10.24193/ed21.2022.23.07

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Educatia 21 Journal, (23) 2022, Art. 07
doi: 10.24193/ed21.2022.23.07
Research article

Mobile Augmented Reality Applications in Higher Education

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Abstract

Visual technologies such as AR (Augmented Reality), VR (Virtual Reality), or MR (Mixed Reality) show an increase in popularity in the educational field. In addition to the fact that they can significantly improve the transfer of information in education, they can turn lessons into more interesting and interactive activities. Among these technologies, AR has become the most accessible, due to the rise in the popularity of mobile devices. The increasing popularity of distance teaching and the increasing performance of mobile devices and applications will make this topic an important one in the future in educational psychology. The current study aims to evaluate the effectiveness of using AR in learning and compare it with classical 3D models. Following the calculations, we discovered a minor influence. This implies that the group of students who used simple 3D outperformed the group of students who used Assemblr AR, but the gap between the 2 learning methods was not very wide. The results indicate that the use of 3D models is effective in learning but there is no significant difference between the AR and normal 3D models. The limited effects and the findings of other studies on AR in education imply that additional research is required.

Keywords:
augmented reality; 3d models; education; mobile applications; performance evaluation

Zusammenfasung

Visuelle Technologien wie AR (Augmented Reality), VR (Virtual Reality) oder MR (Mixed Reality) erfreuen sich im Bildungsbereich wachsender Beliebtheit. Neben der Tatsache, dass sie den Informationstransfer in der Bildung erheblich verbessern können, können sie den Unterricht in interessantere und interaktivere Aktivitäten verwandeln. Unter diesen Technologien ist AR aufgrund der zunehmenden Popularität mobiler Geräte die am besten zugängliche geworden. Die zunehmende Popularität des Fernunterrichts und die zunehmende Leistungsfähigkeit mobiler Geräte und Anwendungen werden dieses Thema in Zukunft zu einem wichtigen Thema in der Pädagogischen Psychologie machen. Die aktuelle Studie zielt darauf ab, die Effektivität des Einsatzes von AR beim Lernen zu evaluieren und mit klassischen 3D-Modellen zu vergleichen. Nach den Berechnungen entdeckten wir einen geringen Einfluss. Dies impliziert, dass die Gruppe der Studenten, die einfaches 3D verwendet haben, die Gruppe der Studenten, die Assemblr AR verwendet haben, übertroffen hat, aber der Abstand zwischen den beiden Lernmethoden war nicht sehr groß. Die Ergebnisse zeigen, dass die Verwendung von 3D-Modellen beim Lernen effektiv ist, aber es gibt keinen signifikanten Unterschied zwischen den AR- und normalen 3D-Modellen. Die begrenzten Effekte und die Ergebnisse anderer Studien zu AR in der Bildung implizieren, dass zusätzliche Forschung erforderlich ist.

Schlüsselworte:
erweiterte Realität; 3D-Modelle; Ausbildung; mobile Anwendungen; Leistungsbewertung.

1. Introduction

For many teachers or educators, the learning experience with the help of augmented reality (abbreviation that we will use below - AR) is a new concept. Although these technologies have been studied and analyzed in the educational context, these technologies have not been implemented in many institutions (Geroimenko, 2020).

AR technologies can help pupils or students develop new techniques to study and memorize, compared to classical ways of learning. Studies on these types of applications have highlighted several advantages such as: (1) the application transforms the representation of the problem so that difficult concepts are easier to understand; (2) the application presents relevant educational information at the right time and place, providing easy access to information and reducing extraneous elements in student tasks; (3) the application directs students' attention to important aspects of the educational experience; (4) the app allows students to be physically active while also providing immersion to educational concepts; (5) the application allows students to interact with spatially challenging phenomena (Radu, 2014).

Even though there are many studies that confirm the usefulness of AR technologies in education, many contemporary researchers claim that the research of AR in education is still at an early stage. Wu et al. (2013) argue that evidence of the effects of AR on

learning and teaching "appears to be superficial". In a meta-analysis conducted by Radu (2014) where he reviewed 26 studies on AR in education, he identified both positive and negative effects of using this technology and possible factors underlying them.

A study by Ibanez et al. (2014) investigated how effective these types of virtual learning environments are. The study showed positive results in terms of its effectiveness, which led to several further studies. Examining studies on the effectiveness of AR in the educational system, especially those published recently, proved that the use of this technology leads to increased performance and motivation in students, creates positive emotions, and helps students adopt a more positive attitude towards the subject studied (Wang, Duh, Li, Lin & Tsai, 2014). It should be noted, however, that these experimental studies have shown effectiveness only in some fields of science. According to a review by López-Belmonte et al. (2020), the majority of augmented reality research has been directed to educating users on how to utilize the technology effectively in the learning environments it creates and its use in education considering the diversity of learners.

Future research should concentrate on emerging AR devices like smartphones and AR glasses. Three generations of augmented reality in education are described in a review by Garzón (2021). The study identifies some significant issues with prior AR applications and, at the end, offers some suggestions for resolving these issues to maximize the advantages of AR for education. In the third generation (starting in 2020), smartglasses are frequently used as hardware. Smartglasses are a type of wearable technology that, like smartphones, has the potential to change how we live. Smartglasses have a variety of benefits over competing technologies, including voice activation and control, non-intrusive display technology, no need for touchscreens, and more.

2. Theoretical clarifications

A strong trend that can be observed in the field of education is digitization. This type of education modernization consists of transmitting and receiving printed or handwritten information into digital information (Machekhina, 2017). This process was accelerated with the onset of the COVID-19 pandemic, during which online distance learning became standard in several countries. During this time, much has been invested in increasing the quality of digital education (Bubb & Jones, 2020). For digital education, in the past, specialized rooms were needed, equipped with computers and projectors. Recently, more and more students have acquired learning experiences through portable devices such as smartphones and tablets (Geroimenko, 2020).

Electronic learning (or e-Learning) describes a set of technology-mediated methods that can be applied to support student learning and can include elements of assessment, guidance, and instruction. There are many media and technologies available to support e-learning. The Internet, for example, can be a communication medium that connects many students in virtual space, creating learning communities (Jonassen et al. 1999).

An e-learning course can reduce study time by 30% compared to a traditional face-to-face course without sacrificing course content (Le & Nguyen, 2020). At the same time, students can save around 60% of expenses due to the elimination of costs for travel, accommodation, or purchase of learning materials. Studies show that people prefer hybrid ways of learning, with both types of learning having advantages and disadvantages (Oliver & Trigwell, 2005).

For different learning situations and outcomes, several theories are acceptable. If we wanted to define it briefly, we can say that learning is a long-term change in associations or mental representations because of experience (Ormrod, 2011). Although there is no universally accepted definition of learning due to its subjective nature, we can draw on one of multiple learning perspectives or paradigms (Ormrod, 2011). Below are briefly presented the theories of learning according to the most studied paradigms:

According to the behaviorist paradigm, all behaviors are the result of our interaction with the environment. Many behaviorists argue that internal processes should be excluded from psychological studies because we cannot directly observe and measure them (e.g. thoughts, motives, representations, etc.) (Watson, 1925). In the same way that real science researchers examine events in the physical world, behaviorists argue that psychologists should investigate learning through objective scientific investigation. Psychologists can remain unbiased by focusing on two things they can see and measure - specifically, the stimuli in the environment and the body's responses to those stimuli (Gredler, 2008).

A study by Lampropoulos et al. (2022) found that virtual rewards delivered through augmented reality can be crucial components for enhancing learning motivation. Students showed beneficial behavioral, attitude, and psychological changes in an AR environment, as well as enhanced engagement, motivation, active participation and information acquisition.

According to cognitivism, people are active participants in their learning. From their perspective, knowledge is actively constructed and is not simply a result of interaction with the environment (Ashworth et al. 2004). Individuals select how they process their knowledge in their minds, and these cognitive processes determine what information is remembered and what information is ignored. Unlike behaviorism, cognitivism tries to understand complicated cognitive processes (the so-called 'black box'), looking for links between learning, information processing, perceptions, and memory. At the same time, learning involves establishing mental representations or connections that are not always reflected in visible behavioral changes (Ormrod, 2011). AR applications can be developed to activate different areas of the brain, such as improving reflexes, promoting critical thinking, and helping people learn new patterns of connections. AR games based on cognitivism are useful for learning a foreign language and memorizing new content (Geroimenko, 2019).

Constructivism is a philosophy of teaching and learning that holds that learning (and knowledge) is the consequence of "mental construction". In other words, people learn by combining new and old knowledge. Constructivists believe that the environment in which a concept is taught, as well as people's ideas and attitudes, influence learning (Olusegun, 2015). AR applications can provide a variety of opportunities to build new knowledge by combining physical and mental components. Recording video, taking photos, recording sound, and modeling and integrating that perceptual information, through various sensory modalities, with the user's real-time surroundings are examples of AR-based constructivist activities (Laine et al. 2016). Ideas from this theory are also found in augmented reality applications such as Leometry, which is a collaborative AR application that allows students to build three-dimensional mathematical and geometric models in a shared AR workspace, providing new dynamic opportunities for interactions, thus promoting higher-level learning and to help develop their ways of learning. Discovery learning is a constructivist method of problem-based learning in which learners acquire new information by experiencing a domain and deducing rules from the consequences of their interactions with it (Ozdem-Yilmaz & Bilican, 2020). In a study, Liang et al. (2021) explore the potential of augmented reality in training medical professionals through the use of a stroke assessment simulation. According to the study's findings, the majority of students thought that extended reality would be an excellent educational tool for clinical training and healthcare. . Simulators, with their interactive features, allow learners to gain information using the scientific method and are suitable for learner-centered learning.

Humanistic theories of learning are based on humanistic concepts from the works of Abraham Maslow and Carl Rogers. In this paradigm, the emphasis is on the individual, who has a holistic approach to learning (Sharp, 2012). According to the paradigm, in addition to intellect and environmental stimuli, personal interests, enthusiasm, and intrinsic motivation are also important (Seel, 2012). Humanistic learning theory focuses on personal development and involves consideration of emotional factors such as an individual's self-concept, values, and emotions. Humanistic education enhances learning by relating to students' lives, emotions, and experiences on a personal level. As a result, children learn more and more deeply (Johnson et al. 2014). AR technologies can help create a learning environment that sparks students' interests. In AR, it is easy to change the working environment and can make learning more enjoyable and immersive.

According to connectivism, learning is a network phenomenon affected by technology and socialization. The basic idea of connectivism is that most information acquisition takes place through social networks (Siemens 2006). Connectivists argue that a person's knowledge is dynamically shared and created through continuous interactions with other people within a network. AR technology can help provide the necessary framework for connectivist learning as well as channels to connect with dynamic data sources (Revelle et al. 2014). These principles are used in AR apps like Assemblr, which allows students to acquire knowledge by interacting with other students in a virtual classroom. Augmented reality users may be more inclined to study a certain subject in a classroom setting (Li & Liu, 2022).

3. Methodology

3.1. The research design

For this study, we have two hypotheses: H1: Students who use 3D models for learning neurology subjects will have significantly better results, and H2: Students who learn using AR technology – compared to simple 3D models with the same digital content – will have better results.

To test the proposed hypotheses, this study used a two-condition (AR vs. Simple 3D Models) between-subjects design, with participants randomly assigned to each condition. The independent variable in this study was the learning modality: in AR or classic 3D. The dependent variable in the study is the amount of information retained after the learning session. A t-test was conducted to compare students' learning achievement in terms of their post-test scores between the experimental (AR) and control groups (3D Models). In addition, we used Cohen's effect size index d (Cohen, 1988) to illustrate the magnitude of practical significant difference between groups. It should be noted that Cohen's d values of 0.20, 0.50, 0.80, and 1.0 are interpreted as a small, medium, large, and very large effect sizes, respectively.

3.2. Participants

This preliminary study recruited 27 dyads of 3rd-year students (N=54) from the Faculty of Psychology of Babeș-Bolyai University, Cluj-Napoca. The criterion for being a participant was that he/she had learned about neurology since the first year. The experimental group consisted of 26 students whose ages varied between 21 and 26 years. Additionally, none of the students had prior experience using AR technology. The control group included 26 students between the ages of 21 and 26. To ensure the two groups of students had equivalent prior knowledge prior to treatment, a t-test was performed on their pre-test scores. The result shows that the learners in both groups had no statistically significant difference in their pre-test scores indicating that the two groups had similar prior knowledge on the topic of brain and neuron structure.

3.3. Measuring instruments

For this study, we used the Assemblr Edu application. Assemblr Edu is an augmented reality platform designed to facilitate the learning process of pupils and students. The application is compatible with mobile devices with Android (version 7.0 or later) or IOS (version 11 or later) operating systems. This application was chosen because it has several advantages from a functional and organizational point of view compared to other available applications. From the perspective of AR representation, the Assemblr Edu app is an easy (cloud-based) way to upload, edit and share 3D models with others. Participants are able to view an item of interest in 360 degrees with subsequent annotations and explanations. The application allows the implementation of animations and interactions through which processes that can be difficult to explain with classic images can be explained to the participants. From an organizational point of view, the application allows the creation of online classes and sharing of real-time instructions with class members. This allows the study to be carried out remotely. At the same time, the application is relatively easy to use. The application also has some disadvantages. On the one hand, the application has many functional problems, occasionally it stops or works hard. On the other hand, it does not allow uploading of 3D models and has a limited set of models for biology. Since the participants were students in their 3rd year of psychology, the course of interest is neurosciences. The neurosciences participants were chosen because the students needed to be a little familiar with the subject studied but not something recently studied (this being learned in year 1). At the same time, choosing an important subject for the license exam can be a motivating factor to participate in the study. The app helped students locate specific parts of the organ or cell being studied on the model and provided animations and additional information to help them remember the properties of the brain and neurons. Two neurosciences knowledge tests were used to measure retained information. The tests had the same content and consisted of 6 questions with 1 or 2 correct options. Both tests could be scored between 0-10. After correcting the papers, the score from the pre-test was subtracted from the score from the post-test to see how much the student retained. A participant-signed consent form was included on the test paper.

4. Results

To understand the effects of learning (H1) with both AR technology (H1b) and 3D images (H1a) on students' learning achievements, a pretest-posttest t-test was conducted for both learning modalities. The post-test results of the 3D group differed significantly from the pretest results (t(26) -0.79, p 0.0002) as shown in table 1. This suggests that learning with the

help of 3D was very effective for learning in a short time of neurology information, so we can accept hypothesis H1a. The post-test results of the AR group also differed significantly from the pretest results (t(26 -1.44, p 0.0001) also indicated in table 1. This indicates that learning with the help of AR of the same subject is effective for learning and memorization of the given subject, slightly higher than those of the AR group. So, we can also accept hypothesis H1b.

Table 1.

Paired Samples Test					
		Paired Differences	t	df	Sig. (2-tailed)
		95% Confidence Interval of the Difference			
		Upper			
Pair 1	Pretest 3D – postest 3D	-.40717	-4.241	26	.0002
Pair 2	Pretest AR – postest AR	-.78632	-4.535	26	.0001

The results in the AR group were even better, but to see how significant the difference was, we did a t-test to compare the results. The first time we calculated the difference between the results of the 2nd test and the first and then averaged them. After this, the means were compared in SPSS to see if the differences between the 2 modalities were significant. To determine if they were significant, we used the Cohen d index. After performing the calculations, we obtained a Cohen d=0.32 coefficient, which can be interpreted as having a small effect. This suggests that students who used Assemblr AR performed better than the group who used Assemblr 3D, but the difference between the 2 types of learning was not very large (see Table 2). Having a small difference between the results between the 2 types of technologies we cannot conclude that the use of AR technology brought a significant advantage, and we cannot accept hypothesis H2.

Table 2.

Independent Samples T-Test				
	t	df	p	Cohen's d
Post-Test results	1.18	54	0.243	0.3116

5. Discussions

One of the aims of the current study was to explore the effectiveness of a mobile application developed for learning in AR called “Assemblr Edu” on the construction of students' knowledge about fundamental concepts in neuroscience. The t-test result of their post-test scores indicates that the learners' knowledge of elastic collision was significantly improved by using the Assembler Edu application. These results may suggest that the introduction of 3D visual elements may be beneficial in education. This is also suggested by other studies: when comparing the AR software to the conventional physical molecular kit in a study by Abdinejad et al. (2021) on the usefulness of AR in chemistry teaching, it was discovered that the app was more beneficial for students, particularly when taking into account the speed of 3D visualization. It should also be mentioned that these applications also allowed the quick sharing of lessons on a device that these days are always present. Students became familiar with the app relatively quickly, suggesting that these types of apps can be easily implemented in courses and classrooms. However, the results were not significantly different between those who used the app's AR feature or just viewed the models in 3D. This suggests to us that the introduction of 3D models is beneficial but there is no significant difference between the way it is rendered. However, there is a smaller difference which together with the results of other studies on AR (see: Huang et al. 2019) where a significantly better result was obtained for learning in AR compared to other methods, suggests that studies in future are necessary. According to a review done by Tang et al. (2020), the quality and scope of AR research being used in medical education at the moment is insufficient to propose its incorporation into curricula. They make the case that it's critical to standardize AR evaluation techniques and outline the technology's place in medical education.

6. Conclusions

According to research and analysis of augmented reality technology in the field of education, higher education in particular, augmented reality is a type of technology that strengthens the replication of students' learning environments and has a strong theoretical underpinning and technical support in its application. The study demonstrated the usefulness of 3D models but did not uncover any compelling data to support student instruction using augmented reality technology to produce three-dimensional displays of real-world scenarios and instructional materials.

Authors note:

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