Interactive Augmented Reality Learning Tool

Darla Drenckhahn
CSC 567 - 3D UI
Colorado Springs, USA
darla.drenckhahn@colostate.edu

ABSTRACT

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The application used in this study is an Augmented Reality application. The intended use of this application is to enhance learning (specifically learning in Computer Science). This is not a brand new technology, but the motivation behind this study was to specifically look into gearing the tool towards computer science and if this could be effective in making the learning environment better. To make this learning tool, I created a mobile application using Unity, and I used Vuforia Developer Portal to help with the image and marker based tracking aspect of it. An experiment was conducted where participants used the application with school material (handouts/homework) and then took a questionnaire afterwards. The results from this experiment showed that this type of application could greatly enhance learning in Computer Science especially since everyone learns differently so creating something that can benefit people who are more visual learners would be really valuable for them.

Author Keywords

Computer Science; 3D User Interfaces; Augmented Reality; Mobile Applications; User Study

CCS Concepts

•**Human-centered computing** → **Human computer interaction (HCI);** *Augmented Reality;* User studies;

INTRODUCTION

For my final project, I chose to create an augmented reality application to enhance learning, specifically learning in computer science. The intended use of this application is to enhance learning (specifically learning in Computer Science). There are three main ways that this application can be used to enhance learning. It uses marker-based tracking - and in this implementation it uses QR codes as markers. The idea is that eventually in textbooks/class handouts/homework assignments/etc, there could be QR codes (or other types of markers) that when scanned would bring up supplementary material to help students. This supplementary material could be a link to a website that explains more in depth a certain concept, a link to a video for a more visual explanation, or a 3D model or some type of augmented material that comes up on the phone to help explain the material.

This is not a new technology or new idea, however applying the learning to computer science isn't as widely looked at as other learning areas. According to Simsek, Augmented Reality (AR) is defined as enhancing the real world with artificial object [1]. Simsek also states that using AR in education is emerging and growing rapidly [1]. Augmented Reality can be used daily to improve life standards by designing and developing effective solutions [2]. Kose also states that researchers on the subject think that AR can allow improving people's perceptions, knowledge, and interactions with the real-world and that it can also lead to improved productivity in real-world tasks [2]. AR in education is one of the most popular fields for AR applications, and the e-learning techniques used in the education field are one of the most notable application areas in today's AR oriented solutions [2]. Simsek explains how AR uses computer vision techniques in the following quote:

> Simply, with using a camera, when an AR application faces with a "learned" image named as "target", it overlaps an artificial object on the image.

Kose states that developments and improvements on e-learning techniques are extremely important because they have a really important role on ensuring better educational processes and improving the associated literature [2]. Because of this reasoning, researchers are trying to expand their knowledge and apply this techniques from different perspectives [2]. Another motivation for that is because a common problem in education has been how to engage students with appropriate information and communication technologies during the learning process [3]. According to Kose:

> It can be expressed that the AR can improve learning processes in such courses, by using its effectiveness on affecting student' many senses and enabling them to experience the learning approach, which is enabled with real-world based practices, serendipitous explorations and discoveries.

Finding ways to make students more engaged in classes and helping them enjoy learning more is really important. Many students have a bad outlook on learning because everyone learns so differently and a lot of times it isn't tailored to visual learners. An AR application like talked about here would be extremely helpful because of the visual and interactive aspects of it.

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Figure 1. How an Augmented Reality application looks using Marker Based Tracking [2].

The main thing people are interested in when it comes to an augmented reality application designed to enhance learning is this: how does it affect students' outlooks on learning? This is the main research question that is investigated in this paper, as well as is this something that students' would use and want to have as a tool going through school. The objective of this study is to find answers to those questions and to create this learning tool that can affect students' learning experiences in a positive way. By using the learning tool I created, students can view supplementary material very easily and interact with their assignments to gain better understanding.

The next section this paper covers goes into some related studies that have been done, then there will be the section on methods of this study, then results and discussion, and finally a conclusion.

RELATED WORK

One study that was done was by Zagoranski. He and his partner developed a learning tool that can essentially be used as a virtual laboratory [1]. The results that they came up with show that their application and virtual tools could be used in place of real experimental equipment if necessary [1]. Liarokapis et. al, developed an application which focused on providing the capability to interact with 3D Web content using virtual and augmented reality [3]. They were able to enrich a lecturers traditional delivery using multimedia content locally or over the internet, or in a tabletop AR environment [3].

Another example of related work is by Majid et. al, who created a mobile application that uses a marker that is a real memory stick called random access memory (RAM) [5]. When the marker is tracked, the phone displays a digital image associated with that marker [5]. They used Metaio SDK for the development of the AR application [5].

In general, AR has been used in many other fields such as medicine, biology, etc. It's also commonly been introduced in younger grade school to teach children about geography and plants and animals. An example of using these types of applications in grade school is by Hsieh and Lee, who proposed a method of reducing complexity and increasing capacity with designing AR markers [6]. They used their finding to create an Augmented Reality English Learning System (ARELS) which was created to help kindergarten students learn English. Another example similar to this is done by Medicherla et. al, who created a project that had an interactive solar system developed to help middle school students in the science field understand spatial concepts with the help of augmented reality [7].

Another interesting study done was by Pellas et. al, who studied the combination of AR with game-based learning (ARGBL). Pellas et. al, were motivated to study this combination because there is a significant body of research relating to strictly AR uses for learning in primary and secondary education, but not nearly as much studying the combination of AR with game-based learning [4]. In their study, Pellas et. al, looked at 21 studies, all published between 2012 and 2017, as well as 11 indexed journals [4]. In their systematic review, the authors talk about how children are benefiting from the use of digital tools on a daily basis, which is a huge reason for this study [4]. Next I'll highlight some of the results that came from their systematic review. One big result was that the majority of primary education studies (50%) reported that the combination of AR applications and game-based learning led to better learning performance/learning gains in educational settings. Another interesting result was that 71.4% in secondary education and 50.0% of primary education studies looked at used marker-based tracking [4]. This was a reason that for my application I went with marker-based tracking as well. The biggest limitation that seemed to be present in both primary and secondary education across the studies that Pellas et. al, looked at was that teachers couldn't manipulate the same system for different educational subjects (i.e. there was a lack of interdisciplinary programs) [4]. An important conclusion that came from their systematic review of studies was that AR technology has incredible potential for education. The benefits include influencing the students' cognitive acceleration, increase of the students' self-management, as well as the enhancement to their engagement in practice-based activities [4].

METHODS

One of the problems that is a motivation for this kind of work is that teachers have a difficult time maintaining motivation and student engagement in the classroom [4]. Pellas et. al, describe that

> games can be used as "bait" for learning, vehicles for content, architectures for engagement, and as "tools" to evaluate the users' strategies for gaining knowledge.

So not only would a mobile application like described here be very beneficial to enhance learning, but making learning into games like described in their study is even more beneficial [4]. A big push in the direction of AR learning is that it can help conceptualize difficult concepts that are not easily accessible in real life. Another reason that augmented reality applications to enhance learning has gotten so popular is because of the challenges in keeping students engaged when learning complex material [5].

When looking at how to make this application, at first the design I was envisioning was on the home screen, having a option to choose what class you wanted to use the application for and then what module in that class. I went away from that when I started using Vuforia, because Vuforia is an augmented reality software development kit and it comes with a target image database to use. So in using that, you can choose what happens for each image target. I realized that it would simplify the application a lot if all the user has to do is hit 'start' and scan the targets to interact rather than choosing their class and module when that wasn't necessary. Using the Vuforia development portal was nice as well because when you uploaded the targets to the database, it rated them on how easy they would be to recognize based on how many features they had.

Looking at Figure 1, that application is using marker-based tracking. It is using images that look like customized QR codes for their targets, and as you can see from the first two images on Figure 1, each target image bring up a different 'activity' on the mobile application. And the third image on Figure 1 shows what looks like a PowerPoint slide with the target image on there for the users to interact with.

For the experiment, I had a packet of documents that I gave to each participant. The first was a document explaining the idea behind the application and how to use it. The reasoning behind giving this document was to give each participant the same information before the experiment was performed, and to make sure there wasn't a variable there that could cause inconsistent results. Then there was a class handout document that I made that was an example of how a teacher could incorporate the supplementary material with the application. There also was a sample homework assignment that had spots to interact with the application and add clarity to the homework. Then the last part of the experiment was filling out a questionnaire. The questionnaire had general demographic information but then asked questions such as how easy the application was to use, what is missing from the application, if they wished they had this in school, and if they could see it enhancing their learning experience.

RESULTS/DISCUSSION

There were 14 participants in this study - comprised of 9 men and 5 women. 78% of the participants had a technical background. This was an important demographic to get from the questionnaire because the application was completely geared towards Computer Science information. I thought it was fine to include the non-technical results as well, to speak about the applicability to the application towards education in general rather than just for Computer Science. There could be somewhat of a bias, because 57% of the participants came from my work - Lockheed Martin. This could potentially be a bias because Lockheed Martin might hire certain people who feel the same about certain technologies, etc. The average age of the participants in this study was 36 years old, with a range from 23 years old to 81 years old.

Ease of Use Results

Difficulty Level	*Number of Responses*
Very Easy to Use	12
Easy to Use	1
Neither Easy to Use nor Difficult	1
Difficult to Use	0
Very Difficult to Use	0

Table 1. Questionnaire responses to question "How easy is this application to use?"

Do you wish you had this in school? Results

Response	*Number*
Yes	13
No	1

Table 2. Questionnaire responses to question "Is this something you wish you had in school?"

One of the questions asked in the after experiment questionnaire was "How easy is this application to use?" and it had the options: Very easy to use, easy to use, neither easy nor difficult to use, difficult to use, very difficult to use. As you can see in Table 1, 92% of the participants responded that the application was either very easy to use or just easy to use, and only 1 participant said it was neither easy nor difficult to use.

Another important metric recorded in the questionnaire was if this mobile application was something the participant wished they had in school. The results for this question are shown in Table 2. As you can see from the results, 92% of the participants responded that this application is something that they wished they had in school. The one participant who responded no said that "using QR codes for additional information is used in textbooks." This is true, and as stated earlier in the paper, this is not a brand new idea that I'm coming up with. I personally never saw anything like this throughout all of my schooling including during my undergrad. So while it may be (and is) implemented, it is not widely used yet because there isn't enough research yet to show how effective it is on the students performance and their outlook on learning. This is changing though as technologies are advancing, there is more and more information about these kinds of learning enhancement applications.

The next results I want to discuss are from the questionnaire question "What is an important feature you think the application is missing?" This question brought so many things back to me that I did not think about but are great points and really

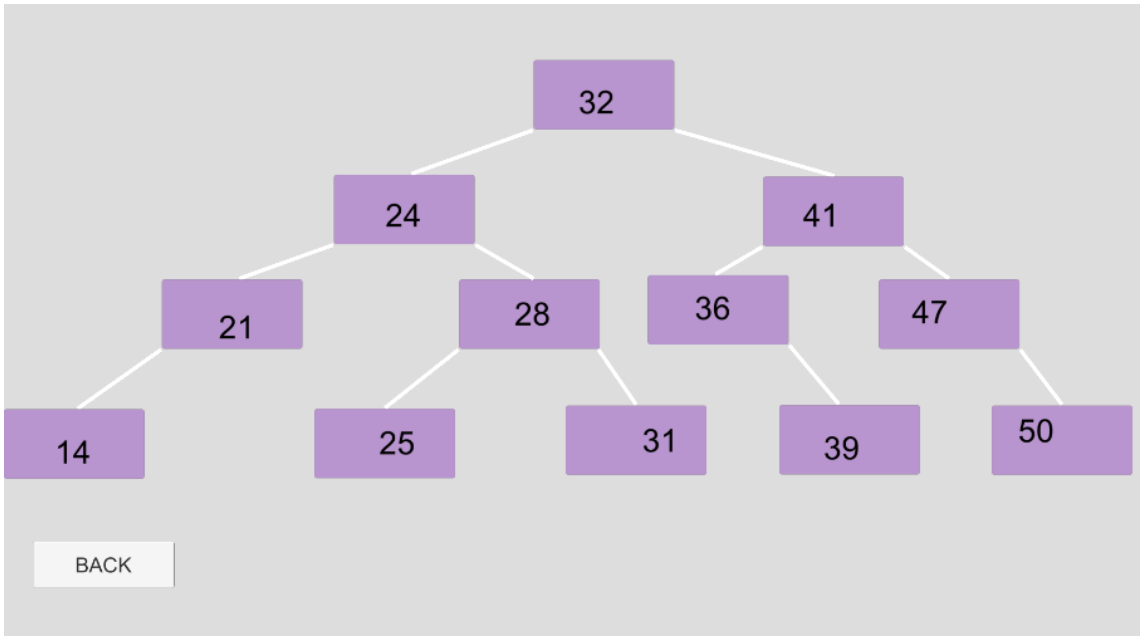

Figure 2. AR Tree Example from Mobile Application.

valuable information for me. One response was focus - which I think comes from the fact that the only phone I had available for this application was a very old Samsung phone, so it was very slow. Along with that, Vuforia doesn't seem like the smoothest AR development kit, so that probably contributed to this as well. Another comment was to add a flashlight capability to the AR part of the application for when you are faced with low lighting situations. This was a very good point and one that did not even cross my mind. If this application were to be used to enhance learning, being able to use it even with different kinds of lighting would be an important feature to have. Another really important feature to add to make this a feasible learning enhancement application would be the option to view your history, that way if you are on the go and don't have immediate access to your material with the QR codes, you could look back at your history and find that information. This would be very valuable because say in class the teacher has the QR codes (or other image targets) on a PowerPoint but don't send the PowerPoint out, you could just go back to your history and get that supplementary material. Another good comment is that adding a way to quickly get back to the application when a QR code is scanned and brings up supplementary material would be helpful.

There were a couple of other comment son things that participants thought the application was missing, but they are all very similar. If we look at Figure 2, that is a screenshot from the mobile application that comes up when you scan one of the QR codes after it asks what the tree would look like when you add the node 24. A big comment that the questionnaires showed was that there was a wish that this was more interactive, such as moving tree nodes with your fingers and manipulating the tree in that way, and then the application would tell you if that was correct or not. This was an amazing comment because I was really struggling with how to make something that was more interactive and this didn't even cross my mind. That was the hardest part for me, because there wasn't a lot of typical 'AR' things that I could relate to Computer Science. For example, if this was an application geared towards biology, when a certain QR code was scanned a 3D model of the digestive system could appear augmented on the phone. I couldn't find any free resources that I could do something similar with that related to Computer Science. Similarly, one participant thought it would be nice to have the application somehow look at the progress made and determine good hints to give to the user to move forward.

One participant commented that "I did not see anything in the app that is augmented reality/3D." This is a valid comment in the traditional sense of what most people believe augmented reality is. There are different kinds of augmented reality though, and marker-based AR (the type used in this application/experiment) works by scanning a marker which triggers an augmented experience which can be an object/text/or animation to appear on the device. Essentially it is interacting with the outside world to make activities happen on the mobile device. So while I agree that the way this application works now is not a typical augmented reality where there is a 3D model that comes up, but it is still a form of augmented reality. If I had thought to do the interactive tree in time, that would have been a stronger AR example, but by the time I had the survey results back I didn't have time to add that feature in.

The last big question that I asked in the questionnaire was if the application could enhance learning experience and impact students' outcomes on learning. I got some really great results on this question. 92% of the participants said that an application of this variety would enhance their learning.

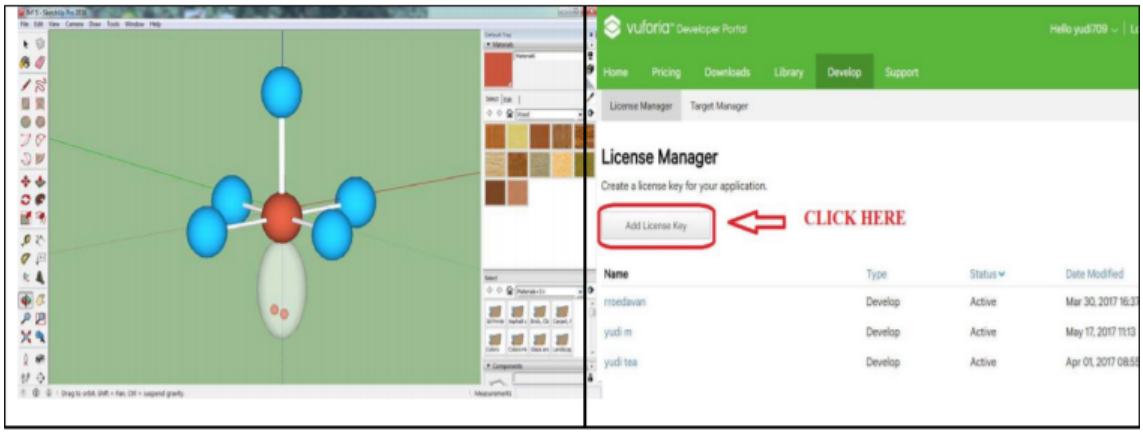

Figure 3. Example of application to create 3D models. [8].

One participant said that

> I am an advocate for all computer-based learning. I like it when you get immediate feedback about right/wrong between problems. It lets you achieve understanding at each step before you tackle the next. As an instructor, I would probably require the student to review each answer before proceeding.

One person said that their textbooks had this type of capability but that they never used it. As with everything, one type of way to learn won't fit all student's needs. At least having this functionality as an option could help the 92% of the participants that are more visual learners, and for the ones that it doesn't help - they don't have to use it.

Many student's are visual learners or just don't do well with only lectures and having more interaction and hands on material would be drastically helpful. Most students' end up on google to help them with their homework when they don't understand the book or teacher. Another thing to consider is that textbooks aren't always written to the level of the student, so having supplemental information that goes along with the textbook would give students' more confidence in finding answers on their own and not having to rely on TAs or the professor. One participant commented that a common frustration he went through was finishing an assignment thinking that he had everything correct, only to receive his grade and be disappointed to realize he had made a stupid mistake. Having an application like this could almost replace a tutor. An even bigger upgrade to the application was that it could view your work and give you an estimate the amount of points you would receive if it was an assignment.

CONCLUSION/FUTURE WORK

The hardest part I had with coming up with this application was coming up with valuable supplementary material to add into the application. Having the application bring up links to more information and/or videos with more detailed explanations is definitely an important feature of the application. However, it was hard coming up with a truly interactive 3D/augmented feature. From the experiment results, there are definitely things that I would add to the application to help make it a better experience for the users. A couple of which include adding a flashlight option into the AR camera part, adding a history feature to access previously visited pages/activities/graphics without having to re scan the target images, and adding a way to quickly get back to the mobile application from activities that get brought up.

Another thing that I would want to add to make the application better would be looking into other augmented reality development kits, as Vuforia seemed to lag a lot and be slow, and finding a better resource for image tracking would improve the usability of the application by a lot. Another reason to look into a different augmented reality development kit would be to find one with better image tracking. I attempted to use an image of a binary search tree as a target image, and when the picture was on the computer screen it would sometimes scan but inconsistently. Then when the picture was printed on paper, I was not able to get it to recognize it and scan once. This is an important feature to consider when picking the image targets - if it doesn't have enough features then it won't scan and the usability of the application goes down. Using an augmented reality development kit that has better feature and image tracking could improve the experience for the users.

The biggest improvement that is critical for the application to have is to add a more interactive tree example so the users get more interaction and instant feedback on doing various operations with adding and removing nodes with that tree. Also, next time I would use a resource like Sketch Up, which can be used to create 3D models. If I had known that resource was out there earlier, I would have used that and added better 3D models into this application which would have increased the value of it a by a lot because that was the hardest part for me and having this resource would have been awesome to use. An example of using Sketch Up is shown in Figure 3 with creating a geometry molecule [8].

Based on the results from the experiment conducted in this study, using an augmented reality application to enhance learning in computer science is very valuable and would help students' be more engaged in their classes.

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