An Augmented Reality Greenhouse to Demonstrate Game-Based Learning

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***Abstract*—Augmented Reality is an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by information generated by a computing device. We propose a mobile-based AR application that provides an immersive simulation of a portable plant nurturing experience. The application utilizes the Unity AR Foundation framework to augment a portal to their own virtual garden. The user is able to explore their garden, build terraria, nurture and maintain various plants, thus providing an end-to-end simulation. This is a novel approach in experimental learning. We explore and evaluate concepts of information absorption, immersion, user satisfaction and experience emotions by conducting a comparative study between traditional E-learning methodology and E-learning using AR.**

***Index Terms*—Augmented Reality, Human Computer Interface, Simulation, EdTech**

I. Introduction

As of early 2021, big tech companies like Apple, Google, and Facebook, have invested millions of dollars into Augmented Reality technology. AR is estimated to have a market value of over 50 Billion USD by 2024. AR is widely used as a form of entertainment, advertisements, image alteration, and, among others, education. E-Learning techniques have seen several innovative additions over the past few years with the advent of low-cost powerful hardware that can support highly immersive AR experiences. Our application utilizes AR technology to provide an immersive portable for nurturing and maintaining plants. The application does this by simulating a greenhouse to visualize a step-by-step, interactive gardening experience. Through this, users can learn about various plant and animal species and techniques for their maintenance. To test the quality of learning, a comparative study on information absorption, immersion, user satisfaction, and emotional experience is done between traditional e-learning systems and our application.

II. Related Work

[1] proposed a game-based learning system that injects Augmented reality to increase the motivation and interest of learning English vocabulary for elementary school students. The questionnaire results of the control group and the experimental group demonstrated that using AR-enhanced the interest and efficiency of the students.

Similarly, [2] proposed a comparative study between a mobile game and a mobile game-based AR application to educate high school students on Biodiversity with the help of a science museum. The study indicated positive inclinations towards the usage of AR in game-based learning.

To study the range of interactions and gestures that AR offers, [3] proposed a comprehensive analysis and compilation of the various techniques of implementing 3D object manipulation on mobile handheld devices namely- Touch-based, Midair Gesture-based, and Device-based. Various metrics of user experience such as ease of use, intuitiveness, occlusion, fatigue, precision were evaluated.

To emphasize the infusion of AR in education, [4] proposed "Geo+", an application to showcase, wrap, unwrap and visualize 2D and 3D shapes as 3D models drawn over premade markers. Studies have concluded that students of grades 3 to 4 have demonstrated very positive results. Apart from the traditional curriculum, AR makes it possible to divulge in several areas of interest.

[5] proposed a real-time interactive piano learning AR web application to help teachers and students eliminate the shortcomings of virtual classes using Microsoft HoloLens HMD via a 2 system LAN connection. It was concluded that there was an improvement in feedback exchange and error correction and ease of use.

III. Implementation

Fig. 1: An AR Portal

In order to maximize performance and accessibility of the application and provide a smooth user experience across various devices and platforms, we use the highly performant, and platform-agnostic Unity Engine and the AR Foundation plugin. It allows us to write code once and deploy for all major AR platforms like ARCore and ARKit.

In order to achieve a portal effect (shown in Fig 1), we mark the portal as a stencil mask. Then, we tell the device to only render geometry that is present behind the mask. Any geometry that does not fall behind the mask is hidden. Once the player enters the portal, we override the behaviour of the mask, and tell it to render everything. Upon exiting the portal, the masking behaviour is restored.

This application follows the best practices of object oriented programming, with a focus on performance, stability, and scalability. As it is an open-ended experience, where the player can perform any self-contained action in any sequence, it is important to develop a robust system to maintain and manipulate this data.

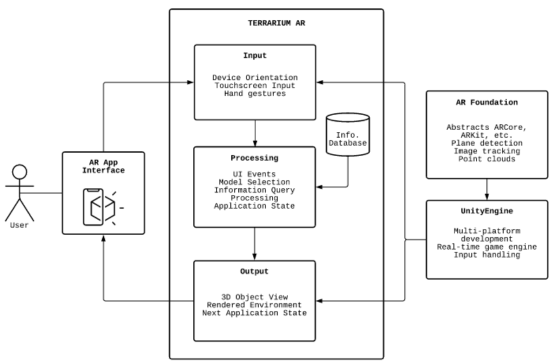

Fig. 2: Architecture diagram of the AR application

A. AR Portal Setup and Navigation

Fig. 3: Interiors of the greenhouse

The AR portal can materialize anywhere (shown in Fig 1). The AR scene initially has 3 tables, with 1 table containing gardening related tools and appliances like seed packet, fertilizer packet, sand sack, water-can and pruning scissors (see Fig 3). Throughout the experience, the user is prompted with information and indications with regards to the next course of action. Several plants can also be simultaneously grown to demonstrate a real life simulation of a greenhouse.

B. Application Design

1) Planning phase: The application starts with building one's first terrarium. This phase is called the planning phase. The user can select from a variety of glass pots or jars, add gravel, charcoal soil, and coco peat. The user also selects the plant that they would like to grow at this stage. They will be presented with information about the time it takes for the plant to grow, the maintenance requirement, and other information.

2) Growth phase: The second phase covers the first two weeks of the plant's growth. The user logs in every day and waters their plant. It is also recommended to them to look into adding fertilisers or organic substances in order to help with the growth of the plant. The users actions are recorded and scored. For example, maintaining a watering streak for 10 days provides a high score.

3) Maintenance phase: The next two weeks involve maintenance of the plant (shown in Fig 4). The user checks in every day, waters the plant, prunes the plant, and deals with pests. As the days go by, there is an increase in the number of pests that appear. The goal of the user is to maintain their plant, grow more plants, implement efficient ways of pest management, and decorate their greenhouse. Throughout the flow, there are various tips and facts presented to the user.

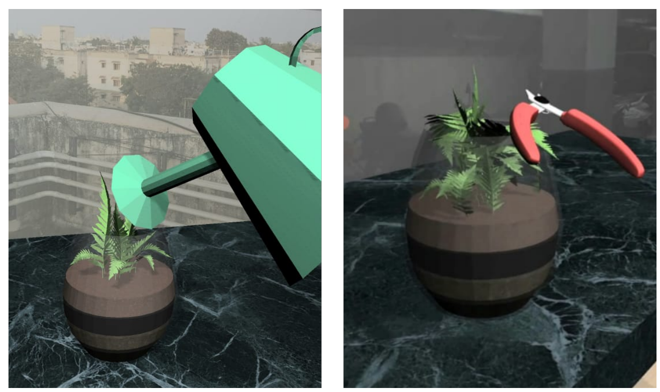

Fig. 4: Fern plant being watered and pruned

IV. Research

A. Research design

A comparative study was conducted between traditional E-learning methodologies and E-learning using our AR application. The application experience was accelerated in order to facilitate a shorter research timeline. The preparation and evaluation were remotely moderated. The user research consisted of 12 people in the age of 18-25 being divided into 2 groups of 6. The plant that was chosen for the purpose of the experiment was a fern. A preparation period of 2 hours was given before the evaluation. Group A learned about the fern through a slide deck. Group B used our AR application for the same duration to learn about the plant. The information imparted by both sources was similar, in order to facilitate a common evaluation system. The survey given to the users consisted of 2 sections. The Assessment section

Group	Subjective Score (out of 4)	Objective Score (out of 6)	Total score (out of 10)
Group A	2.5	3.83	6.33
Group B	3.5	5.17	8.67

TABLE I: Average assessment scores of both groups

had questions about nurturing ferns and their growth cycle. The Feedback section consisted of evaluating the experience of the users. This included the Experience emotions, user satisfaction, Immersion, and miscellaneous user feedback.

B. Research results

1) Assessment results: The Assessment section comprised 10 questions, of which 4 were Subjective and 6 were Objective. They were tested on their knowledge of the fern plant, with questions pulled out of their common information base. The users were given an hour to complete the test. The average score in Group A was 6.33 and the average score in Group B was 8.67 (see Table 1). Group A found it difficult to remember the small details of growing a fern, which Group B excelled at. Subjective answers indicated that Group B found it difficult to provide the exact technical explanation for watering and pruning procedure-related questions. Furthermore, the majority of the questions answered correctly by Group B were related to the information learned at the start of the presentation, indicating the reduction in interest while learning. Group A showcased consistent learning throughout the experience.

2) Feedback results: Experience emotions were evaluated on a 5-point Likert scale. It was observed that both groups had overall positive emotions, with Group A finding the presentation more annoying and less exciting compared to Group B (see Fig 5). Group B also found the experience to be more inspiring compared to Group A.

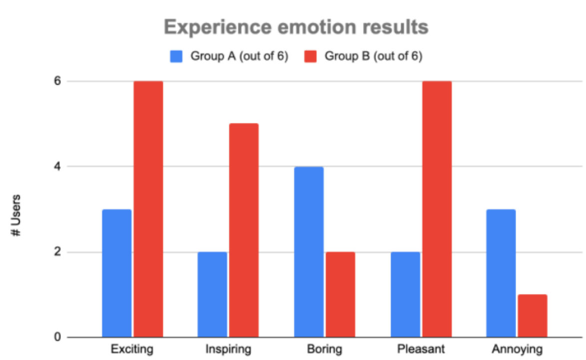

Fig. 5: Experience emotion results of Group A and Group B

Overall user satisfaction was found to be 38.89% more in Group B when compared to Group A (see Table 2). Users from Group B attributed the positive response to being interested in seeing the growth of different plant species and also showed interest in using AR as an alternative for traditional E-learning systems. Feedback from Group A suggested that reading from a presentation felt cumbersome and long.

User satisfaction Question	Positive feedback of Group A (out of 6)	Positive feedback of Group B (out of 6)
Would you be interested in learning more about gardening?	4	5
Would you try out similar learning methodologies for other subjects of interest?	3	6
Would you recommend this learning technique to your peers?	3	6

TABLE II: User satisfaction feedback of both groups

The next part of the questionnaire consisted of both groups being asked to rate the overall immersion of the experience. Group A found the experience 48% immersive whereas group B found the experience 90% immersive. The response suggested that Group B found the actions of pruning, watering, and growing multiple plants rewarding. This helped them learn the information presented with more ease. The visual cues and responses also made the simulation close to the real world. The questionnaire concluded with the collection of miscellaneous user feedback of both the learning methodologies. Participants of Group A found it difficult to memorize the information presented. They also found it difficult to relate the images to real-life scenarios. 2 out of 6 wished they had more time. Participants of Group B provided overall positive feedback. The average rating given for the AR application is 8.83 out of 10. Users expressed their pleasant surprise while experiencing the portal simulation.

V. Conclusion

This paper has described an AR mobile application for creating, maintaining, and nurturing one's own Augmented Greenhouse. This novel application uses an AR portal to transport the user into a controlled environment where the user can experience growing and visualizing the different stages of a plant grown in a terrarium. The user is also given the option to grow an array of different plants simultaneously, to make the application closely resemble the real world. The user regularly waters, prunes, fertilizes, and disinfects the plants. E-learning was facilitated by providing On-Login prompts and messages explaining the status of the plant in the vicinity of the user as well as suggestions to take care of the plant. Facts about the species were also regularly provided to expand the users' knowledge . A comparative study was done to analyze traditional E-learning methodologies and E-learning using AR.

The Assessment test results showcase that Group B scored higher than Group A by 2.37 points. It can be concluded that injecting AR into E-learning has a better information absorption rate. Results also showed that users of the AR application depicted consistent interest in learning compared to users learning from the presentation. The feedback section results show that Group B found the learning experience to be more Pleasant, Inspiring, and Exciting when compared to Group A. It was also gathered that Group B found reading information from a presentation to be Boring and Annoying. Consequently, the high level of user satisfaction and immersion in Group B can be attributed to providing a hands-on plant nurturing experience through AR. The detailed look and feel of the application also added to the same. Using AR made the users feel more responsible and involved with the life-cycle of the plant when compared to obtaining the information in a more traditional way. Furthermore, Group B was found to be interested in expanding their knowledge on gardening. The results also showed that the users were very open to trying out other E-learning AR applications in the future.

Our future work includes extending the immersion by providing a shared experience feature to view and share user's terraria with one another. We further strive to improve the single user experience by adding more tools and species of plants. We also aim to increase the information presentation rate in order to provide users with professional knowledge with regard to gardening.

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