# Interactive Teaching Learning in Kindergarten Education: Augmented Reality as a Digital Tool

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**Abstract.** The traditional classroom setting is giving way to virtual, immersive learning made possible by interactive technologies in education. Children can quickly acquire ideas in a fun, game-based learning environment. Teaching-learning process in kindergarten is much affected during the prevailing COVID-19 lockdown. Children are facing difficulty in understanding the concepts taught in online classes and they are unable to concentrate in the class for a long time. This work focuses on creating a mobile application that uses augmented reality (AR) to boost kids' interest and motivation for learning in online courses. This marker-based augmented reality application was created with the Unity game engine. It is developed to teach English and Mathematics courses. There are two modes in the application: learn and play. Learn mode is used to teach the concepts and the play mode is useful for the children to practice the concepts and also to test them by the teacher. Kids may engage with 3D objects, and the application's audio-visual elements entice kids to use it. Evaluation of the application through a survey indicated that the AR-based application is useful in all the aspects of evaluation considered in this study.

**Keywords:** Marker-based augmented reality, Mobile devices, Interactive learning environments, Educational games, and Collaborative learning

## 1 Introduction

Education is crucial for developing in children a variety of talents, including the ability to observe, learn, and solve problems. Kindergarten education aids in the knowledge development necessary for future success. The internal and environmental factors that affect the educational process make teaching children a hard endeavour. Children in kindergarten classes find it difficult to understand the concepts taught in online classes during COVID-19 lockdown. It demands the use of technology so that the children's participation in the class can be improved for which the teaching-learning process must be fun and game based. The prevailing condition due to COVID-19 lockdown has made the traditional way of teaching learning process into technology-based due to developments in electronics and software. Computer technologies have made a wonderful impact on the teaching-learning process [1]. It transforms the learner from passive to active. Any alternate method of instruction should offer

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a stimulating atmosphere for pupils to study in. Young children are motivated and involved in the learning process by the technology-enhanced learning environment.

Pedagogical innovations in various subject domains are brought out by the Augmented Reality (AR) technology. AR has three main qualities that allow it to be utilised to superimpose virtual components on the real world. Augmented Reality (AR) combines real and virtual items, allows for real-time interaction, and makes it easier to accurately register three-dimensional virtual objects with actual ones [2]. AR lies between the real environment and virtual world as shown in Figure 1. According to Milgram's Reality-Virtuality continuum [3], AR is located close to the virtual environment and hence it does not eliminate the virtual environment while projecting the data. AR is considered as one of the visualization methods that is used to enhance the three-dimensional perspective skills and for collecting information. It integrates computer graphics and computer vision. Computer graphics is used to create interactive animations and photorealistic rendering whereas computer vision is used for image recognition, feature detection and tracking.

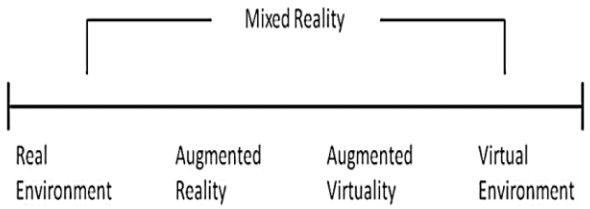


**Fig. 1.** Milgram's Reality-Virtuality continuum [3]

There have been studies recently conducted to determine the efficacy of game-based learning. The guiding concepts for creating an environment and designing educational games for kids under five years old were defined by Miller et al. [4]. This study yielded the result that games develop content that are mentally appropriate and effective. It is helpful in striking the ideal mix between opportunities for play and real-world learning. Lin et al. [5] looked into the efficacy of game- and video-based training for teaching mathematics utilising multimedia devices. As each unit was designed with learning outcomes, the user can identify their level of learning. It was found that employing a gaming environment enhanced learning and cognitive abilities. Additionally, it demonstrated that the monopoly game was more dynamic and productive for learning than a typical video-based learning environment. According to Burguillo [6], users' motivation and learning outcomes are enhanced by competition-based learning. Competition is recognized as the most important feature in the development of game that attracts the attention of the players. Results indicated that computer games made the students to enjoy the learning. The advantages of using competition-based learning approach are more active participation, collaboration of the work, and improves the creativity of the learners. Fengfeng Ke [7] designed a computer drill game for teaching primary mathematics that resulted in creating a positive attitude among the learners to learn mathematics. It also led to improved participation of the students and their performance. Students were very active in playing game and peer communication was improved. Results insisted that the user interface of the game should be more informative and attractive for the students and it should have instructional supporting feature for active engagement of the students. Results showed that more informative and attractive user interface and instruction supporting feature in the game-based environment leads to active engagement of the students in learning. Maria Virvou et al.

[8] evaluated the effectiveness and issues of software games in education. It was found that the instructional virtual reality games were beneficial to the kids who showed less interest in studying. Results showed that the children who used the game-based study exhibited more interest towards learning. Kristian Kiili [9] designed a game model that contain flow theory and experiential theory. Computer games created a new kind of learning method and enhanced the problem-solving skills of the learners.

As a result, research has shown that game-based learning environments are effective and inspire pupils. It is clear from the review that academics and game developers are attempting to combine game-based learning and instructional content in an effort to make learning enjoyable.

To teach chemistry, Bolestis and McCallum [10] created a cooperative AR game called Table Mystery. This study examined the efficiency of AR-based system in teaching and learning. The students were tested after every teaching session by observation and open interviews. The work's outcomes showed that students were more enthusiastic and involved in learning using AR-based game environments. Interaction within the student teams were improved. It was suggested that AR games be utilised for teaching. Through a survey, Di Serio et al. [11] examined the results of utilising augmented reality technology in visual art courses Vs regular art courses. Qualitative data was collected to study the parameters like learnability, usability and efficiency. The pupils that utilised AR-based learning had improved levels of focus when performing different tasks, according to the results. Improved satisfaction, attention in learning and memorizing the concepts were the noticeable outcomes of this study. Oh and Woontack [12] developed an AR-based application for gardening that resulted in interactive experience of the user in gardening. The programme was created using simulations to learn how to water plants, fertilise them, and determine how light affects plant growth. It is a marker-based AR system in which each marker indicates its specific function through pictures. Liarokapis et al. [13] developed an AR interface technique for E-learning of engineering applications. The system was developed with a computer, camera and head mounted display. It computed the real time camera position and its orientation relative to defined markers using the machine vision technique. This work enhanced the learning methods by directly overlaying the system generated information into person’s sensory perception. Construct3D is a technology created by Hannes Kaufmann and Dieter Schmalstieg [14] that uses augmented reality to teach geometry and mathematical subjects in high schools. It demonstrated how augmented reality may enhance learning and sharpen spatial skills. Thus, studies indicated that using augmented reality in the classroom increases students' chances of grasping the material in the simplest way possible. Additionally, it significantly enhances student-teacher connection, increases learning benefits, and inspires pupils [15].

Yilmaz [16] created an educational magic toy for kids in the 5–6 age range that includes puzzles, flash cards, and match cards to teach them about fruits, animals, colours, and numbers. The usage of educational magic toys in the teaching-learning process was preferred by both the teachers and the students. Tarng et al. [17] combined virtual breeding activities with campus host plants to create an augmented reality ecological system. Kids bred virtual butterflies using digital tablets and smart phones. Tracking telescope was used for the children to learn the various species of butterfly. It has been shown to be a useful educational tool for promoting children's learning about butterfly ecology. The idea behind creating an augmented reality learning environment was to investigate how well-usable a classroom could be. The design concepts that should be applied when creating an augmented learning environment were demonstrated by this study [18].Five design principles—integration, awareness, minimalism, empowerment, awareness, and flexibility—were taken into

consideration for this project. Squire and Jan [19] investigated how well students were engaged in learning scientific concepts by using handheld gadgets. Location-based augmented reality was used in this study. Qualitative and quantitative analysis proved that the application helped the users for sharing information, developing inquiry, investigation and understanding skills for the students. Additionally, it demonstrated how the AR storybooks improved students' comprehension and narrative reading experiences.
These reviews reveal that augmented reality (AR) technology can be beneficial for teaching and learning in kindergarten classrooms. The majority of AR research was conducted with scientific education in mind. There aren't many AR-based maths and English teaching and learning programmes available for early childhood education. Since AR-based applications may help reach learning objectives quickly, there is potential for AR-based education in kindergarten schools to manage online lessons during the COVID-19 lockout. Marker-based augmented reality, marker-less augmented reality, and projection-based augmented reality are the three forms of augmented reality now in use. Marker-based augmented reality is employed in this work. Visualisation is typically accomplished with the use of display devices such as portable, spatial, and head-mounted displays.

## 2 Methodology

There are four stages to this work. Making 3D models and importing them into Unity programme is the first step. The creation of multiple learning modules with animation and audio effects is the focus of the second phase. The third stage involves developing the user interface, integrating the several learning modules, and scripting in C# to enable user interaction in the learning environment. Evaluating how well the application helps the kids grasp the ideas is the fourth stage of the project.
It is necessary to transform the different learning modules into an augmented reality learning environment. This programme uses marker-based augmented reality (AR) because it is kid-friendly and was designed specifically for each learning module, allowing the kids to scan a marker and begin learning the material on their own. The 3D depiction of the graphics that appear over the marker allows for interaction and immersion. Because smartphones and tablets are the most popular pieces of hardware (42.33%), the programme is designed to run on them in order to provide an affordable and user-friendly augmented reality system [20].
The way the user interface is designed draws in students and increases their level of engagement with the augmented reality world. C# scripting is used for interaction. The code is transformed by the compiler into a widely used intermediate language so that the programme can be executed. By writing C# scripts, appreciation messages with animations are made to inspire students.

## 3 The AR Application’s Design and Implementation

### 3.1 Design of 3D Models and Conversion of File Format

Any digital depiction of an object requires 3D models. Creating an AR learning environment is a crucial undertaking, and Maya software was utilised in this project. Compared to 2D models, 3D models enhance the objects' visual impact. The 3D model was given texture and material to give it a more realistic appearance. The 3D models were then saved in. mb file format and imported to Unity environment. The 3D models that were created using different

modelling software must be converted to one of the neutral file formats, such as Initial Graphics Exchange Specification (IGES) or Standard for the Exchange of Product Data (STEP), and then converted to the.fbx or.obj file format, because the Unity game engine is a different platform and only supports these file formats. Making ensuring that the file conversion process preserves all of the original image's data is crucial. The most effective file interchange format is.fbx, which is used as a communication medium between modelling programmes and Unity game engines.

### 3.2 Development of AR-Based Environment

There are many applications that may be developed with the Unity game engine. The AR-based learning environment was created using certain imported models and predefined 3D objects that were included in the Unity software. To enhance the interactive nature of the environment, collisions were incorporated into each model. An augmented reality application was created for the English and Mathematics courses. Every module in the AR-based application has two modes. These modes are called learn and play. Using interaction with the 3D pictures, the learn mode makes it easier to teach the topics in a course module. The learner's comprehension of the concepts covered in class is assessed and practiced with the help of the play mode. For every module, markers are created to enhance the pictures.

### 3.3 Mathematics Module

Three sub-modules were developed in the learn mode for the teaching and learning of mathematics course. They are: numbers, measurement and shapes sub-modules.
The sub-module on numbers offers four stages for learning numbers and fundamental arithmetic operations. Children can view the 3D model of numbers as displayed in Figure 2a while in learn mode. The child's task in the play mode depicted in Figure 2b is to count the numbers and select the appropriate number when 3D objects are displayed. The following question will appear and the student will receive voice and visual feedback if their response is accurate. If not, the youngster will see the same question repeatedly until they select the right response. Comparably, learning modules for addition and subtraction were created, as seen in Figures 2c and 2d. The augmented reality application's 3D representations of numbers and objects, interactive features, and audio-visual effects enhance immersion and spark curiosity about the subjects being studied.


**Fig. 2.** a) Learn mode for numbers; b) Play mode for numbers; c) Learn mode for addition; d) Learn mode for subtraction

Shapes sub-module is developed to teach both the 2D and 3D shapes. Background audio support is enabled to make the child to understand the parameters of the shape that is augmented. In learn mode, the 2D and 3D models are popped up above the marker along with the required description as shown in Figure 3a and 3b. It provides more realistic visualization of shapes. In play mode, options are displayed as menu buttons and children are allowed to find out the correct name of the shape as shown in Figure 3c and 3d. The question will be displayed until the child chooses the correct answer.

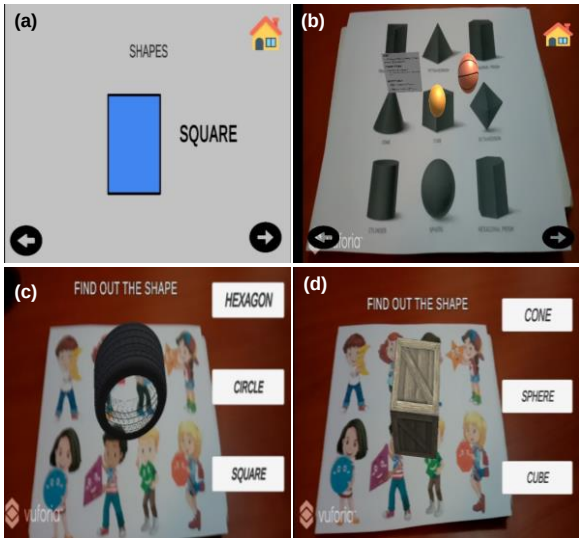


**Fig. 3.** a) Learn mode for 2D shapes; b) Learn mode for 3D shapes; c) Play mode for 3D shapes; d) Play mode for 3D shapes

Measurement sub-module is developed to learn the measurement concepts like tall, short, long, heavy and light weight as shown in Figure 4a and 4b. After learning and understanding the concepts, children can practice the learning and be tested using the play mode. This module improves the understanding of measurement concepts in a better way than the conventional methods.

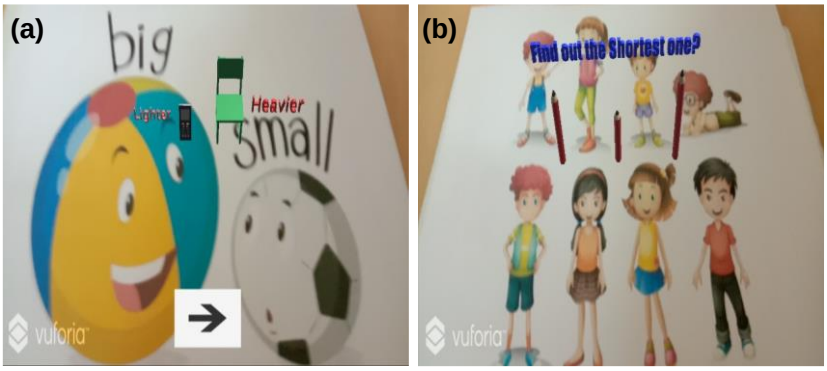


**Fig. 4.** a) Learn mode for measurement module; b) Play mode for measurement module

### 3.4 Development of English Language Module

This module has four sub-modules to learn alphabets, colors, preposition and actions. Learning alphabets is the foundation to learn any language. Alphabets sub-module is developed to teach both the upper and lower case alphabets in English as shown in Figure 5a and 5b. After learning the alphabets, play mode is used in which the questions are randomly generated in the form of images. The child has to choose the correct alphabet representing the image. Once the child attempts the question successfully, an appreciation message will pop-up. Otherwise, the question will remain displayed until the child chooses the correct answer.

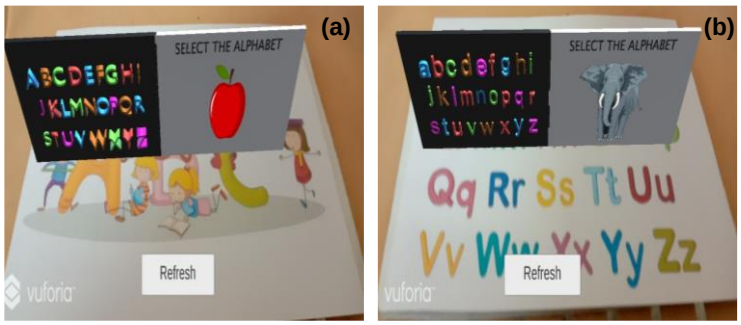


**Fig. 5.** Alphabet's module

Colours sub-module is developed for the children to learn different colours. It contains colour cubes as options and questions are displayed as 3D models as shown in Figure.6. The child has to match the colour of the object with the correct cube and an appreciation message will be displayed for the correct answer. Subsequent questions will get displayed after the correct

answer. Otherwise, the question will remain displayed until the child chooses the correct answer.


**Fig. 6.** Colors module

Preposition sub-module with learn and play mode is developed to understand the prepositions with the help of images and interaction as shown in Figure 7a and 7b. Prepositions are displayed as well as the audio message is created. In the test mode, the child has to pick the 3D model of the object displayed in AR environment and place it appropriately according to the preposition displayed. It makes the learning joyful.

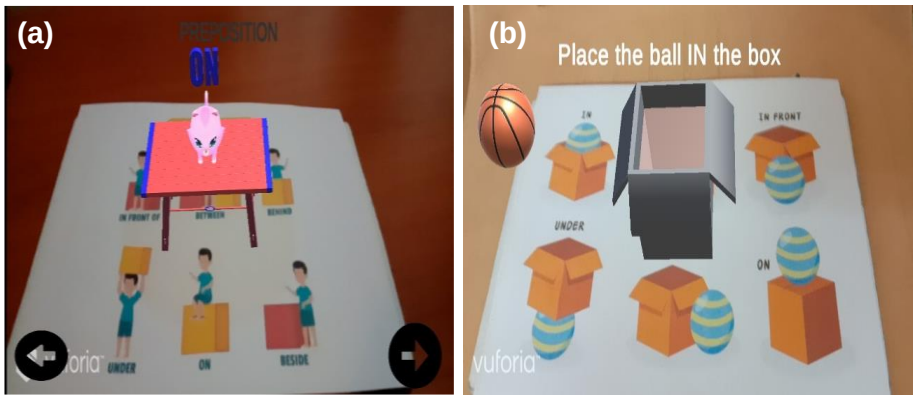


**Fig. 7.** a) Learn mode for preposition module; b) Play mode for preposition module


**Fig. 8.** Action's module

Children will be more active in the classroom activities when taught using actions as shown in Figure 8. In actions sub-module, actions like run, walk, jump, dance, sit, and punch are taught using animations. The moment the child selects a particular action verb in the display, the action is executed by the avatar.

## 4 Results and Discussion

A survey was conducted among the children in the age group of 3-5 in order to evaluate the effectiveness of the AR-based application and the user experience. A total of 30 children participated in the evaluation of the AR-based application. They were taught first by the conventional method and then using the AR-based application. Children participated with enthusiasm and were very much active in using the application. Students' participation is shown in Figure 9. The results of the survey and the questions included in the questionnaire is shown in Table 1. The response of the children was measured in a five level Likert scale that has been very popularly used in various studies (2). The metrics of various levels of the scale is: 1- Unhappy and strongly disagree, 2-Not satisfied, 3-Neutral, 4- Happy and agree, 5-Very happy and strongly agree. The results of the survey strongly indicates that the AR-based learning application is very much effective and influenced the learners as the mean score of each category of analysis is more than four. Average score obtained for the questions under different categories like user friendliness of the application is 4.27, easy to learn is 4.49, engaging is 4.66, motivation is 4.61, and fun is 4.75. Most of the children expressed that they could use the application and learn the concepts much easily and without the assistance of their parents. The 3D models that augment while using the application in any module is very much helpful to visualize the objects.


**Fig. 9.** Children interacting with AR-based application

**Table 1.** Measurement of effectiveness of the AR-based learning application

| **Parameter** | | **Mean score** |
|---|---|---|
| **User friendliness of the application** | | **4.27** |
| 1. | Is the AR-based application easy to use? | 4.16 |
| 2. | Are the instructions given in the applications easy to understand? | 4.33 |

| | | |
|---|---|---|
| 3. | Is the marker-based AR application better than multimedia-based learning material? | 4.33 |
| **Easy to learn** | | **4.49** |
| 1. | Do you understand the concepts clearly? | 4.66 |
| 2. | Whether it is easy to learn the concepts without the assistance of the teacher/parents? | 4.33 |
| 3. | Are the examples given in the application helpful to equip you for the test? | 4.50 |
| **Engaging** | | **4.66** |
| 1. | Are you interested to use the AR-based application repeatedly? | 4.83 |
| 2. | Does the application improve your interest towards learning? | 4.66 |
| 3. | Do you enjoy learning using this application? | 4.50 |
| **Motivation** | | **4.61** |
| 1. | Does this application motivate your learning experience? | 4.66 |
| 2. | Do you want to include more courses and concepts in the application? | 4.50 |
| 3. | Does it improve your involvement in learning? | 4.66 |
| **Fun** | | **4.75** |
| 1. | Do you like the animations and appreciation messages used in the application? | 4.83 |
| 2. | Whether the learning is made fun filled using the application? | 4.66 |

The percentage of children reacted to various levels of satisfaction for each question under the user friendliness of the application category is shown in Figure 10 a to c.

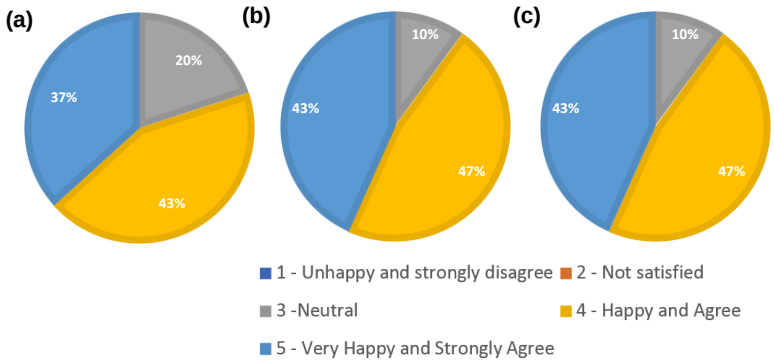


**Fig. 10.** User friendliness of the AR application a) Is the AR-based application easy to use? b) Are the instructions easy to understand? C) Is the marker based AR application better than multimedia based learning material?

Is AR easy to learn?

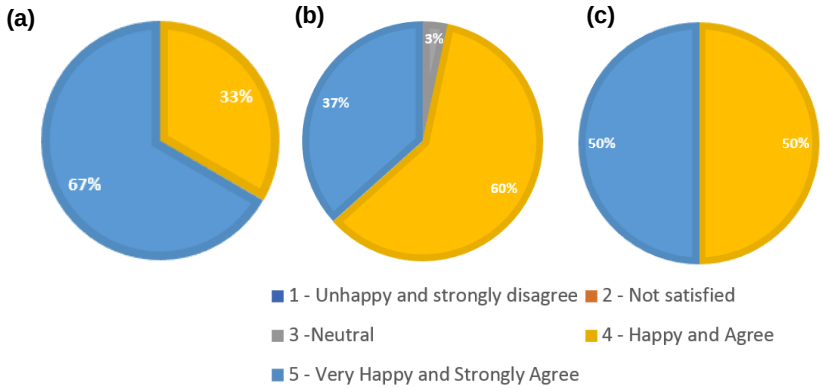


**Fig. 11.** AR-Easy to learn a) Do you understand the concepts clearly? b) Whether it is easy to learn the concepts without the assistance of the teacher/parents? C) Are the examples given in the application helpful to equip you for the test?

Is AR engaging in the teaching learning process?

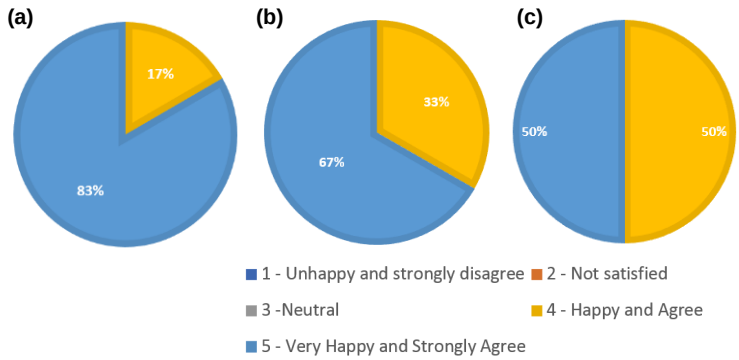


**Fig.12.** AR - engaging a) Are you interested to use the AR-based application repeatedly? b) Does the application improve your interest towards learning? C) Do you enjoy learning using this application?

Is AR motivating to learn?

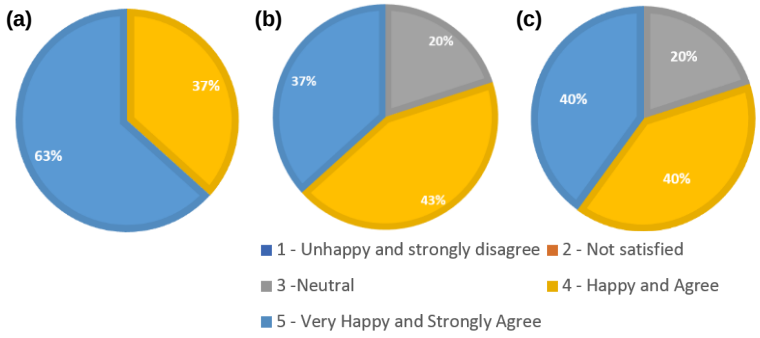


**Fig.13.** AR - Motivation a) Does this application motivate your learning experience? b) Does this application motivate your learning experience? c) Do you want to include more courses and concepts in the application?

Is AR a fun-based learning?

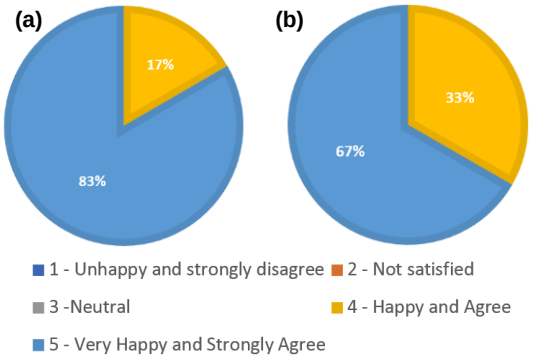


**Fig. 14.** AR - Fun a) Do you like the animations and appreciation messages used in the application? b) Whether the learning is made fun filled using the application?

## 5 Conclusion

Thus, the AR-based learning application was developed with the intention to help the children learn the concepts taught in online classes during COVID-19 lock down. The concepts can be learned with the help of 3D images that augment when using the application. Learn mode in each module is useful to teach the concepts and play mode is useful to practice the concepts learned and to test the learners. The effectiveness of the application on learning was evaluated under the categories like user friendliness of the application, easy to learn, engaging, motivation and fun. Average score obtained for questions under different categories like user friendliness of the application is 4.27, easy to learn is 4.49, engaging is 4.66, motivation is 4.61, and fun is 4.75. The study also yielded the following findings. Feedback from the children about this application is positive compared to conventional teaching method. Provisions like the voice command for correct and wrong answers and animated appreciation messages in the application made the children very much engaged and motivated in the learning process. The AR-based application can be extended to teach various subjects in higher classes also.

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