Enhancing Learning at Primary School Through Augmented Reality

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Abstract. Studies have shown that interaction with the subject content in class is important to allow students to enrich their learning. Augmented Reality (AR) provides this unique capability of blending real and virtual worlds to allow students to be engaged in practical experiences. According to studies, the application of AR in the education sector is minimal mainly because government is not giving support financially. In Mauritius, the government vision is to equipped schools with tablets thereby increasing ICT literacy among students. Hence an AR application based on android platform has been developed to help Mauritian primary students to better comprehend the history and Geography subject. The AR application has been tested on different mobile phones in order to know the minimum requirements of device that can support the application. Furthermore, the application has been deployed on mobile phones of 10 teachers and feedback received from teachers was encouraging.

Keywords: Augmented Reality · Learning · ICT · Application

1 Introduction

The application of appropriate technologies in education can impact on students learning behavior and can encourage them. According to research, the use of different types of media to teach theory can improve knowledge and maintain better cooperation among students [1]. Augmented Reality (AR) is a new emerging technology which consists of virtual information overlaying the physical world in real time thus connecting the real and virtual world together continuously [2, 3]. Educational researchers acknowledge that AR can offer new opportunities for teaching and learning [4, 5]. AR can enhance the academic environment by engaging a learner in different interactive techniques that were impossible before. AR can offer students a deeper learning experience by allowing them to handle spatial link of existing physical objects. This can in turn supplement another mode of learning mainly for visual–motor [1]. In addition to that, AR gives the opportunity to students to adjust their own way of learning and hence allow for more genuine education and training styles. Several studies have revealed that AR applications in academic environments are interesting,

P. Fleming et al. (Eds.): ELECOM 2018, LNEE 561, pp. 245–255, 2019.
https://doi.org/10.1007/978-3-030-18240-3_23

motivating and thrilling [2] [6]. In Mauritius, the Ministry of education has initiated various ICT projects and the ICT infrastructure in schools is being upgraded. Nowadays, most schools are equipped with ICT labs and ICT is used as a tool for teaching and learning [7]. In this respect, an AR application to promote learning of students in history and geography has been developed in primary school. Section 2 relates to the work already done in the educational field, Sect. 3 gives an overview of the proposed system, Sect. 4 is based on implementation and testing and finally Sect. 5 gives the conclusion.

2 Related Work

The application of AR in education can range from learning basic set of letters in kindergarten to studying more complex theories in post graduate studies. The use of Augmented Reality in education run the whole gamut of learning styles from visual to verbal. This technology makes students become active learners by giving them the opportunity to engage in activities and view simulations of what they are being taught. According to research [8], the learning of mathematics can be enhanced with the use of AR. Several studies have been carried out and several educational apps based on AR have been designed and used to enhance learning. For instance, SUNRA is an AR application used to complement students learning about the solar system. The GeoAR is an AR application used for teaching geometry. The SMART application uses AR to teach basic concepts about different transportation and types of animals [8]. Augmented Reality System has been proposed for training autistic children [9]. The authors in [10] have proposed an AR systems for infant which is based on picture puzzle. Anatomy 4D is a mobile app that provides an interactive way to learn about the human body through augmented reality [11]. ARCircuit is a mobile app that can be used by students to build and test electrical circuits using AR [12]. In another study, an AR application was implemented to teach preschoolers about natural sciences [13]. According to several studies, the use of AR systems in class can motivate, entertain and hence provide a better and favorable environment for learning. However, these AR applications require some investments in research and design to be effective as compared to traditional teaching techniques. Consequently, this can hinder their use in class in spite of all the mentioned advantages [3].

Additionally, there are two types of AR applications namely marker based and markerless. In order for any AR application to estimate the orientation and position of a camera with respect to the real world frame, the applications require some form of tracking. Marker based AR make use of printed images (bar codes or QR codes) [14], while markerless AR use some types of localization technology (GPS, RFID) to interpret the physical and virtual world [15]. Some tools that can assist in building AR applications include OpenGL®, Vuforia, Unity and Blender among others.

3 Proposed Solution

In order to decide the AR application which has to be designed, a survey was conducted among 30 teachers from different primary schools in Mauritius. The goal was to find out the current technologies that they are using for teaching and also to obtain their opinions of using 3D models as teaching. A questionnaire consisting of several questions were designed but there was no mention about 'Augmented Reality' so as to prevent any biased opinions. The feedback received reveals that more that 60% of the teachers use technology as an aid for teaching in class. Results shows that 30% use projectors and 30% use tablets in their class. The concept and use of 3D in class were accepted by all 30 teachers and 61% found that the concept of 3D is more suitable in subjects like History and Geography. Therefore, the AR application that will be implemented will be based on a History and Geography topic namely; the Naval Battle of Grand-Port and it will make use of markers. Until now, students have learned Mauritian history only via text or artistic rendering of the battle. Students find it hard to relate to something that is nearly over 200 years old. However, there is no AR application that is specific in context to Mauritius. Hence the AR application that will be implemented will be custom-made for Mauritian students and will allow students to better relate to what they are learning. The Naval Battle of Grand-Port is an ideal choice because it will depict the battle between the British and French colony as well as the geographical location of the battle of Grand Port in one single application. The student will be able to interact with the battle, view it in from different angles through the use of a mobile or tablet in class. Hence, students will have the ability to watch and interact with past events in the present.

4 Implementation

The AR application has been developed using Blender as the 3D Modelling Software, Unity3D as the game Engine and Vuforia SDK for the augmented Reality API. C# has been used as the scripting language. The implementation phase consisted of modelling, creation of marker database and creation of the AR mobile application (Fig. 1).

Some illustrations of the 3D models created for the Battle of GrandPort as shown in Table 1.

The markers to be used in the project are created using an online QR code generator. In this study, four QR codes have been used as Markers. They are each generated by unique keywords to make them distinct. The User Interface has 2 parts, the main menu and the information menu. Table 2 illustrates the user Interface.

A narration track about the Battle of GrandPort and sound effects were included in the application. Table 3 shows some screenshots of the AR application.

4.1 Performance Testing

The application has been tested on 5 different Android devices each having different hardware specifications. This test will determine the ideal hardware specifications of a

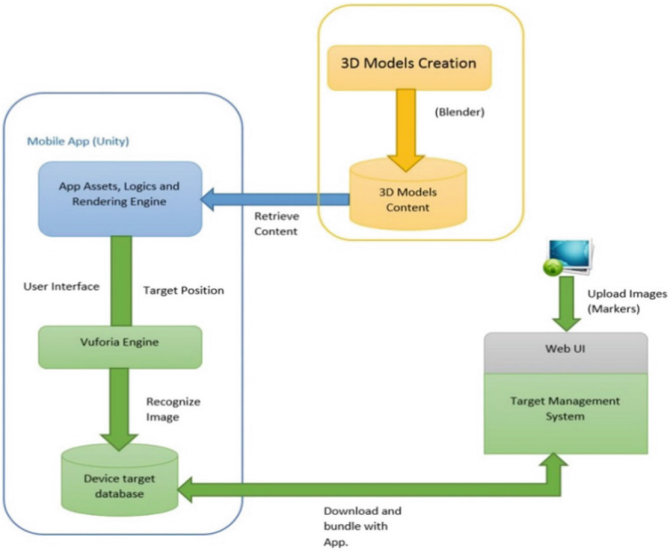
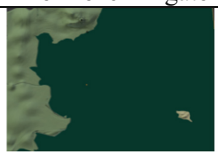
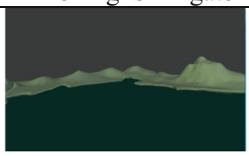


Fig. 1. System architecture

Table 1. 3D models created for the Battle of GrandPort.

 The French frigate	 The English frigate
 Top battle field model	 A perspective view of the battlefield model.

device that can run the application efficiently and with good responsiveness in a school setting. System Monitor by Pavel Petrov was used to measure the performance of the app. The specifications of the Android devices used for testing are listed below. Table 4 illustrates the devices number from low to high CPU specifications.

Table 2. The user Interface.

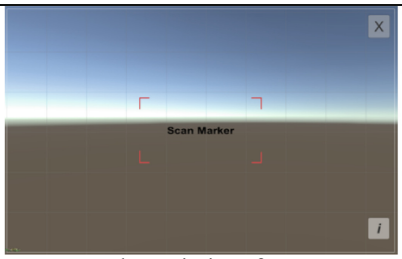
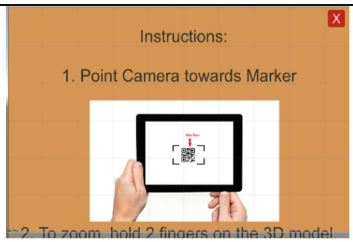
 The main interface The interface consists of a panel designed as a target to show focal point, so that the camera can detect the marker easily. It also contains two buttons, the Exit button to close the application and the Info Button to navigate to the Information Interface.	 The information Menu The Information Interface consists of a panel containing a Scroll View which is an UI GameObject in Unity. This panel displays text and images to show instructions on how to scan, translate, rotate, zoom in and zoom out 3D models. It also contains a HideInfo button to go back to Main Interface.

Table 3. Some screenshots of the AR application.

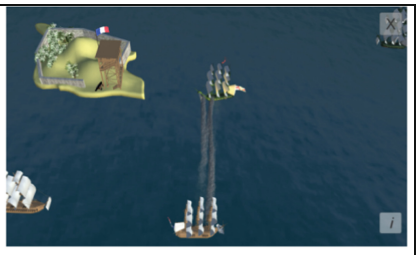
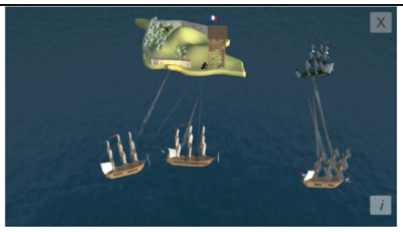
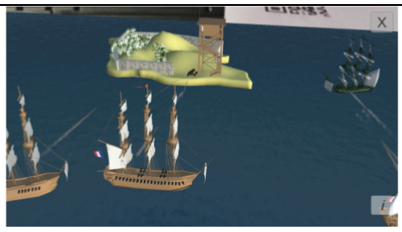
 English Frigate approaching the island	 The French Frigate attacking the English Frigate
 The English and French frigates approaching the battlefield	 The French frigates close to the battlefield

Table 4. The devices number from low to high CPU specifications.

Device No	Device Name	CPU	Memory/ GB	Battery/ mAh	GPU	OS Version	Resolution
1	Samsung Galaxy Core Prime	Quad-core 1.2 GHz	1	2000	Adreno 306	5.1.1	480 x 800
2	Samsung Galaxy E5	Quad-core 1.2 GHz	1.5	2400	Adreno 306	5.1.1	720x1280
3	Samsung Galaxy On5	Quad-core 1.3 GHz	1.5	2600	Mali-T720	5.1	720x1280
4	Samsung Galaxy J7 Pro	Octa-core 1.6 GHz	3	3600	Mali-T830 MP1	7	1080x1920
5	HTC Desire 820G+	Octa-core 1.7GHz	1	2600	Mali-450MP4	4.4	720x1280

During testing, the following measures were taken to ensure consistent result in all devices:

- Flight mode was activated.
- All background apps were terminated except when measuring memory usage and CPU load, which required the System Monitor application to be running.
- Testing was done using the same full size A4 paper marker.
- The orientation of the rear camera was kept perpendicular to the marker at a distance of 0.20 m.

The performance testing was done based on the FPS (Frame per second), Loading time, Battery usage, Memory usage, CPU load, Maximum marker distance. For each one, five trials have been carried out and an average has been calculated. A waiting time of 2 min was allowed between trials. During each trial, the app was closed and

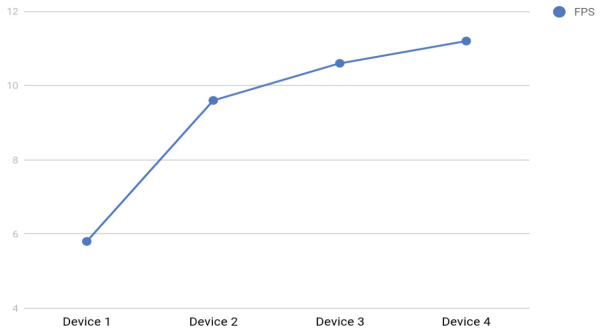


Fig. 2. The higher the specification of the device, higher is the frames per second

rerun afresh. Device 5, with OS 4.4, was used as an extreme test case. As expected, the app crashed for all the above mentioned tests. This shows that the app only works on OS above version 4.4. Consequently, device 5 was not included in any graph displayed (Figs. 2, 3, 4, 5, 6 and 7).

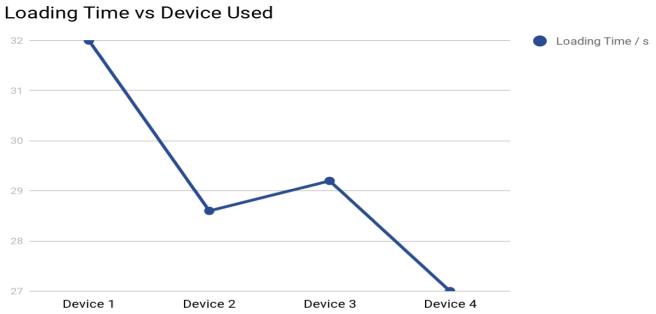


Fig. 3. The higher the specification of the device, lower is the loading time

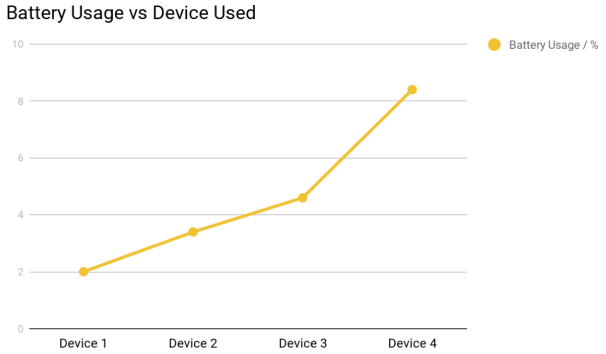


Fig. 4. The higher the specifications of the device, higher is the battery usage

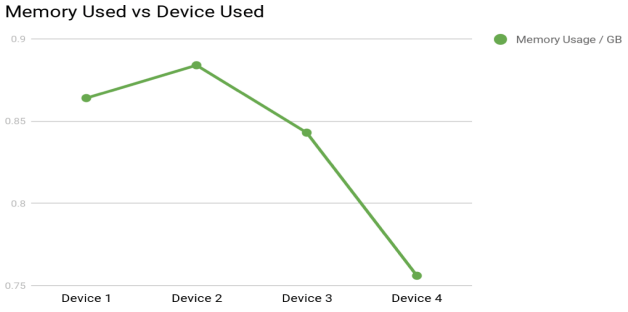


Fig. 5. The higher the specification of the device, lower is the memory usage

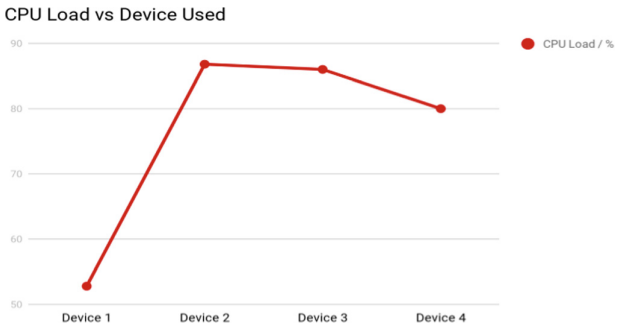


Fig. 6. A low CPU load for device 1 but the other devices are decreasing gradually towards 80% range.

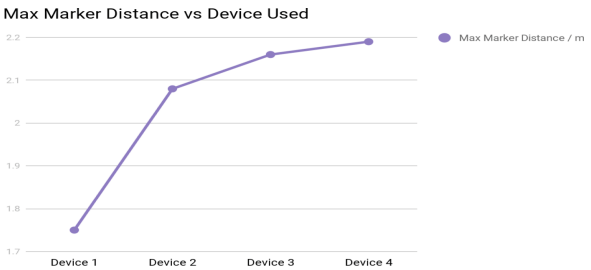


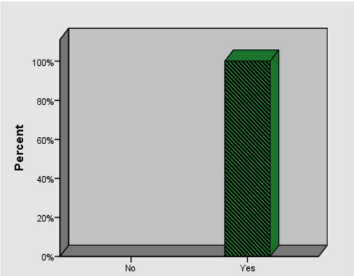
Fig. 7. The higher specifications devices are detecting markers from larger distances.

From the test carried out, it can be deduced that a device with high CPU cycles, greater number of cores and large memory space, is desirable for achieving high FPS. A high FPS is preferable as responsiveness is increased. Low FPS will result in lagging. Secondly, high specifications also result in lower loading time, but the difference between a 1.7 octa-core and 1.3 GHz quad-core is only 2 s. Given that the user has already waited 29 s, it would not be advisable to use a high performance device just for a reduction in 2 s waiting time.

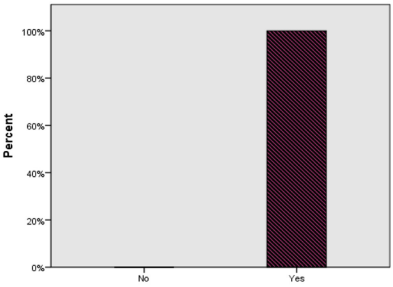
Device 1 having low CPU load may be the cause for its low FPS. On the other hand, the other devices all have above 80% CPU load. High specifications devices also suggest efficient memory usage. Device 4 has the lowest memory usage. High specifications devices maintain larger distance from the marker before the app loses track of the marker. This may be specifically caused by the high resolution of device 4, which is at 1080 $\times$ 1920 pixels. Larger number of pixels means easier to find marker details. However, as seen in the Battery Usage graph, a high specification also means high battery usage. It would be pointless to have an app that drains the battery during a short period of time and requires constant recharging. It can be seen that Device 4 drains 4

Table 5. Response from questionnaire for acceptance testing

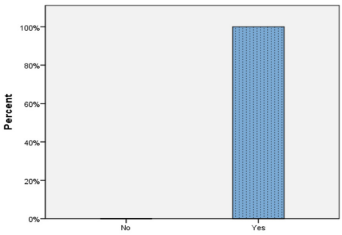
Question 1 - Was the user interface easy to use?



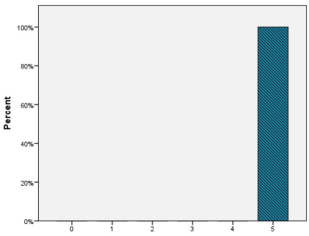
Question 2 - Were the instructions provided in the app clear to understand?



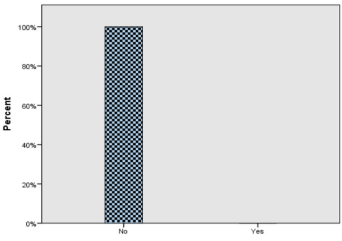
Question 3 - Were the 3D models interactive?



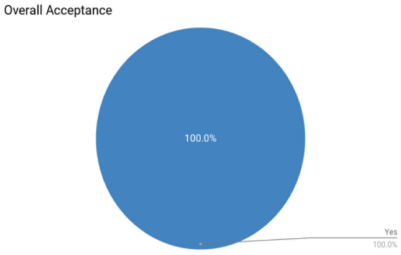
Question 4 - Was the application content relevant to the syllabus of your class?



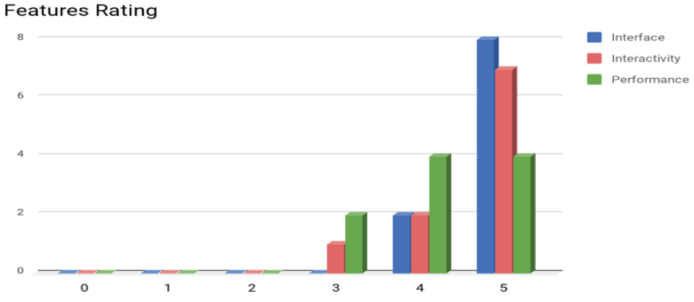
Question 5 - Did you encounter any problems while using the application?



Question 6 - Will you use such application as a teaching aid?



Question 7 - Rating Features of the App



times as much battery as Device 1 in 1 5 min session. After evaluation, the minimum requirements of a device are as follows:

Name: **Samsung Galaxy Core Prime**
CPU: **Quad-Core 1.2 GHz**
Memory: **1 GB**
Battery: **2000 mAh**
OS version: **5.1.1**
Resolution: **480 × 800**

4.2 Acceptance Testing

The application was made available to a group of 10 primary school teachers. After using the application, the teachers were asked to answer a questionnaire in order to get an overview of the success of the application. Table 5 shows the responses that were obtained from the questionnaire.

From the results, it can be deduced that the user interface was very appealing to the users. The instructions were added as help to allow users to use application autonomously. According to the participants, the instructions were very clear and simple to understand. The users were asked to interact with the model. The answers reflect the success of the operations (rotate, scale, translate) implemented in the application as all users were able to interact successfully with the 3D models. In the survey conducted in the analysis phase, the teachers had a requirement of 3D Model for History and Geography as teaching aid. The aim of this question was to find out whether the content of the application developed was in line with the topic that was taught in class, the battle of Grand Port in this case. The users confirmed that the application content was indeed relevant to what the students are learning and this can be used as a teaching aid. From the results, it can be concluded that no major problem was encountered by the users. The application features were given an overall rating of 4–5 by most participants except for some. The user greatly appreciated the user interface, however one or two users experienced some lagging and heating of mobile phone. It is worth knowing that these minor problems were due to the capacity of the users' device.

5 Conclusion

Augmented Reality applications are powerful tool that can be used to supplement teaching and enrich learning in any academy. With the widespread use of mobile devices in classroom nowadays, instructors can harness the potential of AR applications and enhance students learning by generating immersive and in context understanding. However, AR applications are still in infancy phase in Mauritius though it shows promising benefits in the education sector. This is mainly because many educators are unaware of this technology or they do not possess the required technical expertise to design and use the AR application. In this paper, an AR application has

been proposed for primary students to enhance their learning in subjects like Geography and History. Responses obtained after a survey carried out shows that such application has promising future in the schools.

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