Augmented Reality in Education: A Study on Preschool Children, Parents, and Teachers in Bangladesh

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Abstract. Augmented reality (AR) is a technology that is being used in various aspects of life, including education. Many studies have been performed to investigate the effectiveness of using AR in educational settings. The purpose of this study is to investigate the effectiveness of AR in teaching preschool children in a developing country such as Bangladesh. To conduct the study, we have developed two AR-based apps for Android using marker-based tracking techniques. We have run our study in a classroom of a school in Bangladesh where 25 students, 13 parents, and three teachers voluntarily participated. We taught students using our AR apps and evaluated their learning improvements through pre- and post-test results. The results show at least 30% learning improvement. We have observed children's reaction and engagement, and surveyed parents and teachers for acceptance of such technology and suggestions for improvement. Our preliminary study finds that AR can be useful for preschool students learning in a developing country such as Bangladesh. Through our study, we also identify a list of requirements for designing and developing an AR app for education.

Keywords: Augmented reality · Preschool teaching · Early childhood education · Learning technology · AR in education · Bangladesh

1 Introduction

Augmented reality (AR) can be defined as a technology that integrates virtual 3D objects into a real 3D environment in real time [2]. It has been widely used in various disciplines, including defense, medicine, manufacturing, training, and tourism [1]. Lee [11] reports how people can be educated and trained using AR

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technology. In particular, the paper presents how AR is being used in various sectors, such as education, business, astronomy, and different sectors of science. With such a technology, doctors can see the internal organs of a patient interactively in 3D without performing surgery [9,13], and customers can see a 3D model of a product from home before they buy it online [4].

In recent years, AR has gained much research attention for its potential use in education [18]. Researchers are mainly focused on demonstrating the various advantages of AR in education, such as enhancing learning achievements, increasing motivation, raising the level of engagement, decreasing the cognitive load, and so on [1]. Research in this domain is usually conducted in a specific setting – for example, in a specific country, with a specific age group of children, with a specific subject (children, parents, or teachers), and focusing on a specific teaching topic (e.g., the alphabet, animals, geometry, etc.).

In a developing South Asian country such as Bangladesh, the education system is mostly outdated and does not contain digital resources. Therefore, student engagement with textbooks is low, and the lack of motivation eventually increases the dropout rate. Given that a smartphone is available to almost every family and, thus, to the children, AR-based mobile apps could attract the attention of children and enhance their learning experience. To the best of our knowledge, no such research has studied the impact of AR in education for preschool children in Bangladesh.

In this research, we have studied the effectiveness of AR in teaching preschool children in Bangladesh. In particular, we have developed two AR-based mobile apps to teach children the alphabet and about animals. The key distinctive feature of our apps compared to other research apps is that ours feature learning tests. We have studied both the usability of the apps and the effectiveness of AR in education (in terms of degree of satisfaction, impact, knowledge, and creativity) from the perspective of the students, their teachers, and their parents.

Some design requirements should be considered to create a successful AR app for the classroom, including flexible and customizable content for the needs of the children and a focus on institutional and curricular requirements [10]. Considering these requirements, we have developed one of our AR apps based on a government-provided textbook that is easily available to preschool children for free. Our other app is developed to teach animals that are not generally visible in residential areas and that children are not familiar with.

The contributions of this research are summarized below:

- We have developed two AR-based apps with testing features to teach the Bangla alphabet and about common animals.
- We have investigated the effectiveness (in particular, the learning improvement) of using AR apps as a teaching and learning tool for preschool children.
- We have consolidated our study from the perspective of the students, their parents, and their teachers in a South Asian developing country, Bangladesh.

The rest of the paper is organized as follows. Section 2 describes the two AR apps we have developed in this research. The methodology and empirical study of our research are presented in Sect. 3. Section 4 reports our results and findings

followed by a discussion in Sect. 5. Section 6 reviews related work. Finally, Sect. 7 concludes this paper and highlights future work.

2 Augmented Reality Apps

We have developed two mobile apps, AR Zoo and Bangla AR Book, to teach animals and the Bangla alphabets, respectively. These apps were developed for Android using a game engine called Unity3D [17] and a marker-based AR technology called Vuforia [15]. A marker is an image that is recognized by the app to visualize a corresponding 3D model in a real-time video. Vuforia uses advanced computer vision techniques to detect and track markers in a video and super impose the virtual content accordingly so that virtual objects appear as real in the video.

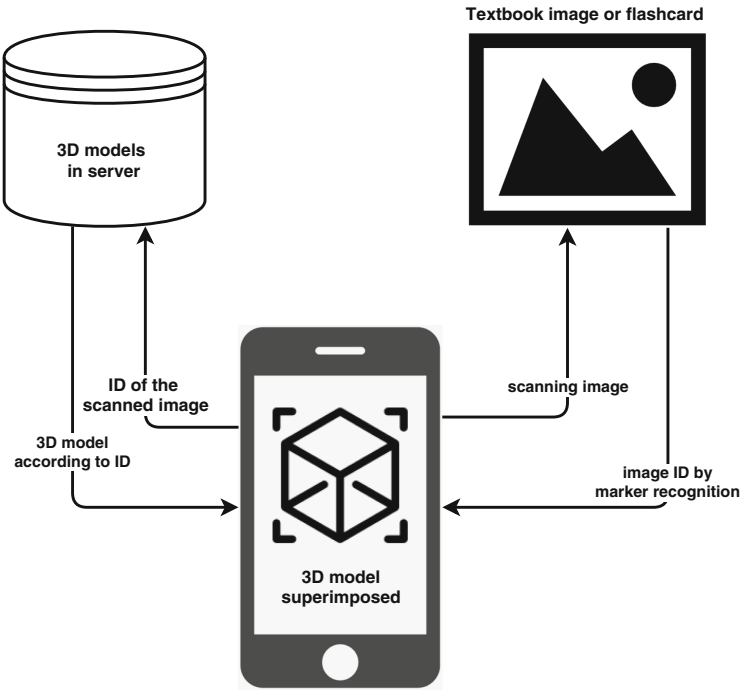


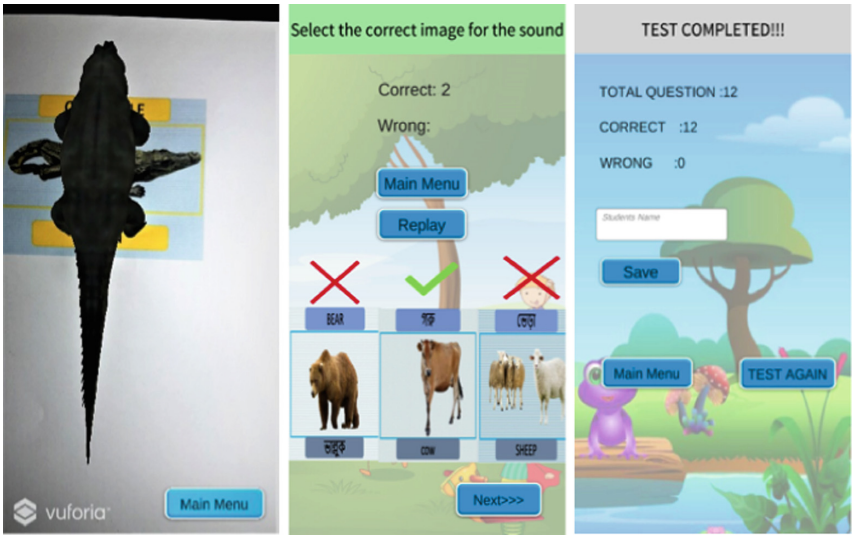
Fig. 1. Working procedure of developed AR apps.

The working procedure for both apps is visualized in Fig. 1. We have created unique IDs for all the pictures in the book. When a picture from the book is scanned using the app, the app obtains the unique ID of the corresponding picture. After the scan is completed, the obtained ID is used to find the respective 3D model from a server. Then the respective 3D model is downloaded and stored

in the app directory of the mobile phone so that the model can be used later from the directory without downloading it again. The 3D contents used in both apps were either purchased online or custom developed using 3D modeling tools such as Maya [8].

2.1 AR Zoo App

The AR Zoo app (Fig. 2 shows some screenshots) includes 3D models of 24 animals with animations and their sounds. For each animal a printed flashcard is used as a marker. During learning, the user holds the phone over the marker, and the corresponding 3D model of that animal appears on the screen, and the sound of the animal is played (Fig. 2a). The user could see the presented 3D model from any direction. In the test, the app randomly shows three images of different animals and plays the sound of the target animal as a hint (Fig. 2b), and the user has to select the image of the correct animal. After the completion of the test, a summary of the test results with the number of correct and wrong answers is displayed (Fig. 2c).



(a) AR tutorial. (b) Test quiz. (c) Total score.

Fig. 2. Screenshots of the AR Zoo app.

2.2 Bangla AR Book App

The Bangla AR Book app (Fig. 3 shows some screenshots) is based on a national curriculum textbook for preschool students in Bangladesh entitled “Amar Boi”. Like the AR Zoo app, Bangla AR Book uses images from that textbook as

markers, and custom-designed 3D models that are superimposed when the user holds the phone over the pages of the book (Fig. 3a). Two types of test sessions are implemented to assess how much children could learn from AR contents. In the first test, the children are given a letter and three images and are required to choose the one image whose name is starting with that letter (Fig. 3b). The other test is reversed – that is, the children are required to choose the one letter from a list of three that corresponds to the image (Fig. 3c). Each of the testing session contains ten matching tests. At the end of each test session, the app presents a summary of the entire test, which is also saved in a text file for further analysis.

(a) AR Tutorial.

(b) Letter-to-image matching.

(c) Image-to-letter matching.

Fig. 3. Screenshots of the Bangla AR Book app.

3 Methodology and Empirical Study

We ran our empirical study in a primary school in Bangladesh. Twenty five preschool children ages five to six years old (8 male, 17 female), 13 parents, and 3 teachers participated. None of the participating subjects had knowledge of AR. We conducted a pre-test to determine what the children knew about the letters and animals before teaching them using our app. We printed flashcards of animals to be used as markers for AR Zoo app. Students had their textbook of which we made the Bangla AR Book app. We started the pre-test with the textbook by asking students to identify letters randomly. Then we asked students to name the animals by showing them the flashcards randomly. Students answered some of the questions correctly but were mostly incorrect. We took their answers as pre-test results so that we could compare them with the post-test results.

After a short presentation on AR and how to use our apps, we divided the students into five groups and assigned two volunteers to each group. The volunteers taught the students the letters and animals using our apps (Fig. 4 shows some pictures of our study session in the classroom). Students were shown both apps in groups. Each group had only one mobile phone, and children used it by taking turns. They were given enough time to play with the apps and were very engaged. While using apps, a student was so excited that he said, "I can't believe what I'm seeing! Is this magic?" The students were learning through the mobile apps. Overall, we found the students to be very engaged and highly motivated. The students were so keen that they kept asking how they could get the apps. The parents and teachers were present in the classroom during the process and observed the children's engagement and performance.

(a) Students learning with AR apps. (b) Volunteers helping students.

Fig. 4. Students and volunteers during the learning session.

After the learning session, we used the built-in testing feature of our apps (described in Sects. 2.1 and 2.2) to test the students' learning improvement. Students found the test feature of our apps interesting, and they completed it with enjoyment. Test results were automatically saved to the mobile phones. After completing the test session, we conducted a survey consisting of eight questions (answers ranging from 1 for *strongly disagree* to 5 for *strongly agree*) with each of the subjects (i.e., the children, their parents, and the teachers) to identify the effectiveness of AR in education. Table 2 presents the questions for the students, and Table 4 presents the questions for teachers and parents (these tables can be found in Sect. 4). These questions covered various aspects such as usability, degree of satisfaction, impact, motivation and vividness.

We asked the parents for their opinions about the apps and student engagement. Because the parents observed the entire learning session, we asked them what they thought about AR apps, what could be improved, and what type of content should be taught using this type of technology. We also asked how their children passed the time at home and what they do when they have a mobile phone. We received very good responses and ideas from the parents. Some of them told us that they were concerned that their children were becoming addicted to the mobile phone for games and cartoons. They were happy to

see that their children could now learn through mobile apps as well. Many of them installed our apps on their mobile phones after the learning session. They also suggested adding more animations to the apps.

We also surveyed the teachers who had observed the entire process as well, and they completed the survey we designed for them. One of the teachers suggested that we shall add a reward system to our apps for answering test questions correctly and that the app cheer students with a voice saying phrases such as "That's good", and "Very good".

4 Survey Results and Findings

In this section we present our findings from both quantitative and qualitative analysis.

4.1 Quantitative Analysis

Table 1 presents the average scores of the pre-test and post-test with the learning improvement of the 25 students. On average, 6 out of 12 questions were answered correctly before learning through the AR Zoo app. After using the app, students could answer 10 out of 12 questions correctly, which is a 33% improvement. Similarly, the learning improvement for the Bangla AR Book app was 30%.

Table 1. Average test scores and learning improvement of 25 students

App name	Pre-test score	Post-test score	Learning improvement
AR Zoo	6 out of 12 (50%)	10 out of 12 (83%)	33%
AR Book	8 out of 20 (40%)	14 out of 20 (70%)	30%

Students were asked to answer eight questions from five categories (two questions in each category) by rating their agreement on a scale 1 to 5, where 1 means strongly disagree, 2 means disagree, 3 means neutral, 4 means agree and 5 means strongly agree. Our interview results with students are presented in Table 2, and Table 3 shows the average and standard deviation in the question categories. The results show that the average score is around 4.61 out of 5 with a standard deviation of around 0.18 for all categories. This score indicates that students feel very positively about AR apps in general.

Similarly, we conducted surveys of the parents and teachers with another set of eight questions in four categories: impact, satisfaction, motivation and creativity. Table 4 presents our interview results with 13 parents and 3 teachers, and Table 5 shows the average and standard deviation in the question categories. The results show that the average score is around 4.73 out of 5 with a standard deviation of around 0.11 for all categories. This score indicates that both parents and teachers feel very positively about AR apps in general.

Table 2. Students' interview results

Category	Question	5	4	3	2	1	Avg
Usability	The apps are very easy to use	15	8	0	2	0	4.44
	The 3D models used the app are fine	22	3	0	0	0	4.88
Satisfaction	Study with AR apps is easy	18	7	0	0	0	4.72
	I am pleased to study using the AR apps	19	6	0	0	0	4.76
Impact	It would be good if we were taught using AR apps	18	6	1	0	0	4.68
	I will use AR apps for my study	12	11	2	0	0	4.40
Vividness	Sounds and animations have made these apps very attractive	18	5	0	2	0	4.56
	The 3D models look real	13	10	1	1	0	4.40

Table 3. Summary of students' interview results

Category	Average	Std. deviation
Usability	4.66	0.31
Satisfaction	4.74	0.02
Impact	4.54	0.20
Vididness	4.48	0.11
All	4.61	0.18

Table 4. Parents' and teachers' interview results

Category	Question	5	4	3	2	1	Avg
Impact	AR app is very potential for teaching	10	6	0	0	0	4.63
	I will use AR apps for teaching	11	5	0	0	0	4.69
Satisfaction	Students enjoyed using AR apps	14	2	0	0	0	4.88
	By AR apps students have learned very quickly	11	5	0	0	0	4.69
Motivation	AR apps are very helpful for teaching	12	4	0	0	0	4.75
	Students will be benefited if AR apps are used in a classroom	13	3	0	0	0	4.81
	AR apps build child enthusiasm to study	14	2	0	0	0	4.88
Creativity	AR increases the imagination power of students	9	7	0	0	0	4.56

Table 5. Summary of parents' and teachers' interview results

Category	Average	Std. deviation
Impact	4.66	0.04
Satisfaction	4.78	0.13
Motivation	4.81	0.04
Creativity	4.56	-
All	4.73	0.11

4.2 Qualitative Analysis

In this section we present our research findings from a qualitative analysis using three perspectives.

Children's Experience Using AR Apps. Most of the children who participated in the research study were familiar with smartphones and used them every day to play games or watch videos. However, none of them were familiar with augmented reality. They were very excited when they saw a 3D model appeared in the book. They were also very excited to learn through a mobile phone or tablet rather than through regular class lectures, which are conducted on a blackboard. When they saw virtual content superimposed onto the real world, they were amazed. They never thought that mobile technology could help them learn. Many of them use mobile phone to watch cartoons, but their experience with AR was exceptional and very positive.

This study makes us believe that AR should be officially integrated into digital education materials. This technology can draw the attention of the students. One child who participated in the study commented, "I use my parents' mobile phone to play video games, but this is really amazing". The students reacted positively to our apps, and some of them amazed to see that the model appeared on the mobile screen. They were checking the book to see whether there was really something on the book. It was like magic to them.

Learning Through AR Apps. First, we guided the teachers on how to use our AR apps and how to teach the students through them. Then a teacher used the apps to teach a group of students. Another teacher taught another group of students traditionally. After that, both groups of students took the tests in our apps. The results show that the group of students who used the AR apps was more successful in both tests than the group of students who was taught using the traditional teaching style. Moreover, the students were happy to use the AR apps. They preferred learning through the AR apps rather than through traditional classroom learning. Thus, we argue that the interactive learning session offered with AR can help preschool children enjoy the classes and, most importantly, learn faster.

Taking Classes Through AR Apps. Traditionally, teachers teach the students by using a blackboard. They write different letters on the board and teach the alphabet. Using AR apps, the teachers do not have to use the board. They can easily teach the students by using a smartphone or tablet. The teachers found it easy to teach using AR. The students were also quiet and cheerful while learning through it. Therefore, managing the classes could become easier for teachers with the use of AR technology. The teachers in this study were comfortable using the AR apps. They stated that if AR were available in the classroom, they would definitely use it to teach their students.

5 Discussion

In our research, we tried to determine whether AR could be used in early childhood education in Bangladesh, and the survey results were very exciting. The motivation level of the students was amazing. The findings from the survey prove that the children learned better through AR technology and were very much interested in it. This technology enhanced the children's motivational level so much that they did not want to stop using the apps, as observed during the survey. Additionally, looking at the moving content on top of the printed material helped them understand and memorize the content of the topic easily.

Parents were surprised when they found their children busy with AR apps and learning through them. One of the ways children learn is through imagination by reading books. However, textbooks and the low-quality 2D images in these books alone are limited in their ability to improve the imagination power of children. AR can be a great tool to help students imagine a real object that they have never seen in real life.

This study has been successful in supporting the potential of AR to teach preschool children. Our comparison between teachers use of AR and their use of traditional teaching materials has illustrated that AR can be used to help preschool students learn the Bengali alphabet. The teachers in this study recognized the potential of AR technology and also said that it would be much more helpful if the app were flexible to use. Their feedback suggests that these features would enable them to involve children more in their studies.

Through our study, we have identified the following requirements for designing and developing a good AR app for education to provide a better learning experience:

- Augmented Reality apps should be flexible for the teachers so that they can adapt them to the needs of individual children.
- The user interface of such apps should be customizable and easy to use.
- The 3D models of the apps should have animations and sounds to engage children better.
- The apps should have test features for children to evaluate their learning outcomes.
- Gamification can be incorporated into the apps to engage students more in learning as suggested by both students and their parents.

6 Related Work

The most traditional way of teaching children in Bangladesh is through the classroom and by the parents at home. Digital content and mobile app based learning opportunities are not yet widely available, but some initiatives have been taken. An Android app called Bino [12] presents 3D educational content using augmented reality. It has its own designed textbook, and the app superimposes related 3D models on top of the book. However, here in Bangladesh, parents are not very aware of teaching and learning through technology. Additionally, parents are reluctant to choose a different textbook than the one that is taught in the classroom and provided by the government. Therefore, Bino is not very popular, especially in rural areas.

In recent years, a number of research studies have been conducted on using AR in learning and education. A comparison of the existing research in connection to our research is shown in Table 6.

Table 6. Literature review summary and comparison

Literature	Alphabets	Animals	Knowledge test	Age Group (yrs)	Country of study	Subjects studied
Parhizkar et al. [14]	No	No	No	4–12	Malaysia	Students
Rasslenda et al. [16]	Yes	Yes	No	6	Malaysia	Students
Dong and Si [6]	No	Dinosaur only	No	–	No study	None
Cheng and Tasi [5]	No	Yes	No	4–5	Spain	Students and parents
Barreira et al. [3]	No	Yes	Yes	7–9	Portugal	Students and teachers
He et al. [7]	No	Yes	Yes	4–6	China	Students
Our	Yes	Yes	Yes	5–6	Bangladesh	Students, parents and teachers

Parhizkar et al. [14] proposed an AR app called Augmented Reality Children Storybook (ARCS) to encourage reading habits among children. ARCS is a storybook for young learners aged from 4 to 12 with different categories of stories for different learning skills and levels. However, there is no evaluation performed to measure how much it can improve children's reading habits. Rasslenda et al. [16] conducted a study on Malaysian preschool children to observe the usability of AR in the classroom. They found that students respond to AR more than traditional teaching styles. Their study indicates that AR apps increase children's engagement in learning, which is also confirmed by our findings. Chunxia and Zhanjun [6] proposed an AR app combined with a paper book called Dinosaur ABC to teach different types of dinosaurs. The 3D models of dinosaurs used in the app had animation, sounds, and different types of interactive actions. The authors concluded that AR could help expand the scope of the traditional book to 3D interaction, which could help regain the attention of readers to read traditional paper books. Cheng and Tasi [5] analyzed the behavioral patterns and

cognitive attainment of children and their parents when they read an AR picture book. They ran their research on 33 parent-child pairs and concluded that shared reading of AR books could be beneficial for children. A game called MOW Augmented Reality [3] was proposed to teach students words in different languages. When a student matches the word with a picture, the related 3D model appears. However, the app taught the name of only a few animals. Finally, He et al. [7] proposed an app to help English as a Foreign Language (EFL) students learn new words. However, the app was developed to teach only eight words.

7 Conclusion

Augmented reality could add a new dimension to our education system if we utilize its potential. Preschool children can acquire much more knowledge and enjoy learning by using this technology in the classroom than by using traditional methods of learning. Our study confirms the previous study outcomes from other researchers and further clarifies that AR can be useful for preschool students learning in a developing country such as Bangladesh. Our study shows that, although the children were not initially familiar with AR technology, they responded well to it. They completed the sessions quite easily with interest and enjoyment. We also found that AR technology increased their motivational levels and engagement in learning, helping them grasp and recall the letters and corresponding pictures. Traditional books combined with an AR app could not only improve children's reading habits of classroom materials but also expand the books' scope to three-dimensional interaction. Our experimental results show that AR technology provides a fun and engaging environment for children. Therefore, using AR technology as an educational tool could be very useful for teaching students. However, the design of the AR app should be very user-friendly and customizable to be used by parents and teachers easily. These design requirements should be considered to develop better AR apps to be used by teachers in preschool education to enhance the learning experience.

In future work, we plan to consider those design requirements, include new features such as interactive gaming and math lessons, and develop better UI and graphics to enhance the user experience.

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