

Comparing the Impact of Augmented Reality and 3D models as Visual Representations

in eBook

by

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ABSTRACT

Electronic books or eBooks have the potential to revolutionize the way humans read and learn. eBooks offer many advantages such as simplicity, ease of use, eco-friendliness, and portability. The advancement of technology has introduced many forms of multimedia objects into eBooks, which may help people learn from them. To help the readers understand and comprehend a concept that is put forward by the author of an eBook, there is ongoing research involving the use of augmented reality (AR) in education. This study explores how AR and three-dimensional interactive models are integrated into eBooks to help the readers comprehend the content quickly and swiftly. It compares the reading activities of people when they experience these two visual representations within an eBook.

This study required participants to interact with some instructional material presented on an eBook and complete a learning measure. While interacting with the eBook, participants were equipped with a set of physiological devices, namely an ABM EEG headset and eye tracker during the experiment to collect biometric data that could be used to objectively measure their user experience. Fifty college students participated in this study. The data collected from each of the participants was used to analyze the reading activities of people by performing an Independent Samples t-test.

DEDICATION

This is dedicated to my family and all my teachers who played a vital role in my life to

build my character and thoughts that are essential to who I am today.

My mother Anuradha Somisetty

My father Shiva Kumar Juluru

My sister Mamatha Juluru

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TABLE OF CONTENTS

	Page
LIST OF TABLES	v
LIST OF FIGURES	vi
CHAPTER	
1 LITERATURE REVIEW AND OVERVIEW	1
2 METHOD	11
Participants And Design	11
Learning Environments.....	11
Instruments And Apparatus	15
Scoring.....	19
Procedure.....	20
3 RESULTS	22
Comparison Between Groups	23
Comparison Within Groups	30
4 DISCUSSIONS AND CONCLUSION	36
REFERENCES.....	40
APPENDIX	
A DEMOGRAPHIC QUESTIONNAIRE	44
B POST- TEST QUESTIONNAIRE	47
C USER EXPERIENCE QUESTIONNAIRE	53
D CTCI COMPLETION REPORT	57

LIST OF TABLES

Table	Page
1. Comparison Between Stimuli	15

LIST OF FIGURES

Figure	Page
1. Image and Location Based AR	2
2. ARBook Using Marker Based AR.....	3
3. Sample Exercise Solved Using DeidricAR	4
4. Final Solution For The Problem Stated In Figure 3	6
5. A Tutor Assisting His Student Using Construct3d	7
6. AR-EBook.....	12
7. AR-Scene.....	13
8. Three-Dimensional Model Visual.....	14
9. ABM X-10 EEG Headset	16
10. Tobii Pro Glasses 2.....	18
11. Independent Samples t-test For ABM Sensor Data.....	25
12. Independent Samples t-test For Learning.....	26
13. Independent Samples t-test For Visual Attention.....	28
14. Independent Samples t-test For User Experience Ratings.....	29
15. Independent Samples t-test For Relative Time Spent on Visuals.....	30
16. T-test on ABM Sensor data for Control group.....	32
17. T-test on ABM Sensor data for Treatment Group.....	34
18. Heatmap For Treatment Group.....	34
19. Heatmap For Control group.....	35
20. Gartner Hype Cycle	38

CHAPTER 1

LITERATURE REVIEW

The term Augmented Reality is thought to be termed by Tom Caudell ("Infographic: The History of Augmented Reality - Augment News", 2017). Augmented Reality (AR) is where a set of technologies are responsible for displaying and presenting three-dimensional objects, generated by a computer, in the real world where users can interact with them in real time. People see both real and virtual objects, which could either be stationary or interactive, in real time. The history of AR goes back to as early as the invention of computers but the development of devices like head mounted displays came into play in only 1960s when Ivan Sutherland first developed it ("Augmented reality", 2017). In 1975 Myron Krueger took it to the next step by creating an AR lab where projectors were combined with video cameras to omit an onscreen silhouette to create an interactive environment surrounding the users. Later, AR systems like Virtual Fixtures were developed to help the military so that they can control machinery from remote space ("Infographic: The History of Augmented Reality - Augment News", 2017).

AR can be perceived in a variety of ways. Initially people used specific labels or markers like quick response codes to fix the position of the three-dimensional model in real world space. Whenever the marker or label is displayed in front of the camera, the AR application processes the image to generate the 3d model and place them in the real world. When the marker is rotated, or moved, the models also move along with the marker. Nowadays markerless AR, which uses GPS to identify the location of the user and is used

as the trigger to superimpose three-dimensional models over real-world, is widely in use. A comparison of both these is displayed in Figure 1 (Cheng & Tsai, 2012).

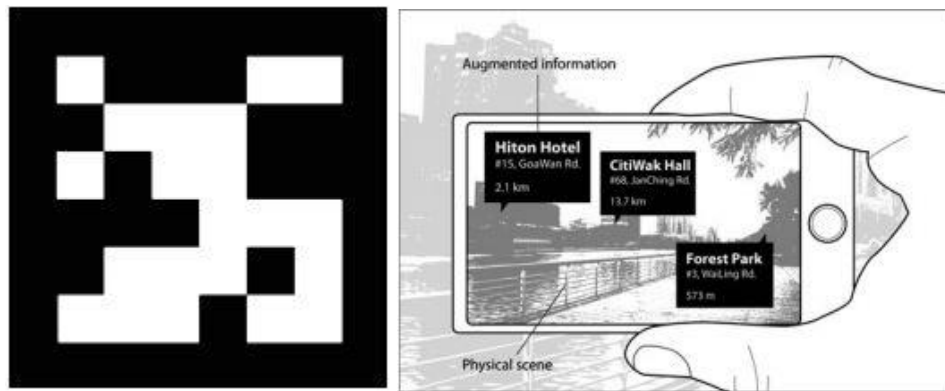


Figure 1: (left) Marker which is used as trigger in Image based AR, (right) Location based AR – display information based on the location (Cheng & Tsai, 2012)

AR has been in use in various fields like advertising and marketing, architecture and construction, entertainment, medical, military, travel and many other areas. Many researchers have seen immense potential of using AR in education (Yuen, Yaoyuneyong & Johnson, 2011). They have found that using AR in different fields directly or indirectly linked to AR in education. Further on it was noted that AR books, AR gaming, discovery-based learning, objects modeling and skills training had an ample scope for using educational applications with AR embedded (Yuen, Yaoyuneyong & Johnson, 2011).

In this section, we shall discuss the various research aspects that combine both AR and education starting with AR Books. An ARBook is an application that uses AR to improve the visuals in paper- or electronic-based books using the three-dimensional visual content (Figure 2). There are two versions of ARBooks. First version is used by readers to read through regular pencil-paper textbooks with the help of devices like mobile phones,

AR glasses, and other wearable devices. The second version is used to deliver a book using a computing device. These devices help users to visualize the multimedia attributes as three-dimensional objects, soundtracks or as videos, which augments the traditional real world textbook, as users go through the book using these devices. The pages in the book are used as triggers for the AR scene to load. The device with which the reader reads the book handles this transition. Figure 2 consists of the sample screenshots.



Figure 2: ARBook using marker based AR (Cho, Jung, Lee, Lim & Yang, 2011)

As textbooks have many pages, the system proposed uses markerless tracking methods for key point extraction, matching and tracking. The three-dimensional models are primarily designed to help the reader to understand the material better. This method used in developing the application was developed using a markerless, robust visual tracking method. This approach can recognize page movements and page turns for key point extraction at 25fps and can track the pages at 60fps over 200 pages for displaying the three-dimensional models. This application can even run on a single core CPU which runs at 1.2

GHz which has a low camera resolution of 640 by 480. The developers claim that their method runs robustly on various environments with a small defect that is to not detect curl pages (Cho, Jung, Lee, Lim & Yang, 2011).

An example of application that was developed using AR is DeidricAR (de Ravé, Jiménez-Hornero, Ariza-Villaverde & Taguas-Ruiz, 2016). It is a mobile AR system designed for learning descriptive geometry anywhere at any time. The application consists of a workbook and a mobile device to interact with the workbook. The application performs the detection of the marker and renders the model to be displayed. All the markers have virtual buttons so that the user can interact with the three-dimensional models. Each dihedral exercise has a statement, intermediate steps and a solution. Markers and a virtual model is present for each stage to help the users to get a clear understanding of the solution. This system help students learn independently using their mobile devices over an exercise material designed specifically for this application.

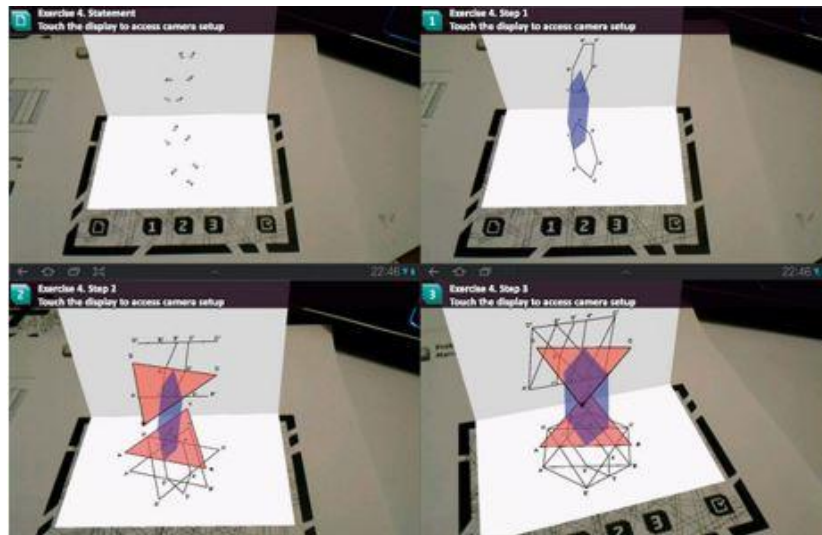


Figure 3: Sample exercise solved using DeidricAR (de Ravé, Jiménez-Hornero, Ariza-Villaverde & Taguas-Ruiz, 2016)

The problem proposed in Figure 3 is one of the sample questions in the exercise material, and it also says how to create a model in a step-by-step process. The solution for the problem in Figure 3 is proposed in Figure 4. The use of this system has helped increase students' interest in the subject. An experiment using this application was conducted with fifty mechanical engineering students varying in age from 18-20 years that were randomly assigned into Control and Experimental conditions. Students in the Control group were taught descriptive geometry with traditional methods while students in the Experimental group were taught the same content using the DeidricAR.

The spatial skills of students in both the groups were evaluated to learn that the outcome of students in the Experimental group was better than those in the Control group, as the average of marks obtained by students in the Experimental group was 17.5% higher than the Control group. The observation was that the time needed to resolve the exercise was 8.1% reduced by students in the Experimental group. DeidricAR gives the chance of interacting with the three-dimensional models using virtual buttons which the authors consider as one of the main reasons for the participants to acquire spatial perception skills. Authors also consider that the tablets and mobile devices have a potential to go global which helps this application to be used widely. Considering these results, Eduardo and Hornero (2016), the authors claim that using DeidricAR helps the students to have a positive impact on their spatial skills.

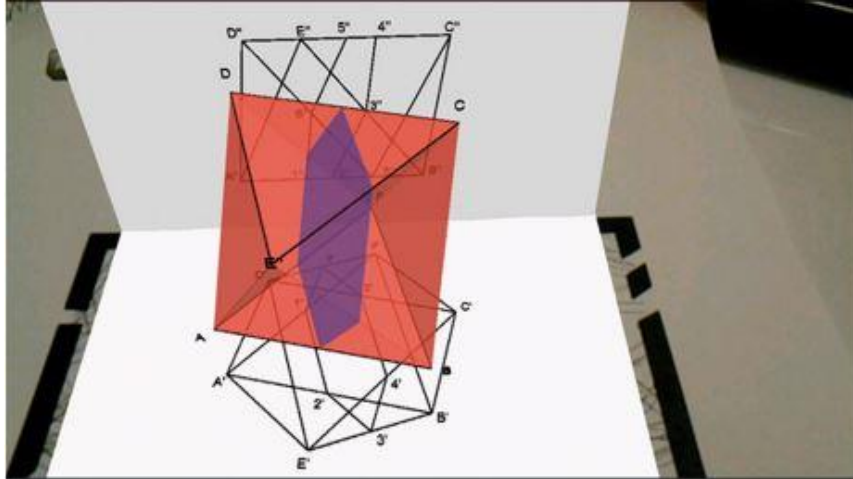


Figure 4: Final Solution for the problem stated in Figure 3 (de Ravé, Jiménez-Hornero, Ariza-Villaverde & Taguas-Ruiz, 2016)

Another application that was designed specially to teach geometry is Construct3D, which was based on a mobile collaborative AR system “studierstube” (Kaufmann, 2003). Studierstube enables multiple users to share a virtual space using AR. This application helps to create geometric objects like point, plane, sphere, cylinder, cone coupled with construction functions like intersections, curves, and surfaces. The user can explain dynamic geometry in Construct3D. In other words, the user can modify the geometric objects in real time with the help of a stylus which has six degrees of freedom (Figure 5). Kaufmann claimed that this application was tested with 14 students to get positive results along with a couple of problems. The test comprises two parts: (1) solving a problem related to construction with the help of a tutor in Construct3D, and (2) all the participants to answer a short survey. All the participants were analyzed based on the survey results. The researchers found that all the participants were interested to experience the environment again (Kaufmann, Schmalstieg & Wagner, 2000). Kaufmann et al. found that

interacting with three-dimensional objects increased the understanding and learning curve of the student because of working with this application.

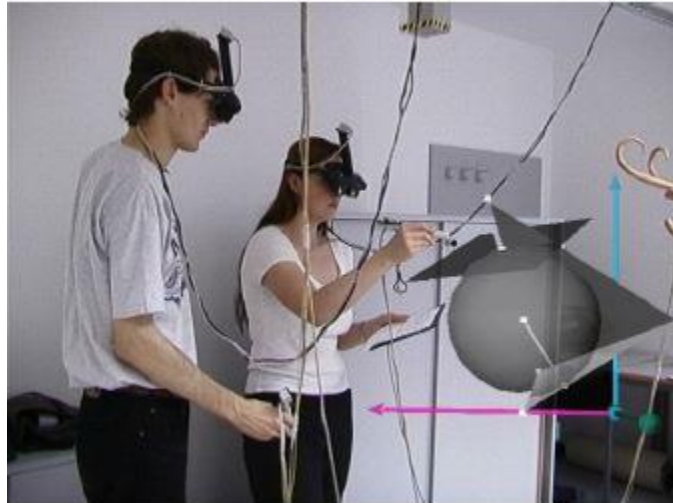


Figure 5: A tutor assisting his student using Construct3D (Kaufmann, 2003)

Another application that uses AR and is helpful in the classroom is EduAR (Farias, Dantas & Burlamaqui, 2011). This application was designed to improve the perception of students and to emphasize information that might not be perceived accurately by the students. By using this application, teachers can enhance the performance of presentation by superimposing three-dimensional models on presentation environment. This tool does not require the user to have any experience or skills with basic programming, three-dimensional modeling or AR applications. Instead, it provides all the necessary information such as three-dimensional models and links between models and markers, allowing the teacher to provide an AR presentation to students. During the presentation, anyone could interact with these three-dimensional models by changing their size as well as rotating and animating the models. Inputs to these models are given using either a marker or through a keyboard.

Farias, Dantas and Burlamaqui (2011) conducted a study to evaluate the application. A group of twenty people with no prior knowledge about EducAR were used to test it. Twenty participants were taken for the experiment and were given the same set of instructions. A laboratory without EducAR was the venue for the experiment. The experiment needed twenty computers which did not have EducAR installed and ten computers with Linux(Ubuntu) installed in it, and ten computers with Windows Vista installed in it. The goal of the experiment was to find the percentage of people that could follow a set of software installation instructions with and without help. The instruction set had 11 instructions and the authors claim that everyone without help achieved one to four instructions. Sixty percent of people reached step five without help. Twenty percent of individuals could not reach step six because of no JAVA runtime installed previously. Seventy percent reached step seven, and ninety percent reached step eight. Also, everyone reached steps nine and ten (Farias, Dantas & Burlamaqui, 2011). The authors just chose the ability to complete the set of instructions as a variable to measure.

There are several examples of tools and studies to evaluate conducted by scientists in the field of education. The main goal of these experiments was to incorporate AR into an educational task to help students understand and learn better. While there is a modest amount of research involving AR in eBooks, this research is primarily helpful for those readers who could wear a device around their ocular region or can afford a computer. But these devices are costly and not every person can afford them. The present study is motivated by the idea of exploring how AR can be used in conjunction with eBooks but with minimal cost to the readers. For instance, we recently experienced a phenomenon where a gaming application named PokemonGo acquired immense public attention and

interest. In this application, AR was used to display the pokemons in real world. The application was free and could be played virtually on any smartphone might account for why this application enjoyed widespread acceptance. This aligns with this study's goal to build an education-friendly AR application that helps students to learn better while not imposing any additional hardware requirement. This thesis explores how AR in eBooks may help students learn better.

Research using immersive environments in education is increasing rapidly (Kaufmann, 2003) and this study marks another step towards the goal of using AR in education. Increased student participation in class, making the students excited to learn new concepts, helping them retain more information, making them visualize while learning, increased usage of visual and audio sensors are certain noticeable advantages of incorporating AR in education ("8 Benefits of using augmented reality in education", 2017). Owing to these advantages AR is chosen for usage in this study.

The present study was designed to compare how students learn from two types of visual representations in eBooks: AR (where the participant must place the device over a marker to see the model) and three-dimensional (where the participant views the model as he clicks on the image). Fifty students were randomly assigned in equal numbers to one of two conditions. They were asked to study an eBook embedded with either AR or three-dimensional visual representations. While studying, the participants wore sensors like an ABM X10 EEG headset and Tobii Glasses Pro2. The ABM Headset collected information related to the workload, distraction, drowsiness and engagement levels which the brain of the participant is experiencing. The Tobii Glasses captured the fixation points at which the participant gazes to know more about the visual attention of the participant. Once the

participants completed the eBook, they were given a Post-Test and User Experience Questionnaire to test the knowledge retained by each participant and their feedback towards each environment.

Reading patterns from both the groups was used to tell which stimulus has an impact on the participants. The experimental procedure began with a Demographic Questionnaire, followed by stimulus and concluding with a Post-Test and a User Experience Questionnaire is chosen. A series of individual sample t-tests was used to analyze differences between Control and Treatment groups on the study's dependent measures. The Demographic Questionnaire was used to gather information about the participants. Post-Test was used to determine how much information the participants had inferred during the experiment. Variables like learning, visual attention, engagement, distraction, and workload were collected to determine if there were differences between the two conditions. The Treatment group was provided an eBook with AR models while the Control group was given an eBook with three-dimensional models.

CHAPTER 2

METHOD

Participants and Design

Fifty students participated in this study including 38 males and 12 females. All the participants were English-speaking students. The age of the participants was between eighteen and twenty-five. The 50 participants were equally distributed between Treatment and Control groups ($n = 25$). Around 94% participants were enrolled full time at ASU with 44% having a Master's degree, 20% having a bachelor's degree and 36% completed high school. Two-thirds (68%) of the participants had not used an AR-based application before. When the participants were asked about their familiarity with dinosaurs on a scale of one to five, around 6% have rated 1, 42% have rated 2, 38% rated 3, 14% have rated 4 (one being low and five being high amount of knowledge).

This study involved one independent variable with two levels. The participants were randomly assigned to AR visuals (Treatment group) and three-dimensional visuals (Control group) with equal numbers in each condition ($n = 25$).

Learning Environments

For this project, Unity was used to create an eBook that could deliver both AR visuals and standard three-dimensional visuals. Unity is a game engine used to build games, but with the wide popularity it has and its ability to develop games with ease, there are modern software development kits like Vuforia which help the Unity developers to create new applications with AR built into the application. An AR-eBook is not much different

from regular eBooks, which are in the market currently. An AR-eBook has AR infused into a regular eBook. The user switches to an AR scene where the reader interacts with all the models related to the context. This transition to the new scene might help the readers get to know more about the topic and help them understand and comprehend the details better, which is the hypothesis that is under verification in this study.

PDFs were built in Unity by creating each page as a scene. Each page of a regular eBook was applied onto the texture of a cube or a plane but they do not provide all the necessary features like zoom, text search which is already present in standard PDFs. Switching between pages was implemented as navigation between different scenes while developing this application. Hence, a script written in C#, which handles the scene transitions, was added as a listener for the previous and next buttons shown in Figure 6.

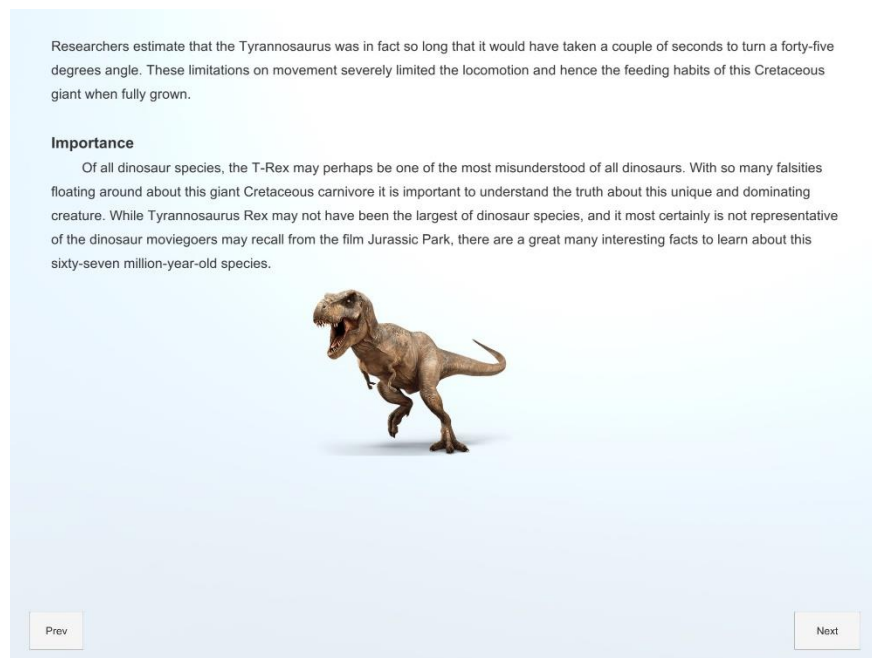


Figure 6: AR-eBook

To include AR into the application, we created buttons (see Figure 6) with the image component of the button set to the picture of the model. On click of this button (or

dinosaur image), the reader was taken to the AR scene where the reader could feel different subjects related to the context and interact with them (whereas for the Control group, the participants see and interact with three-dimensional models in the device itself). Here the reader could interact with the subjects and view them from different angles (see Figure 7 and Figure 8). Image Targets ("Image Targets | Vuforia Library", 2017) were used to attach the AR model to the real-world image of the dinosaur. This helped the user to see the AR model when the iPad is placed on top of the marker. Once the user completes the interaction, he/she can click on the back button to navigate back to the text to resume the reading process.

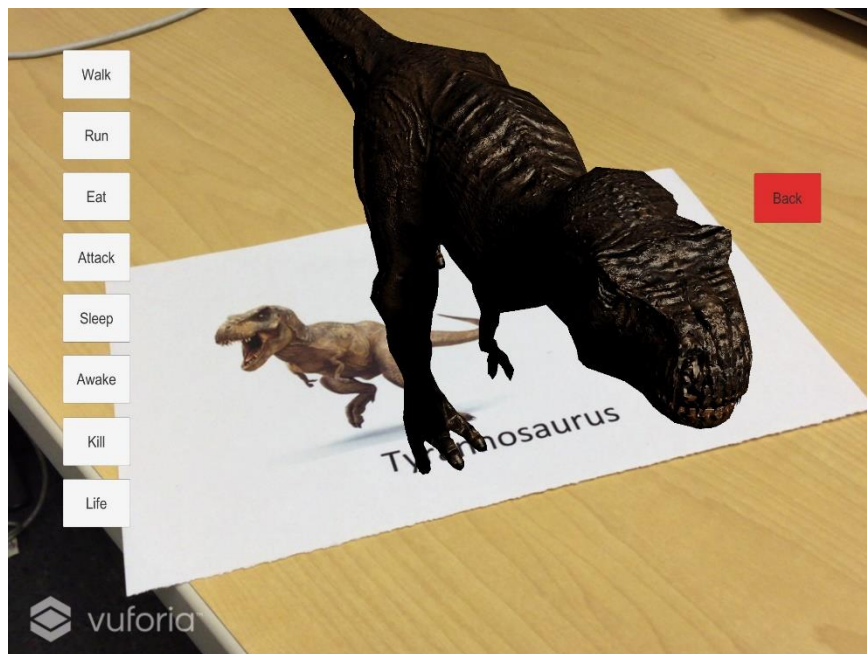


Figure 7: AR Visual

There were two environments used in this experiment. The first environment was for the Control group where participants were presented with a standard eBook embedded with three-dimensional models to represent the book's visuals (Figure 8). The second

environment was for the Treatment group experience where the participants were presented with an AR-eBook, three-dimensional AR models embedded into eBook, as a stimulus (Figure 7).



Figure 8: Three-Dimensional Model Visual

Both the Control and Treatment environments contained 18 pages of information related to dinosaurs. Both the environments consisted of approximately 4,500 words. In total, four dinosaurs were discussed and described in these learning environments. These dinosaurs include Compsognathus, Brachiosaurus, Stegosaurus and Tyrannosaurus. Each dinosaur was described using four pages of information and an image. A demo for both the learning environments was given at the start of the books to ensure that the participants know how to use the book. This demo consisted of instructions that guided the participants on how to interact with the models giving a small insight into the learning environment. A comparison between both the learning environments is shown in the Table 1. The

information required to describe the dinosaurs was collected from several websites ("Brachiosaurus", 2017; "Compsognathus", 2017; "Compsognathus | Extinct Animals", 2017; "Jurassic World", 2017; News & DinoPit, 2017; "Stegosaurus", 2017; "Tiger PNG images", 2017; "Tyrannosaurus", 2017; "Tyrannosaurus rex", 2017).

	Stimulus for Treatment Group	Stimulus for Control group
Number of pages in eBook	16	16
Number of dinosaurs described	4	4
Images per dinosaur	1	1
Models embedded	AR	Three-dimensional

Table 1: Comparison between stimuli

Instruments and Apparatus

During the experiment, the participants were subject to the capture of a few values. This study focused on comparing the reading patterns of people when they read and interact with two types of visual representations presented in an eBook. The study also aimed to find if AR-eBooks were helpful for readers to understand and comprehend information easily by using AR in eBooks. To shed light on this issue, this study captured variables like cognitive load, distraction, drowsiness, engagement, and visual attention. The reading patterns were analyzed to infer the impact that different types of three-dimensional models have on readers.

The devices used in this experiment were the ABM X-10 EEG Headset and the second version of Tobii Pro Glasses. ABM X-10 EEG headset is a wireless headset (Figure 9) that contains sensors placed on the surface of the scalp to perform data sampling of electronic channels 256 times per second ("ABM X-10 - innovative Learner and User

eXperience Lab", 2017). The device consists of a head and host units to transmit physiological signal in digital format. It also has a neoprene strap and a sensor strip. All the sensors placed on the sensor strip collect from the EEG sites. There are three sensor sites in each frontal, central and parietal-occipital region. Responses from the brain that are in analog form are converted into digital measurements of workload, engagement, distraction, and drowsiness ("innovative Learner and User eXperience Lab -", 2017).



Figure 9: ABM X-10 EEG Headset ("B-Alert X10 EEG System with AcqKnowledge and Cognitive State | B-ALERT110CS-W | Research | BIOPAC", 2017)

Once the participants were fitted with the headset, they also were equipped with the second version of Tobii Pro Glasses (Figure 10) around their ocular region. These devices created an environment that was stable enough for performing eye tracking on mobile devices like tablets, phones. These glasses did not restrict the readers to move the device during the experiment. Mobile eye tracker was used to ensure that the users could rotate the iPad and themselves around the AR markers to view the AR visuals in different

directions. The mobile eye trackers also helped the users to move at their free will without any restriction.

There were two infrared cameras to capture the eye movement, record gaze points and get to know how long the reader gazes at a location. The iMotions software to which the device was connected could also create heat maps that contain information about the focus levels and focus areas of the reader. These glasses measured the variables like Time to First Fixation (TTFF), fixation count, total time spent in an area of interest which are required for the study to know more about which part of the content is pleasing for the readers.

Both the learning environments were developed for iPad. iPads were chosen for this study as they are less expensive compared to most laptop or desktop computers (Johnson, 2017) and they are ideally situated to include the AR technology to educate the users. Many schools and educators believed that iPads and tablets play a vital role in the education sector. Using iPads helps the students to save paper, carry less physical load, learn through multimedia objects and receive a personalized learning (Networks, 2017). These advantages strengthened the idea to use iPads for research in education as well as in this study.



Figure 10: Tobii Pro Glasses 2 ("Tobii Pro Glasses 2 wearable eye tracker", 2017)

The devices as mentioned earlier were used during the period of stimulus. Before and after the stimulus, participants had given a Demographic Questionnaire and a Post-Test, respectively. The Demographic Questionnaire contained questions which give us an idea about the characteristics of the population who participated in the study (Appendix A).

Following the stimulus was a Post-Test which contained the questions related to the topics discussed during the stimulus. The Post-Test included objective questions to identify the dinosaur based on their description (Appendix B). It included twenty questions for the topics discussed in stimulus. Readers interacted with the three-dimensional visual of the different dinosaurs and answered the questions related to the appearance, actions and other features of dinosaurs.

After the Post-Test, participants were asked to fill out a User Experience Questionnaire which essentially gathered feedback about the experiment like which part of stimuli was enthusiastic, which part was interesting and other questions related to the

experiment. This survey consisted of ten questions, and it took no more than five minutes. Appendix C contains the questionnaire.

Scoring

There were three questionnaires in this experiment. Participants answered the Demographic Questionnaire before starting the experiment to help the researcher gain knowledge about the population participating in the study. The Demographic Questionnaire took no more than ten minutes to complete. Samples questions for the Demographic questionnaire are available in Appendix A.

Participants answered two more questionnaires after the completion of the experiment. First one is called Post-Test that, as previously noted, tested the knowledge gained and comprehended by participants during the stimulus. Post-Test took no more than fifteen minutes to complete. This test had 20 questions on the topics discussed during stimulus with each question carrying one mark. The marks scored by each participant in Post-Test is used for analyzing the learning variable. You can see sample questions for the Demographic Questionnaire in Appendix A.

After the Post-Test, subjects were asked to answer User Experience Questionnaire which consists of ten questions with each question having options “Strongly Disagree,” “Disagree,” “Neutral,” “Agree,” “Strongly Agree.” The weight of these choices varies from “Strongly Disagree” carrying one point to “Strongly Agree” taking five points. These questions asked the subjects how they were feeling about the experiment and application. Sample questions for User Experience Questionnaire are available in Appendix A.

The EEG headset continuously collected information about cognitive load, attention levels, drowsiness levels and the amount of time the reader was engaged in the stimuli. The values for distraction, engagement, drowsiness and workload variables vary between zero and one. The eye tracking glasses measure the variables like Time to First Fixation (TTFF), fixation count, total time spent in an area of interest which are required for the study to know more about which part of the content attracted the visual attention of the readers. Focus areas are conveyed through heat maps with colors varying from light green (slightly viewed area) to red (highly viewed area).

Procedure

The process of the experiment was as follows. The experiment started with the participants being informed about the aim and process of experiment and they were asked to answer a Demographic Questionnaire initially to know more about the participants in the study. The stimulus contained four topics on dinosaurs for readers.

Once the Demographic Questionnaire was completed, then readers were given the stimuli. All the readers were made to wear ABM X-10 EEG headset and the eye tracking device. Following the stimulus was a Post-Test which decides how much information a participant had gained and comprehended.

This was the process followed by every reader. The estimated time for the Demographic Questionnaire was around ten minutes, followed by 30 minutes of interaction with the stimulus then 15 minutes to complete the posttest. This entire process was conducted for both groups. As previously mentioned, one group was named as Control group with the stimulus as regular eBooks with three-dimensional visual representations

and the second group was named as Treatment group with the stimulus as the AR-eBooks. Each group contained twenty-five participants.

Both the groups were treated with the appropriate stimulus. Results included all the variables like learning, how much the subject was engaged, the distraction levels of the subject, how much cognitive load the subject was experiencing and eye movements were captured. The variables from both the groups were compared and analyzed using Independent Samples t-test to understand more about the reading patterns in people. This was done to which learning environment helped the readers to infer and comprehend knowledge most effectively.

CHAPTER 3

RESULTS

The results obtained from both Control and Treatment groups were analyzed using Independent Samples t-test. An Independent Samples t-test is a statistical test which gives a good measure of how two independent groups differ by comparing their means. This t-test from the t-test family is used to compare the Treatment and Control groups in different aspects. The information is collected from the participants using a brain monitoring headset, an eye tracker and questionnaires. Both the Treatment and Control groups are analyzed and compared using variables like visual attention, amount of learning and different emotions sensed by brain while reading the eBook.

Every second data was sampled multiple times by the physiological devices. Though the participants have been wearing these devices throughout the experiment, only the data collected when the participants read the eBook and interacted with the models was taken into consideration. An average of the data when the participant interacted with the model and read the eBook was calculated separately to analyze the readings sensed by the ABM headset.

Markers were applied to the data obtained from an ABM headset to extract the data when participants interacted with the visuals and when they read the text. Once applied, the data was exported to excel sheets and filtered using the markers for the appropriate information. In case of Tobii Glasses, area of interest was defined as the screen of iPad to analyze the eye movements. Data related to dependent measures like TTFF, fixations count and the total time spent when the participants interacted with the models were captured

using the area of interests. Data related to visual attention, engagement, distraction, drowsiness and workload were extracted from the information collected using brain monitoring headset and the eye tracker. Data related to the participants' interest, biography and the amount of knowledge they gained was obtained from the user experience, demographic and Post-Test questionnaires respectively.

A total of 50 students participated in the study that includes 38 males and 12 females. These participants are equally distributed between Treatment and Control groups. All the participants fall between 20 and 25 years of age. Around 94% of participants are enrolled full time at ASU with 44% having a Master's degree, 20% having a bachelor's degree and 36% completed high school. Two-thirds (68%) of all the participants noted that they had not used an AR based application previously. When these students were asked about their familiarity with dinosaurs on a scale of one (lowest) to five (highest), about 6% rated 1, 42% have rated 2, 38% rated 3, 14% have rated 4.

Information collected from all these participants was used to analyze the differences in the ways college going students interact with eBooks containing AR and 3D models. Let us discuss about how the data is analyzed in terms of all the dependent variables.

Comparison between Groups

Treatment and Control groups were compared based on the values obtained for workload, distraction, drowsiness, engagement, fixations, marks, total time, user experience, time taken for the first fixation to occur and the relative time spent on visuals. An Independent Samples t-test was performed on the data for each variable.

ABM Sensor Data

An average for the data related to each of the variables mentioned above was calculated. This computation was performed for each participant from both the groups. As one can see in the Figure 11, an Independent Samples t-test was performed on the data related to high and low engagement, distraction, workload and drowsy. For each participant, an average of the ABM data was computed for each variable to create a list of means for both Control and Treatment groups. The t-test was then performed on this list to get the above result.

The Control group ($n = 25$) was associated with a high engagement value $M = 0.46$ ($SD = 0.23$), distraction value $M = 0.5$ ($SD = 0.82$), drowsiness value $M = 0.17$ ($SD = 0.22$) and workload value $M = 0.71$ ($SD = 0.1$). By comparison, the Treatment group ($n = 25$) was associated with a numerically larger high engagement value $M = 0.5$ ($SD = 0.19$), larger distraction value $M = 0.6$ ($SD = 0.1$), larger drowsiness value $M = 0.04$ ($SD = 0.06$) and larger workload value $M = 0.72$ ($SD = 0.13$). To check the hypothesis that Control and Treatment groups were associated with statistically significantly different high engagement, distraction, drowsiness and workload values, an Independent Samples t-test was performed.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
High_Engagement	Equal variances assumed	1.597	.212	-0.627	48	.533	-.037483072160	.059753384109	-.157625303134	.082659158814
	Equal variances not assumed			-0.627	46.307	.534	-.037483072160	.059753384109	-.157738881292	.082772736972
Low_Engagement	Equal variances assumed	1.106	.298	1.072	48	.289	.060345025560	.056293473984	-.052840589860	.173530640980
	Equal variances not assumed			1.072	46.646	.289	.060345025560	.056293473984	-.052925553030	.173615604150
Distraction	Equal variances assumed	.113	.738	-0.206	48	.838	-.005194132748	.025241441602	-.055945452565	.045557187069
	Equal variances not assumed			-0.206	46.757	.838	-.005194132748	.025241441602	-.055980343949	.045592078453
Drowsy	Equal variances assumed	9.552	.003	-1.845	48	.071	-.024452890272	.013252978294	-.051099789071	.002194008527
	Equal variances not assumed			-1.845	29.966	.075	-.024452890272	.013252978294	-.051520378980	.002614598436
Workload	Equal variances assumed	.104	.749	-0.439	48	.663	-.014813405880	.033749671457	-.082671668371	.053044856611
	Equal variances not assumed			-0.439	44.782	.663	-.014813405880	.033749671457	-.082797851565	.053171039805

Figure 11: Independent Samples t-test For ABM Sensor Data

The assumption of homogeneity of variances was tested via Levene's F test, satisfied with $F(48) = 1.6$, $p = 0.21$ for high engagement, satisfied with $F(48) = 0.11$, $p = 0.3$ for distraction, unsatisfied with $F(48) = 9.552$, $p = 0.003$ for drowsiness and satisfied with $F(48) = 0.104$, $p = 0.75$ for workload. The Independent Samples t-test was associated with statistically insignificant effect, $t(48) = -0.63$, $p = 0.53$ for high engagement, $t(48) = -0.21$, $p = 0.84$ for distraction, $t(29.966) = -1.845$, $p = 0.75$ for drowsiness, $t(48) = -0.439$, $p = 0.66$ for workload. Thus, it can be inferred that both the Control and Treatment groups have similar brain recordings even though different learning environments were used in stimuli. In other words, all the participants appeared to feel the same way regardless of the visual representations they interacted with during the experiment. A representation of the means and the 95% confidence intervals is displayed in Figure 11.

Learning

The Control group was associated with a learning value $M = 12.08$ ($SD = 3.52$). By comparison, the Treatment group was associated with a numerically larger learning value $M = 12.84$ ($SD = 3.16$). To test the hypothesis that Control and Treatment groups were associated with statistically significantly different learning values, an Independent Samples t-test was performed. The assumption of homogeneity of variances was tested and satisfied via Leven's F test, $F(48) = 0.86$, $p = 0.36$. The Independent Samples t-test was associated with insignificant effect, $t(48) = -0.80$, $p = 0.43$.

Thus, it can be inferred that there was no significant difference in the amount of learning despite participants interacting with different visual representations. In other words, both the environments have helped the participants to retain similar amount of information. Cohen's d was estimated at 0.23, which is a small effect based on Cohen's (1988) guidelines. A representation of the means and 95% confidence interval is shown in the Figure 12.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Marks	Equal variances assumed	.864	.357	-.803	48	.426	-.76000	.94622	-2.66250	1.14250
	Equal variances not assumed			-.803	47.438	.426	-.76000	.94622	-2.66309	1.14309

Figure 12: Independent Samples t-test for learning

Time to First Fixation(TTFF), Total Time Spent, Fixations Count

Time to First Fixation is the time taken for obtaining the first fixation point for a participant. As there were five models described in the learning environments, five TTFF values are observed. An average of all these five values is computed and used for

comparison. Total Time Spent was the amount of time spent by each participant interacting with the visuals and fixations count is the number of fixation point obtained for each participant during the interaction with visuals. A fixation point is obtained when a considerable number of gaze points are obtained around an object or in an area. Fixation point is a measure of visual attention. Both the Control and Treatment groups were compared used these variables.

The Control group was associated with a time to first fixation $M = 915.46s$ ($SD = 221.42s$), the total time spent $M = 175.13s$ ($SD = 76.67s$) and a fixation count $M = 455.84$ ($SD = 163.31$). By comparison, the Treatment group was associated with a numerically larger time to first fixation value $M = 985.11s$ ($SD = 334.28s$), numerically larger total time spent $M = 184.25s$ ($SD = 133.39s$) and numerically larger fixation count $M = 582.24$ ($SD = 367.26$). To test the hypothesis that both the groups had statistically significantly different TTFF, total time spent and fixation count values, an Independent Samples t-test was performed. The assumption of homogeneity of variances was tested via Levene's F test and failed for TTFF, $F(48) = 4.3$, $p = 0.44$, satisfied for total time spent, $F(48) = 1.37$, $p = 0.25$ and satisfied for fixation count, $F(48) = 3.97$, $p = 0.52$. The Independent Samples t-test was associated with statistically insignificant effect, $t(39.705) = -0.86$, $p = 0.4$ for TTFF, $t(48) = -0.3$, $p = 0.768$ for total time spent, $t(48) = -1.57$, $p = 0.12$ for fixations count. We can infer from the above analysis that there was no statistically significant difference between TTFF values, total time spent in interacting with the models and fixations count between both the Control and Treatment groups.

From the above inferences, we can say that neither learning environment produced any differences in visual attention. We can also say that both the learning environments

have created an equal interest in the participants taking into consideration the total time spent interacting with models being in the same range. A representation of the means and the 95% confidence intervals is displayed in Figure 13.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
AvgTTF	Equal variances assumed	4.300	.044	-.863	47	.392	-69.64988	80.68595	-231.96908	92.66932
	Equal variances not assumed			-.856	39.705	.397	-69.64988	81.34480	-234.09195	94.79218

(a)

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
TotalTime	Equal variances assumed	1.367	.248	-.296	48	.768	-9.12332	30.77013	-70.99082	52.74418
	Equal variances not assumed			-.296	38.298	.768	-9.12332	30.77013	-71.39830	53.15166

(b)

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
FixationsCount	Equal variances assumed	3.973	.052	-1.572	48	.122	-126.40000	80.38764	-288.03019	35.23019
	Equal variances not assumed			-1.572	33.134	.125	-126.40000	80.38764	-289.92473	37.12473

(c)

Figure 13 (a)(b)(c): Independent Samples t-test for Visual Attention

User Experience

Information related to the user experience dependent measure was collected through the User Experience Questionnaires answered by the participants after the experiment. Participants were asked questions related to the learning environment they experienced. Each question was given options varying from “Strongly Disagree” (one

point) to “Strongly Agree” (five point). An average computed for all the questions answered by each participant is used as the basis for this comparison.

The Control group was associated with a user experience rating $M = 3.93$ ($SD = 0.59$). By comparison, the Treatment group was associated with a numerically larger user experience rating $M = 4.01$ ($SD = 0.36$). To confirm the hypothesis that participants from Treatment group were associated with statistically significantly different user experience ratings, an Independent Samples t-test was performed. The assumption of homogeneity of variances was tested and satisfied via Leven’s F test, $F(48) = 3.29$, $p = 0.08$. The Independent Samples t-test was associated with insignificant effect, $t(48) = -0.62$, $p = 0.54$.

Thus, it can be inferred that there was statistically no significant difference in the user experience ratings because Control and Treatment participants. In other words, participants from both the groups have same level of interest towards both the learning environments. A representation of the means and 95% confidence interval is shown in the Figure 14.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
Average	Equal variances assumed	3.287	.076	-.619	48	.539	-.08571	.13837	Lower	Upper
		Equal variances not assumed			-.619	39.901	.539	-.08571	.13837	-.36539

Figure 14: Independent Samples t-test for User Experience ratings

Relative Time Spent on Visuals

Each participant had spent a fraction of the experiment duration interacting with visuals. Both the Control and Treatment groups were compared using this information to know if there is any difference in the reading patterns.

The Control group was associated with a relative time spent $M = 16.9s$ ($SD = 5.08s$). By comparison, the Treatment group was associated with a numerically larger user experience rating $M = 17.49s$ ($SD = 6.74s$). To confirm the hypothesis that participants from Treatment group were associated with statistically significantly different user experience ratings, an Independent Samples t-test was performed. The assumption of homogeneity of variances was tested and satisfied via Leven’s F test, $F(48) = 3.18s$, $p = 0.08$. The Independent Samples t-test was associated with insignificant effect, $t(48) = -0.35$, $p = 0.73$.

From the above comparison, it can be inferred that all the participants from both the groups spent relatively same amount of time on visuals. A representation of the means and 95% confidence interval in shown in the Figure 15.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
PercentWithVisuals	Equal variances assumed	3.184	.081	-.347	48	.730	-.58667	1.68900	-3.98263	2.80930
	Equal variances not assumed			-.347	44.607	.730	-.58667	1.68900	-3.98931	2.81598

Figure 15: Independent Samples t-test for Relative Time Spent on Visuals

Comparison within Groups

The data from both the Control and Treatment groups is used to create an analysis comparing the data obtained while reading and while interacting with the models. As performed earlier for the above dependent measures, an Independent Samples t-test was performed for comparison.

Reading v/s 3D Models

Data was initially segregated into two segments. One segment represents the interaction of participants with the three-dimensional visuals and another segment represents the values obtained when the participants read the text. An average of the data related to engagement, distraction, drowsy and workload is computed for both the segments for each participant which was used for the comparison.

The Control group while reading(N=25) was associated with a high engagement value $M = 0.47$ ($SD = 0.22$), distraction value $M = 0.53$ ($SD = 0.73$), drowsy value $M = 0.15$ ($SD = 0.22$) and workload value $M = 0.68$ ($SD = 0.11$). By comparison, the Control group's interaction with the 3D models(N=25) was associated with a numerically smaller high engagement value $M = 0.46$ ($SD = 0.23$), smaller distraction value $M = 0.5$ ($SD = 0.82$), larger drowsiness value $M = 0.17$ ($SD = 0.22$) and larger workload value $M = 0.71$ ($SD = 0.1$). To check the hypothesis that Control group participants, while reading and interacting with the models, were associated with statistically significant differently high engagement, distraction, drowsiness and workload values, an Independent Samples t-test was performed. The assumption of homogeneity of variances was tested via Leven's F test, satisfied with $F(48) = 0.09$, $p = 0.760$ for high engagement, satisfied with $F(48) = 0.14$, $p = 0.71$ for distraction, satisfied with $F(48) = 0.008$, $p = 0.93$ for drowsiness and satisfied with $F(48) = 0.07$, $p = 0.79$ for workload. The Independent Samples t-test was associated with statistically insignificant effects, $t(48) = 0.126$, $p = 0.9$ for high engagement, $t(48) = 0.17$, $p = 0.87$ for distraction, $t(48) = -0.39$, $p = 0.7$ for drowsiness, $t(48) = -0.76$, $p = 0.45$ for workload.

Thus, the participants from Control group have similar EEG activity while reading as well as while interacting with the 3D models within the eBook. In other words, all the participants have felt the same way for both the environments. A representation of the means and the 95% confidence intervals is displayed in Figure 16.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
High_Engagement	Equal variances assumed	.094	.760	.126	48	.900	.007977730360	.063127369784	-.118948353486	.134903814206
	Equal variances not assumed			.126	47.784	.900	.007977730360	.063127369784	-.118963196498	.134918657218
Low_Engagement	Equal variances assumed	.121	.729	-.084	48	.934	-.004924679160	.058857044809	-.123264699184	.113415340864
	Equal variances not assumed			-.084	47.762	.934	-.004924679160	.058857044809	-.123279966675	.113430608355
Distraction	Equal variances assumed	.139	.711	.171	48	.865	.003749238800	.021869486309	-.040222310505	.047720788105
	Equal variances not assumed			.171	47.375	.865	.003749238800	.021869486309	-.040237312722	.047735790322
Drowsy	Equal variances assumed	.008	.927	-.389	48	.699	-.002422986648	.006229294011	-.014947821703	.010101848407
	Equal variances not assumed			-.389	47.989	.699	-.002422986648	.006229294011	-.014947893758	.010101920462
Workload	Equal variances assumed	.073	.788	-.762	48	.450	-.022863020520	.030022985922	-.083228279543	.037502238503
	Equal variances not assumed			-.762	47.731	.450	-.022863020520	.030022985922	-.083237066832	.037511025792

Figure 16: T-test on ABM Sensor data for Control group

Reading v/s AR models

Data was initially segregated into two segments. One segment represents the interaction of participants with the AR visuals and another segment represents the values obtained when the participants read the text. An average of the data related to engagement, distraction, drowsy and workload was computed for both the segments for each participant which is used for the comparison.

The Treatment group while reading(N=25) was associated with a high engagement value $M = 0.45$ ($SD = 0.2$), distraction value $M = 0.59$ ($SD = 0.69$), drowsy value $M = 0.27$ ($SD = 0.64$) and workload value $M = 0.71$ ($SD = 0.16$). By comparison, the Treatment group while interaction with the AR models(N=25) was associated with a numerically

larger high engagement value $M = 0.5$ ($SD = 0.19$), smaller distraction value $M = 0.55$ ($SD = 0.96$), larger drowsy value $M = 0.42$ ($SD = 0.62$) and larger workload value $M = 0.72$ ($SD = 0.13$). To check the hypothesis that Treatment group participants, while reading and interacting with the AR models, were associated with statistically significant differently high engagement, distraction, drowsiness and workload values, an Independent Samples t-test was performed. The assumption of homogeneity of variances was tested via Leven's F test, satisfied with $F(48) = 0.23$, $p = 0.64$ for high engagement, satisfied with $F(48) = 0.18$, $p = 0.67$ for distraction, satisfied with $F(48) = 0.62$, $p = 0.44$ for drowsiness and satisfied with $F(48) = 0.26$, $p = 0.61$ for workload. The Independent Samples t-test was associated with statistically insignificant effect, $t(48) = -0.88$, $p = 0.38$ for high engagement, $t(48) = 0.16$, $p = 0.87$ for distraction, $t(48) = -0.828$, $p = 0.41$ for drowsiness, $t(48) = -0.34$, $p = 0.74$ for workload.

Thus, the participants from Treatment group have similar brain recordings while reading as well as while interacting with the AR models within the eBook. In other words, all the participants have the same recordings for both the environments. A representation of the means and the 95% confidence intervals is displayed in Figure 17.

		Levene's Test for Equality of Variances		T-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
High_Engagement	Equal variances assumed	.229	.635	-.880	48	.383	-.048409175400	.055002430863	-.158998974647	.062180623847
	Equal variances not assumed			-.880	47.901	.383	-.048409175400	.055002430863	-.159004876794	.062186525994
Low_Engagement	Equal variances assumed	.536	.467	1.075	48	.288	.058000946120	.053944895954	-.050462536681	.166464428921
	Equal variances not assumed			1.075	47.556	.288	.058000946120	.053944895954	-.050488684875	.166490577115
Distraction	Equal variances assumed	.179	.674	.163	48	.871	.003864501972	.023733940566	-.043855783866	.051584787810
	Equal variances not assumed			.163	43.654	.871	.003864501972	.023733940566	-.043978818913	.051707822857
Drowsy	Equal variances assumed	.615	.437	-.828	48	.412	-.014867104808	.017948957574	-.050955902769	.021221693153
	Equal variances not assumed			-.828	47.951	.412	-.014867104808	.017948957574	-.050956849376	.021222639760
Workload	Equal variances assumed	.261	.612	-.340	48	.736	-.014213085800	.041841276573	-.098340610781	.069914439181
	Equal variances not assumed			-.340	46.574	.736	-.014213085800	.041841276573	-.098407204712	.069981033112

Figure 17: T-test on ABM Sensor data for Treatment Group



Figure 18: Heatmap for Treatment group

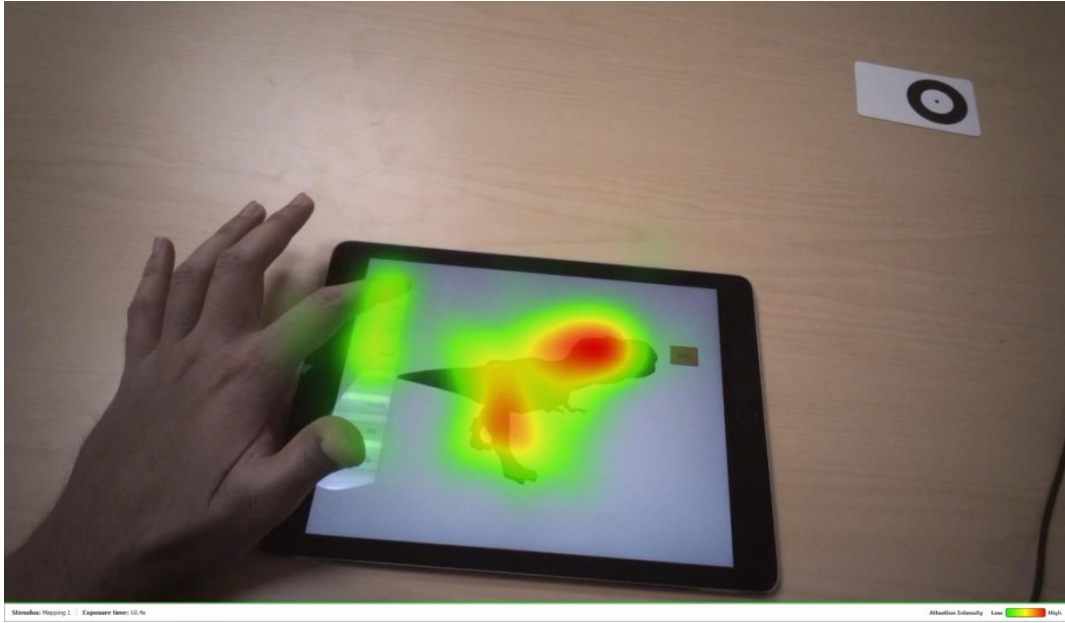


Figure 19: Heatmap for Control group

Figure 18 is a heatmap generated from the eye tracking data of three participants of Treatment group. Figure 19 is a heatmap generated from the eye tracking data of three participants of Treatment group. These heatmaps provide an idea about the areas where the participants are looking. The areas are highlighted from light green to red which indicates the participants' interest varying from low to high respectively. It can be inferred that the participants are more interested in looking at the body of the dinosaur.

CHAPTER 4

DISCUSSIONS AND CONCLUSION

A concerted effort to understand the reading patterns of people using different types of interactive models within eBooks and to help them reduce their effort while reading eBooks has been carried out in this thesis throughout the above-stated experiments. One eBook embedded with AR visuals and another eBook embedded with three-dimensional visuals were given as the stimulus to Treatment and Control groups respectively. The applications were developed in Unity using Vuforia SDK for devices like iPad. The data for the dependent measures like workload, learning, marks, distraction, drowsiness, engagement, time for first fixation, fixation count, total time spent were used to compare both the Control and Treatment groups.

The visual and brain sensor data were collected using Tobii Glasses Pro 2 and B-Alert ABM X10 devices respectively. The learning and interest was measured using the feedback given by the participants through questionnaires. An Independent Samples t-test was performed on the data obtained from both the groups to compare them. The conclusion that people received both the learning environments equally (eBooks with AR models and three-dimensional models embedded) can be observed from the above experiments.

There are several limitations observed in this study. One of them is Cohen's d effect size estimate, calculated for the learning variable, was found to be small (0.22). An effect size of 0.22 means the mean of the Treatment group is at 58th percentile of the Control group. In other words, a small effect size value implies that the change is happening but to observe it one needs to perform a study with a larger sample ("Effect sizes", 2017). A

Cohen's d effect size of 0.8 is large which means the mean of Treatment group is at the 79th percentile of the Control group. In other words, the change can be observed with a naked eye ("Effect Size (ES) - Effect Size Calculators (Lee Becker) | University of Colorado Colorado Springs", 2017). To find the required sample size which gives a large Cohen's d estimate (0.8), a power analysis was conducted. By giving power, alpha, and effect size for the power analysis, it was found that the study should require 35 participants for each group to obtain a large Cohen's d estimate. So, this inference is an important point to remember to carry out this research in the future.

Users cannot load new models of their choice from the eBook simultaneously while using it. We can enable the users to search online and load any interactive model of their choice from within the eBook. This dynamic loading of models helps the users to test their past knowledge and explore new domains. This study targeted only college students. So, as an additional step, one could extend this study by including children in the experiments.

As of today, the existing marker based AR embedded into eBooks did not create any significant difference in the way people comprehend and gain information compared to either the three-dimensional models embedded into eBooks or the regular eBooks. However, the future improvements in AR towards markerless AR, are guaranteed to bring a noticeable difference in the way education is taught in classrooms. Marker based AR, that were used in this study, limited the interactivity with objects and is restricted to the border of the markers. To use these markers, they must be printed in advance and should be preserved. Unlike the marker based AR, markerless AR uses any part of the real environment surrounding the user as a target for object tracking and placement of virtual objects which gives more sense of immergence to the users ("Markerless Augmented

Reality - ARLab Blog", 2017). With these advancements, we see today in AR, the future markerless AR technology can perceive, track real objects and extract information from the user surroundings to use the information later. This future AR technology, with a plausible disadvantage of becoming complex, can be used in eBooks and this study can be performed again for improved results.



Figure 20: Gartner Hype Cycle ("Gartner's 2016 Hype Cycle for Emerging Technologies Identifies Three Key Trends That Organizations Must Track to Gain Competitive Advantage", 2017)

The graph in Figure 20 describes the trends of various technologies put forward by Gartner, a research and advisory firm which provides insights into IT for various IT companies and business leaders across the world ("Gartner", 2017). The hype cycle gives knowledge to differentiate the hype of a technology from what is available commercially. It gives you an idea of how a technology solves real world problems, exploits opportunities,

evolves and adopts over time. Each hype cycle has five stages for a technology's life cycle. First, when a potential breakthrough occurs, the technology garners all the media attention and publicity it can in the initial phase. Usually in this phase, there are no products made for usage and commercial purpose. This phase is called the Innovation Trigger. Second, the publicity reaches the peak by various success stories but they are often followed by the failures. Now comes the trough of disillusionment, where the interest in the technology fades away and companies invest only if the product is improved to satisfy the customers. This is the phase in which AR is currently in per the Hype Cycle. In the next phase, people start to realize the potential of the technology and products will be introduced slowly. After releasing several products which satisfy various needs of the customers, they become a mainstream adoption which is around five to ten years per the Hype Cycle ("Hype Cycle Research Methodology | Gartner Inc.", 2017).

Companies that pioneer in information technology like Apple, Google, Facebook, and others are investing an enormous amount of money for acquisitions and research in AR and VR. Google, Apple, and Facebook have already released their versions of AR development platforms. These platforms perform enhanced object recognition, depth detection, and detect location to perceive the environment surrounding the user so that they can give an immersed experience for the people using it. AR is already making its way into many fields like retail, education, transport, gaming and several others. People are starting to realize the potential of AR and many areas are in line for the field to take over. It would not be too much longer before AR seeps into the day to day life of the common man.

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APPENDIX A
DEMOGRAPHIC QUESTIONNAIRE

- Age?
 - a. Full Time
 - b. Part Time
- Type of enrollment?
 - a. Full Time
 - b. Part Time
- Highest level of degree earned?
 - a. High School or equivalent
 - b. Bachelor's degree
 - c. Master's degree
 - d. Prefer not to say
- Do you use eBooks in your day to day life?
 - a. Yes
 - b. No
 - c. Somewhat
- Do you know about Augmented Reality?
 - a. Yes
 - b. No
 - c. Maybe
- Gender?
 - a. Male
 - b. Female
 - c. Prefer not to say
- Have you ever used an Augmented Reality based application?
 - a. Yes

- b. No
- On a scale of 1-5, how familiar are you with dinosaurs?

APPENDIX B
POST-TEST QUESTIONNAIRE

- Which of the following dinosaurs is the smallest?
 - a. Compsognathus
 - b. Brachiosaurus
 - c. Stegosaurus
 - d. Tyrannosaurus

- Select the correct order (from smallest to largest) from the following options based on their sizes.
 - a. Tyrannosaurus < Brachiosaurus < Compsognathus < Stegosaurus
 - b. Stegosaurus < Compsognathus < Brachiosaurus < Tyrannosaurus
 - c. Compsognathus < Stegosaurus < Tyrannosaurus < Brachiosaurus
 - d. Brachiosaurus < Compsognathus < Stegosaurus < Tyrannosaurus

- Which of the following dinosaurs walk on their toes?
 - a. Compsognathus
 - b. Brachiosaurus
 - c. Tyrannosaurus
 - d. Stegosaurus

- How does Compsognathus travel?
 - a. Using its hind limbs
 - b. Using both hind and fore limbs

- Select all of the dinosaurs below that are quadrupedal.
 - a. Brachiosaurus
 - b. Compsognathus
 - c. Tyrannosaurus

- d. Stegosaurus
- Select all that apply. Brachiosaurus were
 - a. Homeothermic
 - b. Ectothermic
 - c. Cold Blooded
 - d. Endothermic
- Compsognathus' tail is short and not useful while travelling. Is this true?
 - a. True
 - b. False
- Select the carnivores from the following list of dinosaurs.
 - a. Compsognathus
 - b. Brachiosaurus
 - c. Stegosaurus
 - d. Tyrannosaurus
- Does Brachiosaurus have longer forelimbs compared to its hind limbs?
 - a. Yes
 - b. No
- Tyrannosaurus did not move at higher speeds because
 - a. All of its preys move at slower speeds
 - b. It resulted in fatal injuries to the dinosaur
 - c. It cannot carry its enormous body weight
 - d. The environment in which it travelled restricted it to slower speeds
- Why do you think Brachiosaurus got "high browser" as its name?

- a. It has long forelimbs compared to its hindlimbs
 - b. It is the largest dinosaur
 - c. It eats plants, which are high above the ground
 - d. It needs a powerful heart to pump blood to its brain
- "I am a dinosaur who has a long and narrow skull with a tapered snout!!!" Who am I?
 - a. Stegosaurus
 - b. Brachiosaurus
 - c. Compsognathus
 - d. Tyrannosaurus
- Select all that apply for Tyrannosaurus while attacking its prey. Tyrannosaurus...
 - a. attacks based on the movement of its prey
 - b. attacks using its distinctive binocular vision
 - c. has a very accurate sense of hearing
 - d. uses its sense of smell to locate the prey
- Select the correct statement among the following
 - a. Because of the huge size of Brachiosaurus, it is easy to eat other small dinosaurs
 - b. Compsognathus needs a powerful heart to support its size
 - c. Stegosaurus is a bipedal carnivore
 - d. Tyrannosaurus is a bipedal herbivore
 - e. None of the above
- Select all the dinosaurs from the following list that have forelimbs smaller than hindlimbs.

- a. Compsognathus
 - b. Brachiosaurus
 - c. Stegosaurus
 - d. Tyrannosaurus
- Which of the following dinosaurs traveled in groups?
 - a. Compsognathus
 - b. Stegosaurus
 - c. Tyrannosaurus
 - d. Brachiosaurus
- Stegosaurus had spikes to attack their enemies. Is this true?
 - a. Yes
 - b. No
- Which of the following is an armored dinosaur?
 - a. Compsognathus
 - b. Brachiosaurus
 - c. Tyrannosaurus
 - d. Stegosaurus
- How does backwardly curved teeth help Tyrannosaurus?
 - a. Helps to scare the enemies with its beast look
 - b. Helps reduce the likelihood of damage or loss of tooth while feeding the prey
 - c. Helps roar as big as possible, which is used as a signal to its allies
 - d. Helps to swallow its target as a whole

- "I am a dinosaur who is so long that I need couple of seconds to turn at a forty-five-degree angle." Who am I?
 - a. Brachiosaurus
 - b. Stegosaurus
 - c. Tyrannosaurus
 - d. Compsognathus

APPENDIX C
USER EXPERIENCE QUESTIONNAIRE

- "I will use this type of learning environment in the future."
 - a. Strongly disagree
 - b. Disagree
 - c. Neutral
 - d. Agree
 - e. Strongly Agree

- "I was able to learn efficiently in this type of learning environment."
 - a. Strongly disagree
 - b. Disagree
 - c. Neutral
 - d. Agree
 - e. Strongly Agree

- "The topics presented in the eBook were difficult to learn."
 - a. Strongly disagree
 - b. Disagree
 - c. Neutral
 - d. Agree
 - e. Strongly Agree

- "The length of experiment was appropriate."
 - a. Strongly disagree
 - b. Disagree
 - c. Neutral
 - d. Agree

- e. Strongly Agree
- "I will refer this learning environment to your friend."
 - a. Strongly disagree
 - b. Disagree
 - c. Neutral
 - d. Agree
 - e. Strongly Agree
- "This was a very effective learning environment."
 - a. Strongly disagree
 - b. Disagree
 - c. Neutral
 - d. Agree
 - e. Strongly Agree
- "I feel that the interactive visual you were presented in this eBook will help people to learn better"
 - a. Strongly disagree
 - b. Disagree
 - c. Neutral
 - d. Agree
 - e. Strongly Agree
- "The user interface of the application is aesthetically pleasing."
 - a. Strongly disagree
 - b. Disagree

- c. Neutral
 - d. Agree
 - e. Strongly disagree
- "I think the questions asked in the Post-Test are related to the content discussed in the stimuli."
 - a. Strongly disagree
 - b. Disagree
 - c. Neutral
 - d. Agree
 - e. Strongly Agree

APPENDIX D
CTCI COMPLETION REPORT

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)
COMPLETION REPORT - PART 1 OF 2
COURSEWORK REQUIREMENTS*

* NOTE: Scores on this Requirements Report reflect quiz completions at the time all requirements for the course were met. See list below for details. See separate Transcript Report for more recent quiz scores, including those on optional (supplemental) course elements.

- **Name:** Kalyan Kumar Juluru (ID: 5857757)
- **Email:** kjuluru@asu.edu
- **Institution Affiliation:** Arizona State University (ID: 662)
- **Institution Unit:** Computer Informatics
- **Phone:** 4806263694

- **Curriculum Group:** Human Research
- **Course Learner Group:** IRB – Social & Behavioral Research (Group 2)
- **Stage:** Stage 1 - Basic Course

- **Report ID:** 20977593
- **Completion Date:** 04-Oct-2016
- **Expiration Date:** 03-Oct-2020
- **Minimum Passing:** 80
- **Reported Score*:** 83

REQUIRED AND ELECTIVE MODULES ONLY	DATE COMPLETED	SCORE
Belmont Report and CITI Course Introduction (ID: 1127)	24-Sep-2016	3/3 (100%)
History and Ethical Principles - SBE (ID: 490)	24-Sep-2016	3/5 (60%)
Defining Research with Human Subjects - SBE (ID: 491)	24-Sep-2016	3/5 (60%)
The Federal Regulations - SBE (ID: 502)	24-Sep-2016	4/5 (80%)
Assessing Risk - SBE (ID: 503)	24-Sep-2016	4/5 (80%)
Informed Consent - SBE (ID: 504)	24-Sep-2016	5/5 (100%)
Privacy and Confidentiality - SBE (ID: 505)	04-Oct-2016	5/5 (100%)
Research in Public Elementary and Secondary Schools - SBE (ID: 508)	24-Sep-2016	5/5 (100%)
Internet-Based Research - SBE (ID: 510)	24-Sep-2016	4/5 (80%)
Vulnerable Subjects - Research Involving Workers/Employees (ID: 483)	24-Sep-2016	3/4 (75%)
Conflicts of Interest in Research Involving Human Subjects (ID: 488)	24-Sep-2016	4/5 (80%)
Arizona State University (ID: 1001)	24-Sep-2016	No Quiz

For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution identified above or have been a paid Independent Learner.

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COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)
COMPLETION REPORT - PART 2 OF 2
COURSEWORK TRANSCRIPT**

** NOTE: Scores on this Transcript Report reflect the most current quiz completions, including quizzes on optional (supplemental) elements of the course. See list below for details. See separate Requirements Report for the reported scores at the time all requirements for the course were met.

- **Name:** Kalyan Kumar Juluru (ID: 5857757)
- **Email:** kjuluru@asu.edu
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- **Stage:** Stage 1 - Basic Course

- **Report ID:** 20977593
- **Report Date:** 04-Oct-2016
- **Current Score**:** 83

REQUIRED, ELECTIVE, AND SUPPLEMENTAL MODULES	MOST RECENT	SCORE
Arizona State University (ID: 1001)	24-Sep-2016	No Quiz
History and Ethical Principles - SBE (ID: 490)	24-Sep-2016	3/5 (60%)
Defining Research with Human Subjects - SBE (ID: 491)	24-Sep-2016	3/5 (60%)
Belmont Report and CITI Course Introduction (ID: 1127)	24-Sep-2016	3/3 (100%)
The Federal Regulations - SBE (ID: 502)	24-Sep-2016	4/5 (80%)
Assessing Risk - SBE (ID: 503)	24-Sep-2016	4/5 (80%)
Informed Consent - SBE (ID: 504)	24-Sep-2016	5/5 (100%)
Privacy and Confidentiality - SBE (ID: 505)	04-Oct-2016	5/5 (100%)
Research in Public Elementary and Secondary Schools - SBE (ID: 508)	24-Sep-2016	5/5 (100%)
Internet-Based Research - SBE (ID: 510)	24-Sep-2016	4/5 (80%)
Vulnerable Subjects - Research Involving Workers/Employees (ID: 483)	24-Sep-2016	3/4 (75%)
Conflicts of Interest in Research Involving Human Subjects (ID: 488)	24-Sep-2016	4/5 (80%)

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