DEVELOPMENT OF 3D SOLID SHAPES IN AUGMENTED REALITY, AUGMO: A GAME-BASED LEARNING APPLICATION

Malek El Kouzi, M. Omair Shafiq

School of Information Technology, Carleton University (CANADA)

Abstract

Augmented Reality technology is proving itself as a handy tool in daily life. In the field of education, textbooks are used as the main tool for students learning. Even though some schools use tablets and smart boards in their classrooms, still they depend on textbooks for teaching. Implementing augmented reality in classrooms means achieving amazing and cost-effective teaching tools. A teacher’s goal is to make their lessons so exciting and enjoyable that students are enthusiastic about learning. Augmented reality for education transforms a repetitive and unexciting lesson into an interesting and interactive lecture. This study presents an Augmented Reality Educational Application named AUGMO. The application inspires interaction and permits content flexibility, self-evaluation and can be successfully implemented for learning and development in the classroom. Our study successfully helped elementary school students learn about 3D Solid Shapes by introducing them to AR technologies. AUGMO allowed students to interact with 3D Solid Shapes models and learn similarities and differences while just using a tablet, a picture, and their hands. The results show that most students think that AUGMO assisted them to visualize and understand better about solid shapes. Additionally, the data collected from the study proved that there is a substantial increase in correct answers about the solid shapes structures after using our AR application.

1 INTRODUCTION

Over the last few years, projects related to serious games have begun to arise as an essential outcome of the gaming industry. There is a high request for games which are not having the entertainment as the only goal. The demand for games which joins the fun with the ideas, skills, technologies, and techniques is at the all-time high. The creators of those games keep in mind a specific goal that they want the player to achieve from playing this game. So, they use the environment and techniques available in their hands to educate the players or train them or to promote a specific item that they need to sell using this game.

One kind of serious games are educational games. It is a message-based game that aims to deliver a specific message in an educational, informative or persuasive fashion. The player will practice this concept while he/she is playing that game which will help him/her in learning. Education is activity changing since the starting from a long time ago; it is always changing and improving through time depending on the technology and techniques that the human is finding and discovering. Computer technology is experiencing tremendous development in different fields that seem obvious to all of us. The combinations of technology with educational topics and curriculum have seen many changes in the way people learn and acquire knowledge. Nowadays is the era when video games started to include motion tracking, 3-d gaming, VR and AR, and more sophisticated technology. AR applied to education becomes a secret component to improve learning processes right here, right now. Augmented reality turns any usual doings into an engaging, interactive exercise inspiring audience of any age to gain knowledge and spend more time in the pursuit of learning they would never have done otherwise.

It is not difficult to find applications that can show a 3D Augmented Reality Shapes, What makes this application unique is that it was assembled on an existing educational problem (students do not understand well this topic) and it was presented to the students using creative and exciting ways leveraging on Augmented Reality. Giving the students such a tool encourages them to improve their imagination especially that we are putting their little hands on an up to date technology at their early school stages.

For evaluating the performance of the application, we checked the students understanding of the topic before and after they play the application. A survey was created and was given to the students in order to collect the data which has been analyzed and presented in tables and figures. This kind of
evaluation proved the effectiveness of the application and opened the door for more AR applications to improve students understanding and knowledge.

1.1 Related Work

There are quite a lot of research papers that talk about AR technology and how it is related to education. Almost all the papers describe how efficient would be the lesson if it were combined with technology such as AR applications. Viewing those papers can grant the researcher essential ideas how to coordinate his work with the educators to create an effective application which would help the students to improve their knowledge and grasp the most from this extraordinary technology.

A study constructed an AR game-based learning system for elementary science education. The learning content concerns the marine life food chain. The purpose of the study is to facilitate learning motivation, teamwork skills, and learning achievement. After the implementation, the developers noticed that the application interface and learning activities need to be customized by increasing the number of pages and include more activities [1]. Depending on a science lesson “Water Cycle” the paper presents the preliminary results of a study using AR application regarding a teaching intervention about science education in the primary classes. It was created because the students did not understand that concept well. The application should have been conducted to more than one school to make sure that it is useful [2].

LEIHOA presents the AR as a relevant technology for early childhood education. It introduces a system designed to assist young children to learn numbers which initiates reading and introduces English as a second language. There is no formal evaluation and analysis for this project [3]. SEE ME ROAR is a mathematics AR-based social game platform for primary school students. In order to study the effects of different factors in AR-based social learning games, the Self-Determination Theory (SDT) and the Playful Experience Framework (PLEX) are used. The authors did not mention how many students did they test this application on nor how they got the results of implementation [4].

To improve students’ knowledge of English, the developers developed 4 AR activities to be used by the students to get a different approach to the subjects. The noise in the classroom is a factor that negatively influences the practice with the activities that require listening [5]. MAPILS is another AR application created in the science field. The system was tested with 42 local secondary high school students who had designed, developed and creates the AR application. The developers should extend the MAPILS version which may be designed and evaluated with sensor technologies such as BLE [6].

Another paper talked about the steps for developing a set of design dimensions to guide the ideation process, iteratively designing, building, and evaluating six prototypes with the stakeholders. Exploring the space of educational AR experiences for STEM education targeted at students of various ages and abilities [7]. Even in chemistry, the AR applications came to help the students to visualize the 3D picture of molecules. The advantage of this paper is that it describes the development of this application. Adding virtual buttons would have added more usability characteristics of the application [8]. In another paper, the authors discuss the usability of AR in the classroom. They worked on AR augmented books and AR applications for their handheld device. They faced a problem that they do not have highly developed programming and 3D modelling skills currently required to design AR experiences [9].

The authors of this paper analyzed the feasibility of using augmented reality contents with preschool students (four and five years old) as a tool for improving their learning process. Results show improved learning outcomes in the experimental group concerning the control group [16]. Recognizing an AR marker through a Web camera, computer-generated images appear on real space. The developers prepared 3D (three-dimensional) anatomical objects to show, and evaluated their system using the AR platform [17]. Some of the recent studies listed the positive and negative impact of AR in an educational setting. The authors included possible AR application in education for all the subjects with different application idea [10].

Another literature review of 32 papers was done, and the authors mentioned the positive effect of AR applications and categorized that effect and done the same for the negative ones which are less than the positive one. [11]. The three types of technology AR, VLE, AND Mobile Learning were compared in a paper. It aims to encourage educators to include technology in their teaching process. The study gives a detailed idea of each technology and how it can be implemented in the classroom [12]. The authors of this paper had read around 68 research articles which were selected for analysis. The findings tell an increase in the number of AR studies during the last four years [13].
Another research aims to enhance the collaborative learning experience in primary school education. It introduces an interactive AR Book based on primary school textbook using tablets as the real-time interface [14]. A literature review of previous papers made on AR games for learning had included 26 related papers. The authors mentioned that during the design process, five aspects should be considered, which are learner groups, learning objectives, AR features, game mechanics, and social interactions [15]. In another paper, the authors provide us several methods which can be used to evaluate the Augmented Reality application: subjective measurement using human perception or objective measure from observation, or evaluation by an expert through a cognitive walkthrough, heuristic evaluation, lab observation, and questionnaire [18].

The challenges which the developers of medical AR or VR applications are facing were mentioned in a medical paper [20] include Neurosurgical based simulators, Surgical Navigation Platforms, and “Smart OR” systems. Furthermore, new technologies might offer formation of the user-tailored education process, where students might follow a personalized curriculum modified to their educational skills. So, the whole education familiarity could be changed entirely and provided in an ideal means [23].

1.2 Problem Identification

In the related work section, we had mentioned some research papers which talks about developing augmented reality-based applications. [1 to 9, 16, 17, 19] through those papers there are few which are math applications. A growing number of teachers/researchers propose the incorporation of educational games in the teaching of mathematics to support natural motivation through challenging students, scratching their curiosity and providing them with a sense of control and imagination [21]. Some teachers decided to focus on using different teaching styles, methods of valuation, and support classes; they used a variety of visual aids. Instead of the traditional paper and pencil test, they used nonstop valuation. The students were comforted when informed that there would be no written exams [33,34].

During a conversation with a grade one mathematical teacher, she mentioned that the students in her classroom are facing a problem in the 3D shapes lesson. This problem can be summarized that they cannot imagine well the 3D shapes; another problem is that most of the students cannot picture the differences and similarities of the shapes. Such a visualization problem is holding them from following up with their friends, and some are having some difficulties in distinguishing between the shapes which looks similar.

This problem drove into my mind an idea of creating a mathematical AR application which can help the students to visualize the 3d geometrical shapes. This application should help the students to understand their lesson more and give them the option of viewing the 3D models next to each other and they have the option of viewing the comparison like similarities and difference so that they can read and understand this comparison other than just imagining it. Also, they have the option of turning the paper around to view the shapes from all the sides.

2 METHODOLOGY

This study discusses the design and development of an educational application that could be used as a flexible tool for educational progression. The drive of this application is to support the teaching of primary school mathematics, as a complementary learning device that could improve students’ motivation and engagement with the topic [35].

The drive of this project is to use Augmented Reality technology as a supplemental tool to help students visualize 3D solid shapes through their tablet devices Fig. 1. These students tested the Augmented Reality application that is based on the material being learned in the classroom. The participants in this project are the students and their mathematics teacher from the 1st-grade class at the School. The class for this grade has approximately around 20 students.

The project started by taking approval from the school (consents from principal and teacher) and from the university (ethical board). After gaining the acceptance we made three surveys. Two surveys for the students and one for the teacher. The students fill a survey before they use the application and another survey after they use it. Those surveys have some multiple choice questions and others are from the options true or false. Those questions provide us data of the student’s knowledge regarding Augmented Reality and their knowledge in the mathematical 3D solid shapes lesson. A sample of the first survey is in Fig. 2.
Then it was the stage for creating the application. The information given by the teacher was stating that the application should show the basic concepts in this lesson. The development tools that have been used are Unity editor 2017.3.1 and Vuforia software development kit (SDK) for Android. The Android SDK is also required for compilation. Unity engine allows to produce and install applications for PC, Android, IOS using the Unity graphic engine. Additionally, Vuforia is an augmented reality SDK for mobile devices which uses artificial vision to recognize markers. Additionally, it lets the developers locate virtual objects relating them to real world objects. Vuforia SDK is available for Android Studio, XCode and Unity which was selected for this application.

The software is programmed to recognize the shape’s paper as a marker so that it can display the 3D model on top of it. The 3D model consists of two 3D solid shapes next to each other giving the student the chance to compare between the two shapes and visualize the differences between it. The student should open the application using their Tablets then they look through the Tablet’s camera at the page which has the solid shape picture. By looking through their device at those pictures they will notice the AR 3D image floating on that picture. The image will be consisting of two 3D solid shapes next to each other. They can turn around their textbook to view different sides of the two shapes. They can easily view the differences between those shapes. An example of shapes which looks similar is the cube and cuboids as shown in Fig. 3.

To get the similarities and differences feature between the two shapes of each figure, there are virtual buttons between the two shapes of that figure on the target image. One virtual button is labelled Similarities; the other one is labelled Differences. A C# script is attached to each virtual button.

The following is a Pseudo Code for the differences/Similarities virtual button code file:

1. When pressed on Virtual Button of differences/similarities
   - Show Differences/ Similarities
   - Keep it active while still pressed
2. When released the Virtual Button
   - Hide the Differences/Similarities

An example of the virtual button display is presented in Fig. 4.

After that, it was the time for implementation. The teacher was informed how does this application work and some common problems which she may face while using this application. She was given the tablet and the target image. Then she went to the class to demonstrate for the students how does this application work. Then she gave the students the first survey. Once all the students from the class are done using the application the teacher asked the students to answer the second survey. This was when the teacher filled out her survey so we can get her feedback on students using the AR app. For the evaluation, the data was collected from the first survey and was compared with the data from the second survey. So, the most commonly used measurements for learning achievements was used, which is pre-test and post-test regarding knowledge content. The data was filled in tables to be organized. The teacher’s survey was used to add her point of view about the application and incase she found it useful and if it would accomplish its goal.

Novelty: What makes this application unique from other mathematics applications are the following:

- This application is easy to use without a complicated menu or buttons. So that grade one students can use it without help.
- The comparison between similar shapes is very useful for the students to see and later memories.
- The markers of this application are intentionally made simple so that the students will expect what to see as AR above each figure.
• The presence of the virtual button gives the students another view to experience the Augmented Reality features.

### Student Survey #1

**Part 1:** Please use a check mark √ to indicate Yes, No, or Undecided.

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th>Undecided</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Do you like playing educational games?</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2. Do you think playing educational games helps you learn?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Have you played Pokémon GO?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Do you know what Augmented Reality is?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Have you seen a 3-Dimensional (3D) representation of Solid shapes (cube, cuboid, cylinder, etc.)?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Do you like using tablets (i.e. iPad) in the classroom?</td>
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</table>

**Part 2:** Multiple Choice. Please circle only one answer below.

9. The cube is made up of _______ faces.
   a) 2  b) 4  c) 6  d) 8

10. A _______ has no faces.
    a) Cylinder  b) Sphere  c) Cuboid  d) Cube

11. The _______ has equal sides.
    a) Sphere  b) Cylinder  c) Prism  d) Cuboid

12. The _______ has six rectangular faces.
    a) Cube  b) Cylinder  c) Sphere  d) Cuboid

13. The _______ is a solid object that has a curved surface and two circular ends.
    a) Cylinder  b) Cube  c) Sphere  d) Cuboid

**Fig 2. Student’s Survey**

**Fig 3. 3D Augmented Reality Solid Shapes**

**Fig 4. Virtual Button Display**

### 3 RESULTS

The goal of this study is to encourage supplemental learning in the classroom by integrating AR technology into the school curriculum. We want to prove that the effect of this kind of integration is positive on the student’s knowledge and increases their understanding of this kind of lessons. Our study had students use tablets to interact with 3D diagrams of Solid shapes. Hence, students were able to visualize concepts more effectively while using AR technology as a supplement for learning about Solid shapes using a textbook. Also, teachers can use 3D images to help improve both student comprehension and memory.
3.1 Operational Analysis

3.1.1 Students' Perspective

The participants in our study include 20 students in grade 1. Students were asked to do a survey before using our AR application. The purpose of the first survey is to inspire students about AR technology and assess background knowledge of the Solid shapes. The second survey assists in monitoring students understanding of the AR technology and measure their learning of the Solid shapes after using the AR application. Both surveys have the same questions.

The questions asked in the first part of the surveys are the following:

- Q1: Do you like playing educational games?
- Q2: Do you think playing educational games helps you learn?
- Q3: Have you played Pokémon GO?
- Q4: Do you know what Augmented Reality is?
- Q5: Have you seen a 3-Dimensional (3D) representation of Solid shapes like Cube, Cuboid?
- Q6: Do you like using tablets (i.e. IPAD's) in the classroom?

Based on the results in Fig. 5, 80% of the students like playing educational games. 80% think that playing educational games helps them learn. 25% only played Pokémon GO. All of the students did not know what Augmented Reality is. 65% have not seen a 3D representation of a Solid shape. And 85% like using tablets in the classroom.

Based on the results in Fig. 6, 85% of the students like playing educational games. 90% think that playing educational games helps them learn. 25% only played Pokémon GO. 85% know what Augmented Reality is. Now it is clear that most of the students understand the meaning of the term and how it is used. 95% have seen a 3D representation of a Solid shape. It is valuable to see such a result and know that most of the students saw and understood such figures and how to notice all the sides of the figures. 85% like using tablets in the classroom. When comparing the results of part 1 of the survey before (survey1) and after (survey2). There is an increase of 5% of the students who like to play educational games. Also, an increase of 10% of the students who think that playing educational games help them to learn more. There is an increase in the percentage of students who know about Augmented Reality, that increase jumped from 0% to 85%. Augment Reality is. 35% did see a 3D solid shape in survey 1, but after playing the application, it increased to 95%. It is noticeable that there is no change in the percentage of questions 3 and 6.

The answers to those questions were given as multiple choices: a), b), c), d). A quantitative approach is used to test the difference in students’ knowledge of the Solid shapes before and after using our AR application. The questions asked in the second part of the surveys are the following:

- Q7) The right answer for this question is choice c) 6.
  Before using the application, 15% of the students answered the question correctly. After using the application, 90% answered correctly. The students have noticed the number of faces of the cube when they saw it as 3D model and afterwards, they turned the paper to have the chance to see all the faces of the cube.

- Q8) The right answer for this question is choice a) Cuboid.
  Before using the application, 45% of the students answered correctly. After using the application, 95% answered correctly. Seeing cube next to cuboid gave the students a chance to compare both the shapes and notice that the two shapes have the same number of faces.

- Q9) The right answer to this question is choice b) Sphere.
  Before using the application, 30% of the students answered the question correctly. After using the application, 80% answered correctly.

- Q10) The right answer to this question is choice d) Cube.
  Before using the application, 45% of the students answered the question correctly. After using the application, 65% answered correctly.

- Q11) The right answer to this question is choice d) Cuboid.
Before using the application, 55% of the students answered the question correctly. After using the application, 75% answered correctly.

![Survey1 Part1 results](image)

**Fig 5. Survey1 part1 results**

![Survey2 part1 results](image)

**Fig 6. Survey2 part1 results**

- Q12) The right answer for this question is choice a) Cylinder.

Before using the application, 40% of the students answered the question correctly. After using the application, 70% answered correctly.

When we compare the results of the first survey with the results of the second survey, we can notice that there is a progress in the knowledge of the students which is clearly appearing from their answers. It proves to us that the use of the Augmented Reality application was helpful as a supplement resource to provide an additional tool for the sake of student’s lesson understanding. After the students played this application, it is obvious from the results of part 2 that most of them know how to solve correctly the questions which reflect their awareness of this lesson and which proves that the problem that the students were facing is mostly solved.

### 3.1.2 Teacher’s Perspective

The teacher answered a survey which consists of two parts which summarize her point of view for this application and how did she see the effect of the application on the students’ knowledge.

In the First part, the teacher was given six questions with a scale from 1 till 5 where 1 is agree and 5 strongly disagrees. The teacher agreed that the application was easy and simple to use. Thus, she mentioned that the survey was not completed quickly after using the application. Then she agreed that the 3D Shapes model was effective in helping students complete the survey. When asked if the shapes were presented clearly, she strongly agreed that it was. Also, she strongly agreed that the supplication had the necessary information. Finally, she agreed that she was satisfied with the application.

In the second part, the teacher informed us that there were 20 students involved in this survey. She also mentioned that she liked how in this application students were engaged, and that the 3D properties were easy for students to identify. On the other hand, when asked what did she dislike about the application? She replied that the application had no sound, nor verbal instructions. Furthermore, we were informed that the students use IPADs, Chromebooks and they play Dream Math, Star fall learning. She was confident that the Augmented Reality could enhance student’s
learning experience. She can see herself using similar application for other subjects in the classroom.

In the improvement question, she suggested to include verbal prompts and verbal reinforcement.

### Teacher Survey

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How easy was the application to use?</td>
<td>Agree</td>
</tr>
<tr>
<td>2. How well was the application received by the students?</td>
<td>Agree</td>
</tr>
<tr>
<td>3. How helpful was the application in improving student understanding?</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>4. How would you rate the application's performance?</td>
<td>Excellent</td>
</tr>
<tr>
<td>5. Would you recommend this application to other teachers?</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### Efficiency Analysis

As explained in the methodology, this application was built on software which is free to install and use. It only took a couple of days to reach the final prototype which the teacher had accepted to be shown to the students. No expenses were used to create this application. Thus, making it easy to develop other similar applications which reflect a better understanding of class lessons.

In question 7, only 3 of the students answered correctly in first survey; however, we have 18 of the students answered correctly in survey 2. An increase of 75% of the students who knew the answer correctly. In question 8, we have 9 students had correct answer in survey1, but 19 had answered correctly in survey2. So an increase of 50% of the students who knew the answer correctly. In question 9, only 6 students answered correctly, while 16 got the right answer in survey2. So, an increase of 50% of the students who knew the answer correctly. In question 10, 6 students answered correctly, but 13 got it right in survey2. So, an increase of 35% of the students who knew the answer correctly. In question 11, 11 answered right, while 15 got it right in survey2. So, an increase of 20% of the students who knew the answer correctly. In question 12, 9 answered right in survey1, while 14 answered correctly in survey2. So, an increase of 25% of the students who knew the answer correctly.

We have an average of 42.5% of the students who had advanced their knowledge in that lesson. And according to the effort done to reach this was not extra ordinary.

In Fig 8, a comparison between the correct answers in part 2 of survey 1 and survey 2. Survey 1 was answered by the students before they played the application. Survey 2 was answered by the students just after they played the application.

![Fig 8. Correct answer comparison](image)
4 CONCLUSIONS

Previous work shows that Augmented Reality can turn classical classes into exciting new experiences. We decided to set AR to the experiment and developed an interactive application that takes the solid shapes out of a two-dimensional media like paper and presents it to students as a complete three-dimensional model placed in front of them, where they can move around the paper and fully visualize its sides. Now we can stop imagining things during classroom lessons and visualize it to understand how they work while looking at their digital representation.

In order to add a fun way to engage students and reinforce ideas they have seen during class lectures, we developed two virtual buttons (similarities and differences) that allow students to touch to read the similarities or differences according to the pressed button. The text will appear between the two augmented reality 3D shapes. We consider this addition to be a unique feature from previous work done in this field, tackling similar problems inside elementary school education. By integrating augmented reality into the solid shapes lesson, we captured the attention of the students. We can say that we had their undivided attention. After reviewing the pre and post surveys, the data shows a significant increase in the correct answers for the survey’s questions, proving that the students effectively understood these shapes using our AR application. Furthermore, most of the students considered that our AR application is helpful to visualize and learn more about solid shapes. More importantly, the post-survey shows a great interest in using similar AR applications in the future.

The teacher also highlighted the success and was satisfied with the performance and interest showed by the students. Finally, involving augmented reality in the lessons taught to students will support them to see unknown interests and inspire their future accomplishments. We believe that the use of technology as smart devices and AR applications and others is indeed developing the educational field.

REFERENCES


