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Implementing Augmented Reality (AR) on Phonics-based Literacy among Children with Autism

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***Abstract*— The implementation of Augmented Reality (AR) technology in education has created an interesting approach to enhance the effectiveness and attractiveness of teaching and learning for students in real-life scenarios. This medium offers unique affordances, combining physical and virtual worlds, with continuous and implicit user control of the point of view and interactivity. This paper introduces the technology of augmented reality and its capabilities in facilitating children with autism. AR is a technology that overlays digital information on a live view of the physical world to create a blended experience. AR provides unique experiences and opportunities to learn and interact with information in the physical world. Hence, AR can be one of the effective technologies available in developing tools for teaching and learning with the combination of the virtual world and real objects such as transportation, fruits, numbers, and alphabets. This will facilitate the autistic child to recognize the abstract concepts of the real objects and their descriptions. The purpose of this paper was to investigate the use of AR on mobile devices in fostering literacy in academic and learning skills for children with autism using the phonics learning method. This prototype helps the autistic child to capture and associate the graphics or pictures of the surrounding objects so as improving the literacy and learning skills of the children. The results show that the children can pronounce and to distinguish between vowels "a", "i" and "u". The children are also able to answer most of the questions in the exercises provided. The interactivity between the children and the application raises their attention and focus mainly in literacy and learning skills.**

***Keywords*— augmented reality; autism; literacy; learning skills; mobile; phonics method.**

I. INTRODUCTION

According to the National Institute of Mental Health (NIMH), USA- "Autism is a group of developmental brain disorders, collectively called Autism Spectrum Disorder (ASD). ASD is characterized by persistent deficits in social communication and social interaction across multiple contexts. " With the progress of information technology development, the form of digital learning multimedia materials has changed dramatically from traditional books to digital media. Thus, the learning becomes more lively and exciting. As for the traditional teaching in classrooms, the interaction between teachers and students is usually by gestures as well as discussions, lack of exciting learning and interaction. On the shelf, there are many interactive learning media, changing the traditional learning way [1]-[4].

Based on the previous research works, children with autism benefit a lot from audio-visual teaching methods such as Picture Exchange Communication Systems (PECS), visual routines, and social stories. These methods use a picture or graphic printed on cards and other hard copies. Mobile-based AR is a cutting-edge technology that combines the objects in the real world and interactive virtual world to engage the focus of the children using any smart handheld devices.

In school environments, children with autism are categorized as special education and problematic children in learning because it is difficult to stay focus in a lesson [5]. The imagination of children with autism is limited so learning styles such as sophisticated writing and reading are too challenging to understand. Therefore, this will cause them less attention and could not stay focus on learning sessions [6]. Children with autism are individuals with high visual abilities [7]. Visual support is an effective source of help to be applied in their learning style [2], [3],[8]. Recent studies also show that children with autism are more likely to understand pictorial, touch, movement and sound methods [9]. Augmented reality is one of the new potential technologies in education [4], [10], [11]. In the field of

education, technology is one of the factors that influence the reforms in supporting learning activities as well as the potential to help deliver meaningful learning, conducive and interactive lessons to students [12]. The transformation in the educational system caused by this technology will surely provide an exciting opportunity to provide realistic, authentic, engaging and fun learning environments and enhance the learning process [2], [3], [13]. Augmented Reality (AR) offers the best tools for developing integrated learning environments where it supports the manipulation of physical objects and visualization of learning content as well as enriching experiences in children's learning [14]. AR stimulates the imagination of children without reducing them concerning reality and preparing an interface that is normally applied in educational environments where physical objects are used for meaningful delivery purposes [15], [16]. Conventional teaching and education methods that rely on textbooks and basic practical lessons have certain limitations in supporting students to enhance their understanding and intellectual skills [17]. They also have limitations in supporting students with different cognitive abilities and learning styles. Furthermore, this teaching system is believed to be less effective in attracting them to learn to read. Multimedia technology comprising five main interactive components namely text, graphic, audio, video and animation are very useful in encouraging children to learn to read [18].

AR technology had a high impact on children with autism because they are recognized as visual learners and also provide a learning environment that fits their learning style [19]. Besides, the imagination of children with autism is limited, so sophisticated writing and reading are too challenging to understand. In other contexts, they better understand with pictures, movements and sounds [7]. Another research focuses on AR technology that integrates mobile devices in real-world using visual and audio to enhance interactivity in teaching aids as well as provide more intuitive learning methods for children with autism. Visual and audio are the best support to help children with autism improve phonics literacy [20]. There is an improvement indicating that visual support can help some children with autism learn better and pay less attention [21]. Referring to the previous study, children with autism can demonstrate a good response using visuals in mathematics and art [22]. Besides, audio support through phonic literacy can help children with autism to mention and sound a clearer word [23].

Consequently, developers want to study how far mobile AR applications can help children with autism to improve learning through phonics. The method of reading learning for children has now changed from the syllable spelling system to the phonetic reading system. This approach is used as the teaching strategy is more dynamic than the traditional method of a reading system [24]. The phonics method has long been practiced in developed countries. The phonics method focuses on the sound of symbols, in contrast to traditional methods that emphasize the typography technique. This method slightly reduces the burden of children to remember.

Learning the phonics method is a combination of built-in sound words or word built-in sound [25]. For every single word spoken, there are the sounds mentioned in daily activities, eg. me and how to pronounce the word s / a / y / a quickly [26]. Similarly, with other world languages. Examples in English, the word 'paint' consists of a combination of a few alphabet sounds. The word revealed during speech is a combination of the sounds contained in the word. However, in English the sound / k / is represented by the letters 'c', 'k', 'ck' and 'ch'. Typically, each letter has certain sounds. For example, the letter 'a' sounds (aa) not the letter 'ei'. When the letter 'b' is introduced, the sound of the consonant being taught is (beh) not 'bi'. All these sounds will be combined to produce the sounds of the words read [26]. Preferably a start, a word that starts with a short and easy vowel used, for example, the use of a vowel, i, u at the beginning of a word. Next consonants such as, "*ny*", "*kh*", and "*sy*" will be combined as word end or mid-word [26]. The phonics method is the ideal method for teaching children reading because this method has been scientifically proven, how the human brain read [27]. A study by the university Yale, USA, has proven that the brain reads by breaking the words seen to the sounds, then the brain sounds the letters (combining the sounds) seen to read or read the word. In this study, autism children learning styles require software course developers to be sensitive to the need to address communication problems and to speak among themselves. Given the limited autism of autism children, reading materials or interactive multimedia products should be relevant to the child's experience in order to enhance their understanding [28].

II. Materials and Method

The prototype of the android application described here uses Augmented Reality (AR) technology based on marker. This AR application detects an image based on the Flashcard while the camera focuses on the marker. Pattern markers and objects are designed and save as a formatted file in the database to enable the camera tracking. The pattern is generated by using the target manager in Vuforia Unity. The markers are then printed as a card which becomes a medium for autism children to learn the spelling of some simple words via phonics. As the camera tracks the marker, the display shows the 3D object together with the spelling which can interactivity be touched to produce the sound of individual letters. The image is processed and a 3D-object will be generated together with the text representing the name of the object. It allows users to interact with the object and the letters by touching them to produce phonics learning in which the sound of the vowels, the consonants and the whole world will be played back. The application also provides an interesting exercise in which the user can drag and drop the corresponding initial vowels to complete the word. The visual and audio supports from this application are observed to give a positive response towards improving literacy learning. The children are able to answer most of the questions in the exercise very well. The interactivity between the children and the device raises their attention and focus on the learning as well. In conclusion, this application provides an effective approach for phonics literacy learning among children with autism and it is good alternative to teachers and parents to encourage their kids to learn phonics.

This application focuses on a particular phonics approach, which concentrates at the beginning of a word in which the main group target for this approach is the beginner level children with autism, which is defined by the teachers. For that purpose, ten autistic children are selected by the teachers through observation during the class sessions. Besides, the application intended to help children with autism increase their literacy skills which contain reading, pronouncing and spelling particularly in the Malay Language. This mobile AR application provides a content creation platform for the parents and special educators to create various lessons through their regular smartphones, which otherwise make the process tedious and time-consuming. This allows overcoming the limitations imposed by conventional methodologies like cutting and pasting pictures, writing descriptions and teaching the child orally. Since these can be handled by multimedia based three dimensional (3D) images and audio-visuals, a mobile application supporting the implementation would be useful to the parents, teachers and children.

This application supports various multimedia elements such as text, visual, audio and voice narrations. The 3D models can be overlaid over real objects in real-time. AR mobile works by tracking an image on the flashcard which captured in by the camera device. The image is processed and a 3D-object will be generated together with the text representing the name of the object. It allows users to interact with the object and the letters by touching them to produce phonics learning in which the sound of the vowels, the consonants and the whole word will be played back. The application also provides an interesting exercise in which the user can drag and drop the corresponding initial vowels to complete the word. The visual and audio supports from this application are observed to give a positive response towards improving literacy learning. The system architecture is depicted in Fig 1. below.

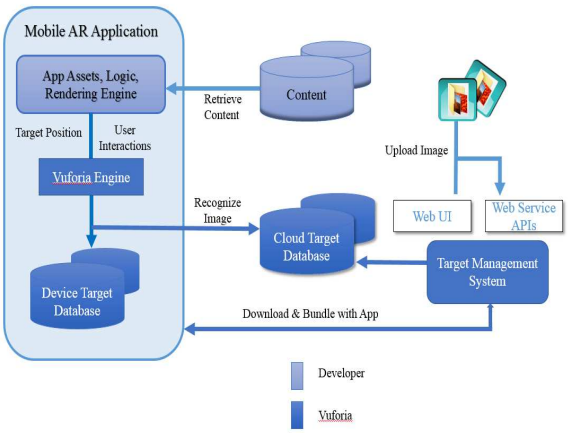

Fig 1. The architecture of Mobile AR Application

The diagram in Fig 1. shows an overview of the application development process with the Vuforia platform. The platform consist of the Vuforia Engine (inside the SDK), the Target Management system hosted on the developer portal (Target Manager), and optionally, the Cloud Target Database. The Framework contains activities, Augmented Reality Phonics Learning Environment" and "3D Education Games".

A. Augmented Reality Phonics Learning Environment

In this study, AR display is built on 3D vuforia unity software while AR marker cards are designed in Adobe Photoshop software. The AR marker card is stored in the format of the .jpeg image format so that it can be registered in the NDK vuforia database to generate virtual visuals when the camera device detects AR marker cards. Camera devices and marker cards are among the essential equipment of a commonly used marker-based AR application. The always-used marker is a card or a rectangular paper on which the card has a specified pattern or line. By detecting the AR marker card through the camera device, the virtual element will then be generated by the AR software and displayed on the monitor screen. Fig 2. below shows the AR mobile application that allows users to choose activities in the menu of AR phonics learning environment. AR Phonics learning activities are separated into three categories. There are animals, fruits and things. Fig 3 is a marker card used in the AR Phonics Learning application. Fig 4. shows the activity interface in the AR environment. There are 3D object interactions in the activity. Additionally, this app provides a text graphic that allows users to touch the 3D object and remove virtual audio.

Fig 2. Augmented Reality Application Mobile Interface Menu

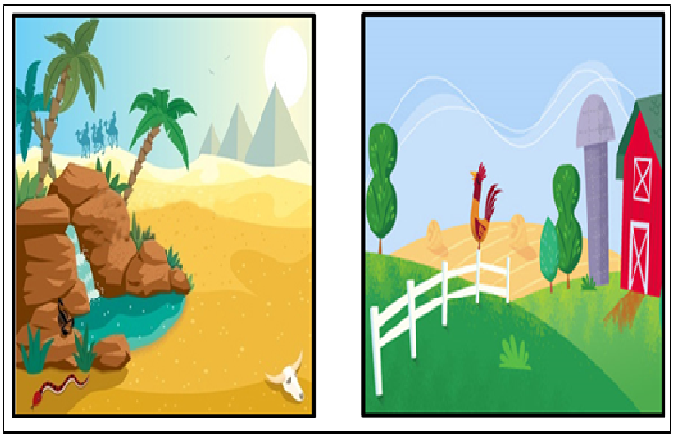

Fig 3. Example of Augmented Reality Marker

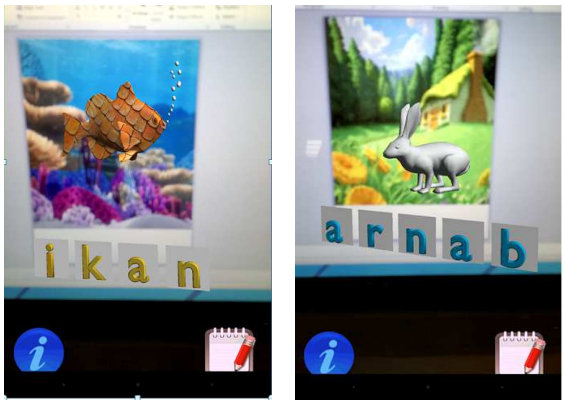

Fig 4. Augmented Reality Environment

B. Three Dimensional (3D) Education Games

The AR camera display has two graphic buttons, i.e., the info button and a phonics learning exercises button. The function of the training button is to allow children with autism to create phonic learning activities. Fig 5. shows one of the activity interfaces in the AR environment. This AR phonetic learning has six activities available. Here is one example of training available to users. There are 3D object interactions in the activity that students can grow, shrink and move 3D objects with their creativity. Additionally, this app provides a text graphic that allows users to touch the 3D object and remove virtual audio.

Fig 5. Example of Phonics Learning Interface

III. Results and Discussion

This study was carried out in the form of the survey by interviewing several lecturers of the Melaka Autism Education Centre and the observation of the current classroom session. Participants involved are children with autism who are currently pursuing education programs at the Melaka Autism Education Centre. To carry out this study, ten (10) children with autism became participants as a sample of the study. The participants are between 8 and 10 years old, male and female. The following criteria have been taken into account as a guide for selecting participants for the testing and verification process. Every autistic child involved in this test has different problems in terms of sensitivity and also the background of language mastery. Expectations on the involvement of children with autism on activities only when they are focused and active in learning activities. The next section summarizes the students' responses to the learning modules provided in the application; i.e., phonics learning in the AR environment, activity 1, activity 2 and activity 3 which include: i) The activity introduces syllable sounds and spell words through phonics learning methods; ii) activity of visual display object through reality augmentation method and iii) phonic learning exercise activity in drag and drop letters in blank space.

Fig 6. is a graphical literacy learning graph in conventional methods and AR mobile applications in autism children at the Melaka Autism Education Centre. In this study, the effectiveness of phonics literacy learning is based on the scores obtained after answering all learning practice modules. The accuracy and accuracy of the results are enhanced by assessing only student-focused points, while the student's score directly gives no exempt response. Results based on frequency distribution and normal distribution. Fig 6. is an activity for recognizing letters. This activity table summarizes the mean score of two different teaching methods which are conventional teaching methods and using mobile AR applications. The mean score obtained shows that the application of AR application in phonic literacy learning exceeds the scale of three, which is 3.26 compared with the conventional teaching method which is 1.79 is less than the scale of two.

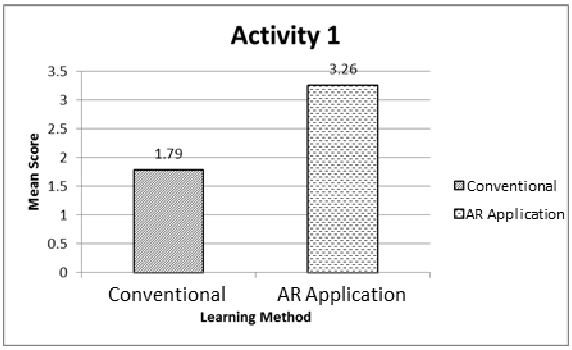

Fig 6. Recognizing Letters by Phonics Method

Fig 7. is an activity to spell and pronounce words in the phonics method. The mean score for activity 2 shows that students get high scores in phonic literacy learning in applying mobile AR applications that exceed the scale of three which is 3.1. Referring to this decision, students can spell words even though they are repetitive rather than conventional teaching methods. On the positive side, mobile AR applications have a good impact on children with autism.

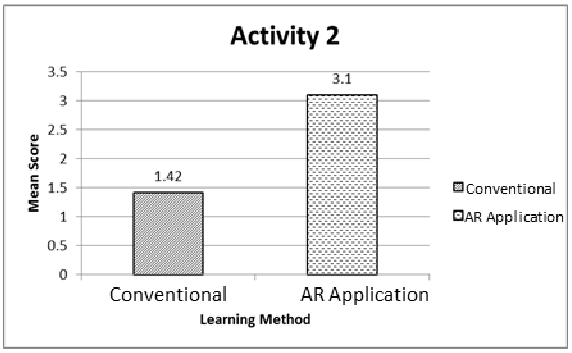

Fig 7. Activity Spell and Pronounce Words by Phonics Method

Fig 8. Student achievement in answer six questions for two different teaching methods. Each question requires the student to choose the prefix vocal of each word by pulling and placing the vowel on the correct answer box. Question 1 and question 2 test the word "*ayam*", "*arnab*" questions 3 and 4 test the word "*itik*", "*ikan*" while question 5 and question 6 test the word "*unta*", "*ulat*". The results showed a mean score for learning exercises using AR application exceeding three scales of 3.28, while the mean score for the conventional teaching method was 2.2.

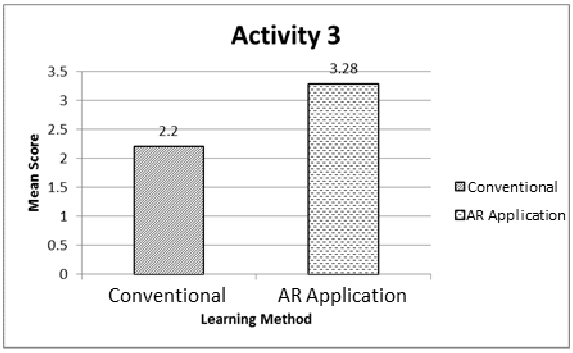

Fig 8. Edugame Activity by Phonics Learning in Augmented Reality Environment.

User assessment results on mobile augmented reality application development are shown in Fig 9. The mean score for easy to use, interaction and visual display factors is3.68, 3.56 and 3.41 respectively. The results show us the mean score usability applications for AR mobile over three scale. This shows that AR mobile applications have user-friendly elements that reach a right level of usability.

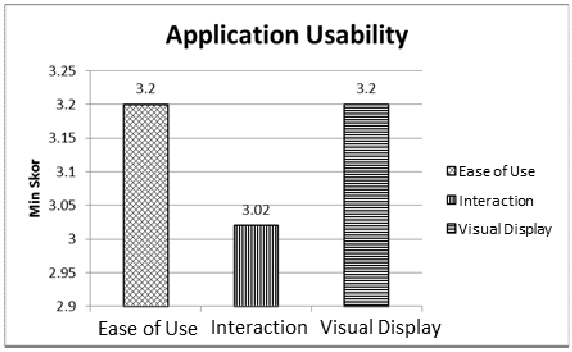

Fig 9. Mobile Augmented Reality Application Development

IV. CONCLUSIONS

Results and user ratings on developed applications and comparisons between two different teaching methods, which are conventional and using AR mobile applications. Results and assessments made on children with autism in the learning of phonics literacy through this AR mobile application give an excellent response although the phonics learning approaches AR is still new to them. From the observations made throughout the testing process, children with autism are keen on simple devices and 3D visual display objects. Visual and audio styles provide positive feedback from them. As such, researchers help attract and care for children with autism throughout the testing process. Based on the tests and assessments that have been carried out, the developed application can help children with autism in the Melaka Autism Education Centre from the point of phonics literacy to sound syllabic terms. Assessment is critical in the development of an application. An application may fail at all if it is not tested. Therefore, negative test results should be accepted as a challenge and guidance in producing better products. In addition, the negative feedback received will be used for further refinement or improvement in the future. Referring to the data analysis performed in the testing and validation, some advanced research problems and recommendations have been identified. It will be discussed in this section.

A. Training Module

Phonics literacy learning in the AR environment through mobile applications is an excellent platform in fostering literacy among children with autism. However, sometimes when a user detects an AR marker card on the camera device, the virtual audio display in the AR view is not very clear. This is due to the vibration of the camera device on the AR marker card.

B. Proposed Expansion Proposal

Based on the findings of this study and previous studies, it can be improved and extended as follows:

- Learning materials in each activity module can be added to the application. Lack of questions in the activity should be avoided especially with the gradual questions from simple questions to increasingly complex questions in order to attract students to learn more deeply. Additionally, games like puzzles and matches in the AR environment can also be loaded in a new module so students are not quickly getting bored and have diversity in learning activities.
- Besides, apart from the Malay language, other languages such as English, Mandarin and Tamil could also be added in this application. This can give more options to users to choose the language they want to learn and also to expand their marketability.
- The use of AR on mobile devices as an effective strategy to support free navigation among children with autism. Additional research may extend the exploration of the advantages and disadvantages of using a markerless approach for children with autism.

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