, and contents with a book cover of 8.5x11 inches in size. A kettle stitch bookbinding is done using needle and thread.

Moreover, the prints of the book will all be done by the proponents using owned printers. The making of the storybook might change shortly. The proponent will be making the consideration of mass production of the book and searches for people who will publish the book. In this way, the proponents will be considering it as an option for the output.

3.2.2 Story Synopsis

Once upon a time, in a faraway land called Dees, there lives a little green man named Goonar. Goonar is a smart boy. He likes to build stuff. Goonar dreams of becoming a great inventor.

Most of the time, he succeeds, but sometimes he fails, but the most important thing for him is that he never stops inventing, no matter how many times he fails or succeeds.

One day, the King of Dees ask the people for help. He said, “My beloved people, my precious book has been taken by a giant bird who flew high in the Floating Land. I need your help to take it back.”

Goonar steps forward, saying he will invent a device for him to fly to the Floating Land. Will Goonar be able to do this impossible task?

3.2.3 Design

Before getting awed by the 3D animation that people see, there is always the two-dimensional design that the artist does. In this part of the asset production process, sketching the assets is done in Adobe Photoshop using Wacom Graphic Tablet, followed by creating illustrations of the characters and the environment of the GooAR system. Figures 3-4 show the sketched storyboard and character design of GoonAR. Further, Figure 5 shows an asset, which is a humanoid based character made in Blender. A blender is a software that is free and an open-source 3D producing suite. This technology is used to render the designs from Photoshop into 3D, making the assets look alive in the augmented reality scene. The character has undergone a process called rigging. The octahedral shapes seen in the character are called bones. This bone indicates that the character is rigged and is ready for animating. Then rigged and animated characters can now be

imported to Unity. Unity is a cross-platform game engine that is free and easy to use. The programming language that is used in Unity and in developing the app in C#. To produce audio of the application, the Audacity software is utilized.

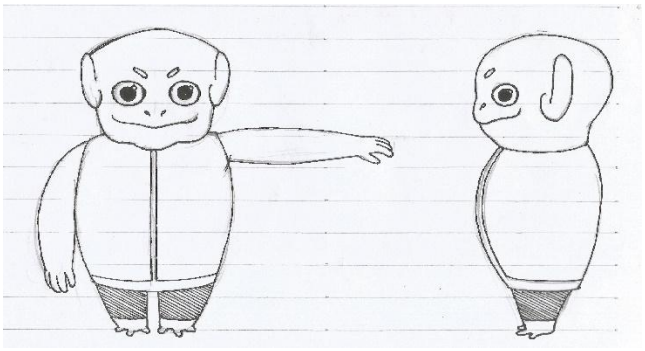

Figure 3: Character Sketch

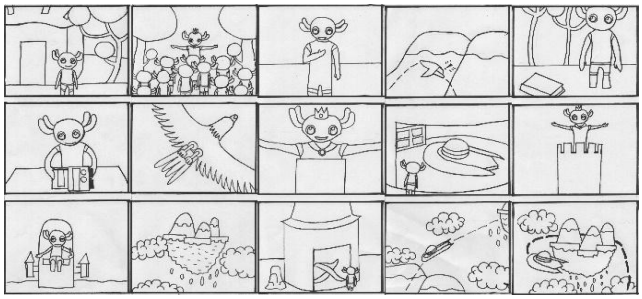

Figure 4: Storyboard

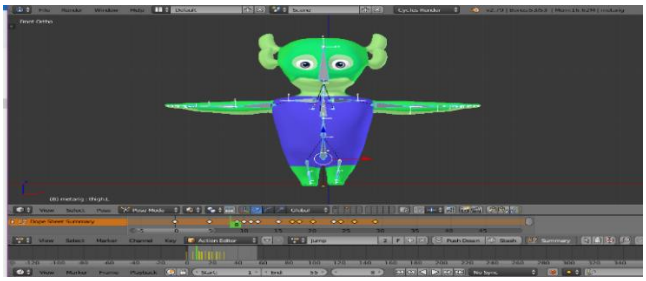

Figure 5: Character Rigging

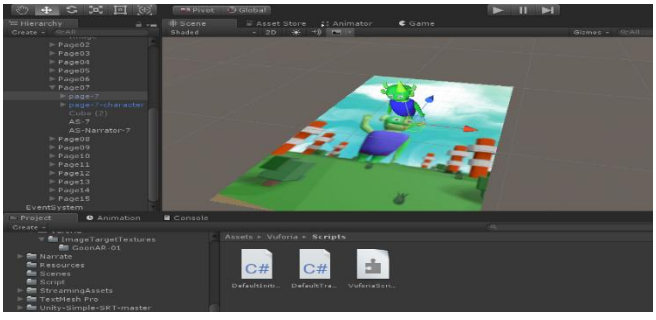

Figure 6: AR image tracking

To observe fluidity in motion, a loop of animation is made to the animation assets imported from Blender to Unity, bringing the character assets to life. Another technology used is Vuforia. Vuforia is an extension of Unity that handles the augmented reality features of the game engine, enabling Unity to make augmented reality animations. Figure 6 shows a 3D green alien standing on the unique image added with unique markers in the Pseudo book. This shows that the unique image triggered the AR scene, thus displaying an AR humanoid asset.

3.3 Use Case Diagram

This section shows the cases to what extent that the intended users can do with the application. The intended users are the parent/guardian and the child/student. Figure 7 shows the use case diagram of the system where system functionalities are accessed by different types of users in the application.

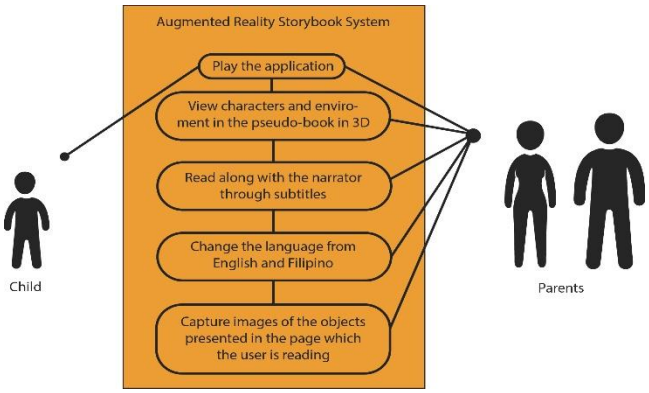

Figure 7: Use case diagram of the application

4. RESULTS AND DISCUSSION

4.1 Usability Assessment

Table 1 shows the result of the usability test conducted by basic education to the grade 1 students from the University of Mindanao, Davao City, Philippines.

Table 1: Indexed usability testing result

	1	2	3	4	5	Total Respondents	Mean
This application is easy to use.				1	9	10	4.9 *Very Highly Satisfied*
I can see the 3D objects display clearly.			3	1	6	10	4.3 *Very Highly Satisfied*
I enjoy using the application				2	8	10	4.8 *Very Highly Satisfied*
I like the book.					10	10	5.0 *Very Highly Satisfied*
I can read the subtitles easily.			1	3	6	10	4.5 *Very Highly Satisfied*
The narrator's voice is clear.			2	1	7	10	4.5 *Very Highly Satisfied*
I love the characters in the book.			1	1	8	10	4.7 *Very Highly Satisfied*
The design of the book is very nice.			3		7	10	4.4 *Very Highly Satisfied*
I like the sound in the application.			2	2	6	10	4.4 *Very Highly Satisfied*
The camera			4		6	10	4.2 *Very*

detects the marker perfectly.							*Highly Satisfied*
I can take picture easily.			1	1	8	10	4.7 *Very Highly Satisfied*
I would enjoy using this application frequently.				2	8	10	4.8 *Very Highly Satisfied*
Rating Scale							
4.20 – 5.00							*Very Highly Satisfied*
3.40 – 4.19							*Highly Satisfied*
2.60 – 3.39							*Moderately Satisfied*
1.80 – 2.59							*Less Satisfied*
1.00 – 1.79							*Unsatisfied*

The main purpose of the application called "GoonAR: The Great Inventor" is to provide a mobile augmented reality storybook application that lets children engage in learning with great interest. The target user of this application are children ages 6-7 years old and will be assisted by their parents when using the technology.

In this study, several tests viz., the alpha and beta test, mobile application test, screen resolution test, camera test, marker distance test, marker light detection test, RAM and CPU test, and Android version test were conducted as shown in Tables 2-9. Tests revealed that the application is operational when used to mobile phones running in an Android operating system with version 5.0 Lollipop and above, having 1GB RAM as the minimum requirement and a free memory storage space of 103mb. The required screen resolution of the application ranges from 1280 x 720, 1480 x 720, and 1520 x 720 pixels with a camera having at least eight (8) megapixels to display the 3D objects within bright daylight, room light, and overcast lighting environment. Lastly, the minimum distance capture of a marker is 15.24 cm, with a maximum distance of 162.56 cm.

Table 2: Indexed mobile application testing

Mobile Phones	OS Version	Camera Quality	Results
Samsung Galaxy J4 Core	Android 8.1 (Oreo)	8 MP, f/2.2, AF	Passed, Clear Image
Realme C1	Android 8.1 (Oreo)	13 MP + 2mp Dual Cam	Passed, Clear Image
Xiaomi Redmi 5	Android 7.1.2 (Nougat)	13 MP	Passed, Clear Image
Oppo A37	Android 5.1 (Lollipop)	8MP	Passed, Clear Image
ASUS Zenfone 4 Max (ZC554KL)	Android 7.1.2 (Nougat)	13 MP	Passed, Clear Image

Table 3: Task performance

Task	Expected Output	Result (Passed/Failed)
Open and Install application	Display application in the homepage	Passed
Tap Play Button	Direct to the camera	Passed
Tap the Gallery Button	Display the Gallery Page	Passed
Tap the Help Button	Display the Help Page	Passed
Tap the About Button	Display the About Application Page	Passed

Table 4: RAM and CPU testing

RAM and CPU Specification	Remarks
1 GB, Quad-core 1.4 GHz Cortex-A53	Passed
2 GB, Octa-core 1.8 GHz	Passed
2 GB, Quad-core 1.2 GHz Cortex-A53	Passed
2GB, Quad-core 1.4 GHz Cortex-A53	Passed
3GB, Octa-core 1.4 GHz Cortex-A53	Passed

Table 5: Android version testing

MOBILE OS VERSION TESTING		
Android Version	**Remarks**	**Results**
Lollipop 5.0	Passed	Runs Smoothly
Marshmallow 6.0	Passed	Runs Smoothly
Nougat 7.1	Passed	Runs Smoothly
Oreo 8.0	Passed	Runs Smoothly

Table 6: Screen resolution testing

Resolutions	Remarks	Results
1280x720 Pixels	Passed	Clear Image
1480 x720 Pixels	Passed	Clear Image
1520 x 720 pixels	Passed	Clear Image

Table 7: Camera quality testing

Mobile Phone	Camera Quality	Results
Realme C1	13 MP + 2 MP	Passed
Xiomi Redmi 5	13 MP	Passed
ASUS Zenfone 4 Max	13 MP	Passed
Oppo A37	8MP	Passed
Samsung Galaxy J4 Core	8MP	Passed

Table 8: Distance testing

Distance Captured	Results
12.7 cm & below	Failed
15.24 cm	Passed
33.02 cm	Passed
86.36 cm	Passed
162.56 cm	Passed
Above 162.56 cm	Failed

Table 9: Lighting condition testing

Lighting Condition	Results
Bright Daylight	Passed
Overcast Light	Passed
Low Light	Failed
Room Light	Passed

4.2 Book Fabrication

Figure 8: Snapshot of book pages

In this study, a pseudo-book for the GoonAR Application was designed and created. The book is a softbound book with 15 pages. The content images are graphically designed, illustrated, and was rendered with 3D scenes in Blender. The images serve as the markers of the application for augmenting 3D objects. Figure 8 shows the front and back cover of the book entitled "GoonAR, The Great Inventor" along with its pages that serves as markers for the mobile application, and Figure 9 shows the actual physical book after fabrication.

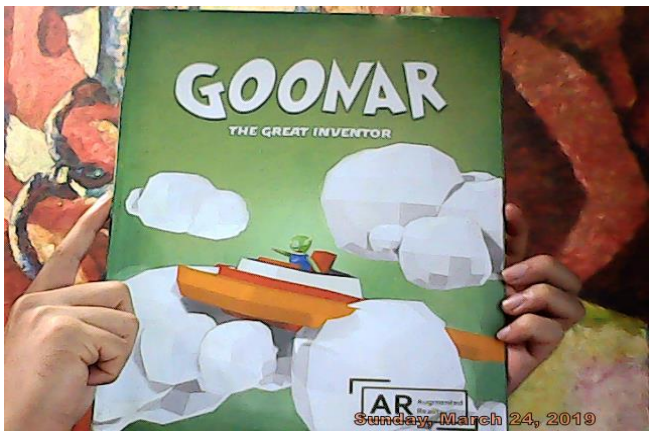

Figure 9: Physical book

5. CONCLUSION

The development of an augmented reality children storybook called "GoonAR: A Bilingual Children Storybook" is a success that is made possible through the use of augmented reality technology. The augmented reality pseudo-book consists of 15 pages illustration that displays 3D objects once the image is scan by a mobile device where the target marker is found by using a mobile application. The animated character, 3D scene, background music, narrator's voice and the subtitle for the story, are some of the most notable functions of the application that is made possible with unity game engine and visual studio for programming the system, and Vuforia framework for the AR markers for projecting 3D objects. Blender was used for designing eye-catching graphics, delivering 3D animation of the app while the Audacity software application was used for audio. In this study, the proposed application has successfully met the users' requirements and accomplished the objectives after a series of testing, verification, and validation being conducted.

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