Augmented Reality for education (Diversity)

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Introduction

The purpose of this research is to develop mobile application using innovative Augmented Reality (AR) technology for interactive study content targeted towards middle school and high school grades. By using the developed AR application, students will be able to learn about diverse science topics more efficiently and visually. The AR mobile application allows the user to project a 3D (3-Dimensional) AR model of science topics on a real-world surface (such as a table or a piece of paper). The users will be able to interact with the model as if it existed outside of the mobile application using touch interfaces.

Visual information helps us to better understand and remember information. This is due to the reason that our brain is an image processor and most of our sensory cortex is used for vision. Words are abstract and sometimes challenging to explain an object based on its size, location, shape or relation to other objects [1]. However, three-dimensional thinking uses our ability to illustrate an idea, location or object. It allows us to rapidly and easily visualize an experience and recall all the fine details involved. It is proven that various types of visual tools can be effective in learning [2], [3].

For young students, visual information helps them to comprehend and recall information with ease and efficiency. Using AR application for education can also help students learn the ability to imagine a concept with full details. However, students in middle school and high school grade level have limited imaginative abilities therefore, it is rather complicated for them to fully imagine a science concept. For example, atom particles containing substances or understanding spatial thinking requirements of physics exercises [4]. However, AR application can assist with science topics in order to help students understand the concept as well as creating an interest in STEM fields of study from an early educational stage.

Some of the visual educational tools used in the schools today include photos, illustrations, symbols, sketches, graphs, concept maps, and models. There are also mobile applications currently available to students that show 3D models of scientific concepts either within the application or using Augmented Reality technology. But applications such as Anatomy 4D only focus on one topic of study. User is then encouraged to purchase the application to use the full version or other applications will display advertisements which can interrupt the learning flow or cause distractions. Textbook publishers also use the same technique, however on a 2D scale, adding images about the topic of each chapter to help students create a memorable visual graphic. Teachers and instructors use similar tools in classrooms since it is much easier for students to remember a visual graphic rather than a lecture that solely uses words.

This is especially useful for science, technology, engineering and mathematics (STEM) education. Today, middle school and high school teachers rely on models of the human body, chemical bonds, or real-life representations such as part of the engine of a vehicle. Augmented Reality models can be useful for education since any student that has access to a device (such as tablets or smartphones) can view their scientific model as the teacher lectures

about the subject. This is also possible with models used in classrooms today, however, it is costly for an educational institution to purchase physical models of different scientific topics per student. Students will be able to interact with Augmented Reality models but unlike physical models, the user will be able to take his/her device inside the virtual model and learn about all of the internal features as well.
Such virtual models can be used in a variety of topics such as human anatomy, the structure of cells and chemical bonds, topography, 3D map reading, 3D geometry models and graphs, understanding the structure of an engine, and much more. The beta version of the application developed contains several scientific models in these topics of study. Such an application can be of benefit for students who are studying from home or for smaller middle schools or high schools with a limited budget. Figure 1 shows a demo of the virtual model of a DNA Helix on a predefined surface. After the application has projected the virtual model on the surface, the DNA model can be zoomed to observe the details in the 3D model.

During the development of this project, we also performed a feasibility study of the app and interviewed various teachers and students who are the primary users.

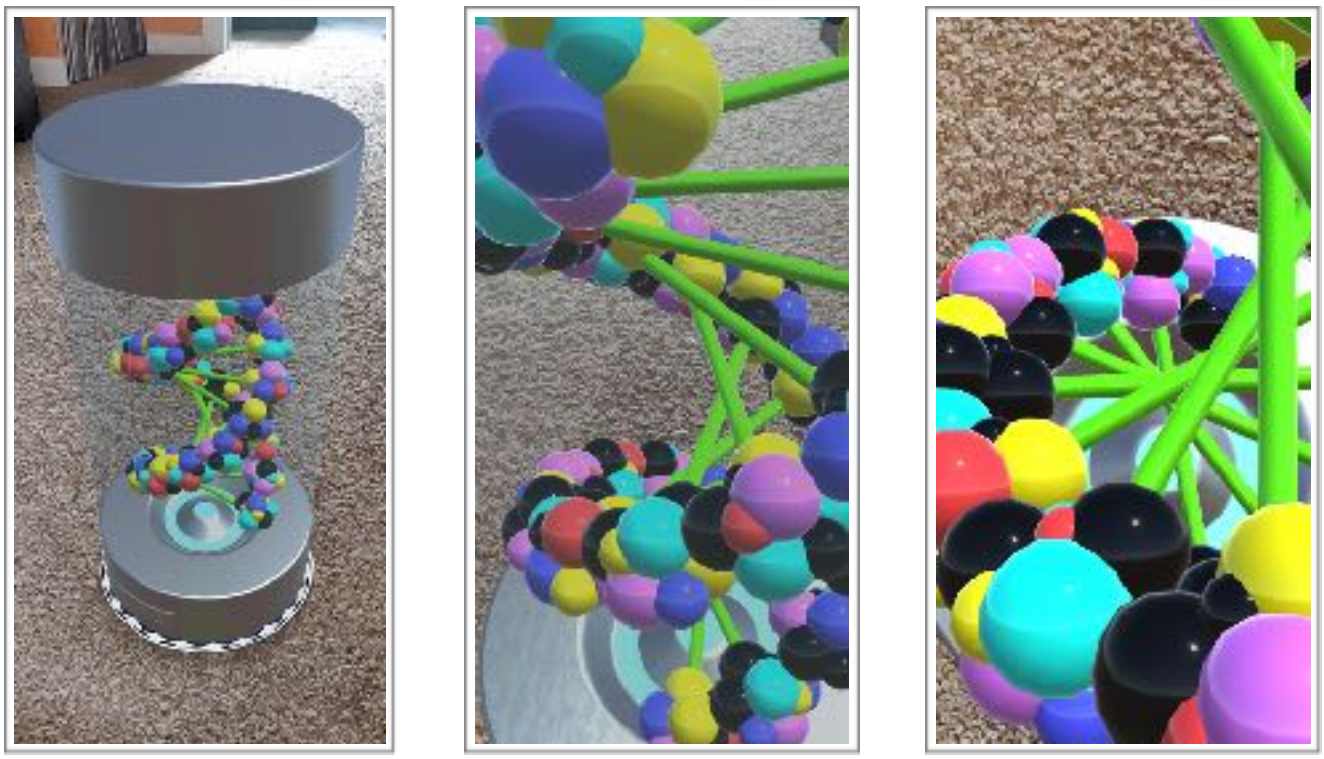

Figure 1. Screenshots from the beta version of the AR educational application with DNA Helix module

Augmented Reality application for STEM education
Augmented Reality is the technology that creates an interactive experience of the environment by enhancing the objects within the real-world or projecting virtual objects to the real-world [5]. The computer-generated perceptual information can have multiple sensory modalities, however,

for this project the mobile application is focused on visual and auditory experiences. An AR application can add 3D virtual objects to the natural environment which can be interacted the user device input interface. The camera of the device will be programmed to scan the environment. Then the user will be prompted to point the camera to ideal surfaces where the software will recognize the best location to project 3D models on those surfaces within the application.

Augmented Reality is different from Virtual Reality (VR) where the perception of reality of the user is completely based on visual information. In a VR system, the user will wear goggles and view a designed 360 degrees virtual space but in an AR system, devices such as iPads or smartphones are used to enhance the perception of reality of the user.

AR is fundamentally divided into two main categories of marker-based and marker-less.
The marker-based AR relies on surface patterns already stored in the database of the application (predefined patterns). This pattern can be a logo on a piece of paper and once the camera is pointed to the logo, the software will recognize and compare the pattern with the one stored in the database. This predefined pattern will become the surface where the 3D virtual models will be projected on. Software is programmed to create tracking points on the predefined pattern therefore once the paper is moved in front of the camera, the virtual object will be continuously tracked on the piece of paper.

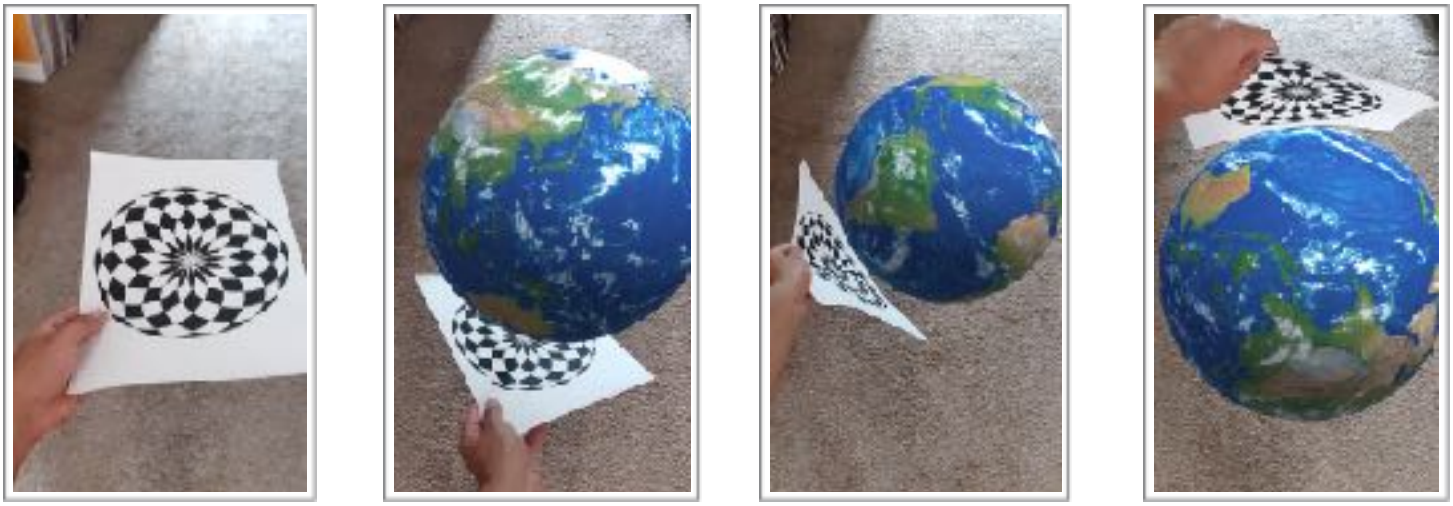

Figure 2. Screenshots from the beta version of the AR educational application with a model of the globe

In figure 2, the first figure shows the predefined pattern printed on a piece of paper, the second figure shows the 3D globe being mapped in the AR app and being displayed after recognizing the pattern. The third and fourth images show the app continuously tracking the predefined pattern successfully even if the paper is moved in odd angles.

The second category of AR is marker-less where the software will not rely on predefined patterns but rather will scan the environment instead. Once the camera is pointed to the environment

around the user, the application will continuously scan the depth and surfaces in order to define a virtual ground and walls. Afterward, the user will be able to place virtual objects on these surfaces and interact with them. Same as the marker-based AR, marker-less AR application will also place tracking points on the virtual ground and wall. Therefore, once the user places an object on this surface, points the camera away from the scanned environment, and then points the camera back to the same area, objects which were placed previously will stay in the same position.

Currently, the beta application developed is capable of creating a marker-based experience and the marker-less feature is under development. The goal of this AR application is to be able to offer both categories of Augmented Reality to the user. In either of the categories, once virtual objects are placed on the surface, the user will be able to turn the object to observe from every angle, change the scale of the virtual object, or (based on the design of model) move their device inside the virtual object for an in-depth insight.

The application is developed using the C# computer programming language within the Unity [6] game engine software. Unity game engine allows developers to package mobile applications for both iOS and Android devices. 3D virtual models are imported within the game engine and added to the final application. Virtual models can be designed with desktop software, using designing software with VR headsets, or downloaded from the free online library. In either of the designing options, the model is usable inside the game engine software.

Case Study: Adopting new technology in education

A case study was performed to understand the need and demand for the use of new technology-based teaching methods such as the beta AR app developed. An IRB (Institutional Review Board) approved survey was conducted with the University and High school faculty and students. The results showed that there is a growing interest in using technology in the classroom as well as the need for an interactive learning environment. Most teachers and faculty interviewed have valued the benefits of three-dimensional thinking and the ability to fully imagine a concept of study. None of the interviewees were notified about the Augmented Reality technology or the beta version of the app. Instead, there were discussions about the faculty's teaching experience and student's perspective on science classes.

Three-dimensional thinking is especially useful in the field of biology and microorganisms where after viewing the organisms under the microscope and learning about their behavior, we must rely on our imagination to fully understand the micro world. However, from a middle school or high school student's perspective, understanding this field can be difficult since they spend less time observing organisms under microscopes when compared to their teachers. They mainly rely on textbooks and diagrams showed in the classroom instead. We found that students prefer visually interacting with 3D models rather than just 2D.

One of the high school students mentioned: "*With a 3D representation there is depth and form. When looking at a flat book with different images, the image is often warped in ways in order to*

show that it is three-dimensional. This can often lead to confusion for the student as to what is actually going on in the diagram and leads to the focus more or understanding the image itself rather than interpreting what is actually being observed".

Electronic tablets or iPads are available to the high and middle school students. These devices are equipped with hardware technology to install and perform AR application software. When interviewing a middle school student, she mentioned that "*We use iPads almost everyday but we can't download any app that we like. But rather, the only app store we can use is the one school has set up with the educational apps available on there*." The Information Technology team of each middle school or high school is currently responsible for adding school's educational applications to the custom-designed app store. Adding the AR educational application can follow the same procedure in order for students to access it in the classrooms.

When asked about the use of technology in classes, a high school student mentioned "*My school has assigned laptops for every student in the school. This allows us to have access to many different learning tools that are extremely helpful. In each class we use different online textbooks too, which helps lessen the book load*.**".** As such, it will not be difficult for the students to use new software as they are already accustomed to such technology.

During the survey, we found that the faculty are also actively looking for new tools that increase the learning experience of the students in practical applications. When interviewing a biology professor about this topic, he mentioned: "*Cell is like a factory with many complex parts and lots of things that are happening simultaneously. Right now, in class I refer to the visual charts to show the structure of cell or human anatomy. If there was a technology that could give my students a tour of these biology related topics in 3D, I think it would make it much easier for my students to fully comprehend the idea*".

While conducting this research we have noticed repeated comments of faculty and teachers about students not having access to their own educational models. Often times teachers introduce the model of study to the class and then they start the lecture. However, for students who are learning about the topic for the very first time, it is confusing to refer the visual images to the words used in the lecture. During our interview with a mechanical engineering professor, he mentioned: "*I use real life models in class that relates to mechanical engineering. For example, I might bring a section of a car's engine to show to the students during the lecture. Students will each observe the item and then pass it to the next student in class. Using a real life item in class is extremely useful but it is definitely time consuming for students to each observe it. It would be great if students could use individual models in class as I lecture about how they work*".

From the case study, we found that students are able to understand better when they can observe the things that they are studying in real or at least in 3D that they can interact with. Similarly, faculty try to bring 3D models in their classroom for the better learning experience of students. As such, an AR app can be designed to provide the best teaching and learning tools for the STEM students.

Implementation and Future Work:
The application developed in this project combines scientific models and graphs from Biology, Chemistry, Engineering, and Mathematics all into one mobile application. Although the application is in its beta stage right now, we believe that it has the fundamentals to be upgraded into a full mobile application. Once this AR application is downloaded to the device, it will include a series of AR models for each course. Users can choose from the specific menus to use the scientific AR models based on the topic of study. Teachers will be able to request additional AR models to be added to the application, such models will be custom designed either using desktop software such as Autodesk Fusion 360 or in a virtual space using VR headsets and Medium software. Models will be uploaded to the main database of the application where all students who have access to the application will be able to use it.

The AR mobile application will use a subscription-based method of payment with its focus on educational institutions as the main customer. The educational institution will pay for the service based on each educational semester. Therefore, the application will not be designed to use distracting advertisements or prompting the user to purchase the full version in order to create profit.

Due to privacy-related issues occurring in the educational system with personal smartphone devices, the application will not be installed on the student's personal device. When asked about the use of personal smartphones in classes, a mathematics teacher mentioned "*Couple of years ago our school tried using educational apps on the student's devices. Each student had the task to download the application and use it during the mathematics classes. But later the Information Technology department found out that the app was faulty and there was a potential threat of phishing attacks for users. Therefore, we had to delete the apps and ban personal smart phones in our mathematics classes.*".

Conclusion
Implementing technological innovations in education plays a major role to help students learn complicated material efficiently. Today in middle schools and high schools across the United States many students are using technological devices such as laptops, Chromebook, or iPads as beneficial tools for education. Students have adapted to use such equipment in a classroom without getting distracted from the course material. This makes the adoption of new technology in teaching very convenient and beneficial.

In this work, we developed an Augmented Reality app that can be used in STEM learning for middle and high school students. This app creates a new and interactive learning experience. It also gives students the opportunity to have their own copy of the scientific virtual models in each class and at the same time, reduces the costs of purchasing multiple physical models for the educational institutions. This can potentially create a better teamwork environment where students can also get fully engaged in each lecture. We also performed a case study in which we learned the need and willingness of faculty and students to adopt and use new technology such as

AR in their teaching. Provided a good cost, the faculty are willing to incorporate new technology that can help students learn better and also provide a better way of teaching compared with the traditional methods.

In the future, we plan to complete our project and provide a beta version to local faculty for testing purposes.

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