Augmented Reality Experiences in Therapeutic Pedagogy: A Study with Special Needs Students

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***Abstract*—Information and Communication Technologies (ICTs) have played a major role in shaping our society, affecting nearly all aspects of our daily lives. In educational contexts, the ongoing technological revolution we are experiencing naturally calls for a transformation of traditional teaching and learning processes. The integration and efficient use of emergent technologies have become fundamental challenges in the educational domain. In this paper, we evaluate the use of Augmented Reality (AR) technology in a classroom with middle school special-needs students. Our primary goal is to quantitatively assess whether AR helps special-needs students to improve their results, performance, motivation, and other aspects of the learning process. Information was collected via pre and post questionnaires distributed to participants before and after an intervention. Our results serve as basis for improving future educational AR-related projects and materials.**

Keywords: Augmented Reality, Special Education, Learning and Performance, Information and Communication Technologies

I. INTRODUCTION

Information and Communication Technologies (ICTs) have significantly contributed to transform our society and drastically influenced the way we live, work, and play [1]. The popularity of computer graphics technology such as Augmented Reality (AR) has been growing steadily and is gradually becoming part of our daily lives.

AR is a visualization technology that merges real-time three-dimensional computer-generated imagery with real video footage to create an enhanced representation of reality. Augmented worlds are typically experienced via computer screens, projectors, or head mounted displays (HMD). The technology originated in 1968 when Ian Sutherland developed the first AR head-mounted display. Due to the technical limitations at the time, the device could only display extremely simple models [2]. In 1997, Azuma [3] published his first study on AR, shortly after which a number of applications began to emerge [4]. According to Azuma [3], the three fundamental features of an AR system include: (1) combination of real and virtual content, (2) real time interaction, and (3) three-dimensional registration and visualization [3, 5, 6].

AR has been applied to a multitude of domains including medicine [7, 8], technical graphics [9, 10], archeology [11], engineering and manufacturing [12, 13] and is being extensively used for entertainment and marketing purposes [14]. In education, AR was listed by the Horizon Report as a technology that will likely be fully adopted by higher education in the near future [15]. According to this report, the interactive nature of AR content confers significant potential for learning and assessment, as students build new knowledge based on visualizations and interactions with virtual models that bring underlying data to life [15]. AR visualizations stimulate the student's sensory system, allowing him or her to use previous knowledge and relate it to new information.

The value of augmented reality as an educational tool has been shown in a number of studies [16-18]. AR technology provides the understanding, the connection between learning and practice, and a mechanism to overcome certain learning limitations [16]. Recent research reveals positive results in terms of student motivation, attention, interaction, and direct contact with reality in areas such as mathematics and sciences. AR allows students to experience situations that would not be possible to reproduce and/or manipulate otherwise [17, 18].

AR also helps maintain higher levels of student engagement [19, 20]. The more immersive the learning process (i.e. the more senses are involved), the more engaging the experience becomes [21].

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Nevertheless, educational challenges become more difficult and demanding when working with special needs populations. Common special needs include learning disabilities, communication and behavioral disorders, and developmental disabilities. Special education requires specialized teaching strategies to ensure student success. In this context, many studies have shown that the use of technology, particularly AR, in a classroom with students with special educational needs provides a useful means to deliver content by using tangible intuitive interactions, facilitating the visualization and execution of cognitive exercises, and generating feedback [22, 23].

In the last few years, some authors have begun to study the benefits of AR applications and their impact on students with special educational needs. For example, researchers Chang et al. [24] developed ARCoach, a marker-based AR system for people with cognitive impairments. Their results show an increase in the participants' rate of success in the assigned tasks [24]. Likewise, the AR game developed by Lin et al. [25] has also proven successful to improve the skills of people with cognitive disabilities in the context of recycling [25].

In this paper, we present the results of a study aimed at determining whether augmented reality helps students with special needs to improve results, performance, motivation, and interest in the learning contents.

II. METHOD

A class of 88 middle school freshmen students with special needs was selected to participate in our study. The average age of the group is 12.6 years. The AR experience was conducted during a regular trimester. All participants have been diagnosed with Asperger's syndrome.

Asperger's syndrome (AS) is a developmental disorder which manifests itself in the form of social, behavioral, and communicative abnormalities. Although every child is different, common symptoms of AS include: attention and communication difficulties, problems in relations and interaction with peers, and limited capabilities for organization, habits, and autonomy in performing tasks.

The class was randomly divided into two groups: control group (which did not use AR), and experimental group (which used AR). Academic performance was analyzed for both groups at the end of the study. Specific data collection tools were developed based on a number of indicators from studies by Cascales et al. [16] and considering the following dimensions: learning outcomes, learning contents, and motivation.

The AR content for the experiment was created by our team and delivered using *SALTET*, a custom tool developed in-house. The experimental setup requires a Windows-based laptop or desktop computer equipped with a web camera and the educational AR software [26].

SALTET was implemented based on the "magic mirror" paradigm where the augmented world is experienced indirectly through a computer screen. *SALTET* is also a marker-based AR system, which means that in order to activate the AR content, the camera must be pointed at specific printed materials called "markers." These markers are typically black and white patterns whose position and orientation are recognized by the AR software and used to place the virtual content in the scene.

The installation of *SALTET* includes the AR software, a user manual, and a pdf file with the AR markers that need to be printed. The user interface is simple and intuitive. A set of icons located at the top of the screen provide access to the educational units. Unit contents are based on the standard curriculum for middle school freshmen and can be rearranged based on the pedagogical needs of the students and the teaching staff.

All units have a consistent interface which includes a group of icons that provide basic functionality, and tools to control specific parameters of the visualization and/or simulation, as shown in Figure 1. These tools include zooming of the content that is being displayed on the marker and the option to freeze the 3D model on the screen, so it can be viewed without holding the marker. The three pedagogical units implemented in *SALTET* and used in our study include:

- Human Skeletal System: in this interactive unit, a detailed visualization of a human skeleton (see Figure 2) is displayed on the marker along with descriptions of the different bones. In addition, students are asked to move various bones to the right location in the skeleton, which facilitates assessment and self-evaluation.
- Water Cycle: in this unit, 3D animations are used to illustrate the typical water cycle (see Figure 3). Textual explanations accompany every stage, which can be played continuously or step-by-step.
- The Senses: in this unit, the five senses and the related body parts can be interactively explored. Additional information can be accessed via internet links.

III. RESULTS

Academic performance was analyzed for both experimental and control groups considering a mixed experimental design, as it combines between-group and within-group dimensions.

Mauchly's test indicated that the assumption of sphericity was not met (0.14). Given that the value of Epsilon is greater than 0.90, we assumed the Huynh-Feldt correction as adequate [27, 28].

In terms of the within-subject dimension, we confirmed that there were significant statistical differences as $F_{(1,86)}=79.782$ ($p=0.000$). These differences explain 48.1% of the total ($\eta^2_{part}=0.481$), which indicates a large effect.

In terms of the trend throughout the intervention process, there was a linear effect (only this effect can occur when two points emerge). These differences explain a 50.3% of the total ($\eta^2_{part}=0.503$). Therefore, a significant effect was found.

The effect of the intervention by group was also significant. These differences explain 48.1% of the total ($\eta^2_{part}=0.481$).

Figure 1. Program interface and features

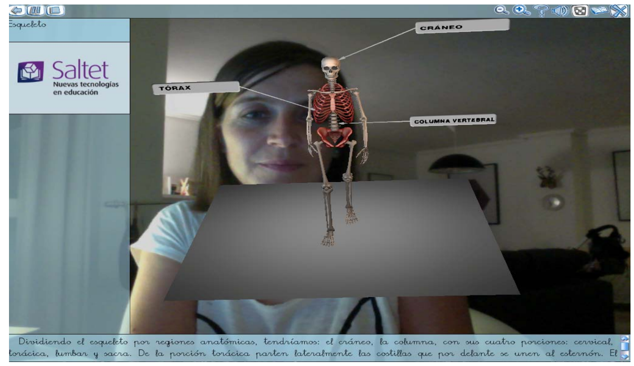

Figure 2. Contents of Skeleton

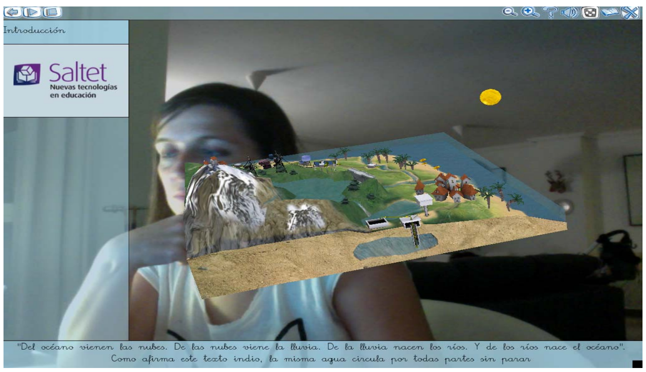

Figure 3. Contents of Water Cycle

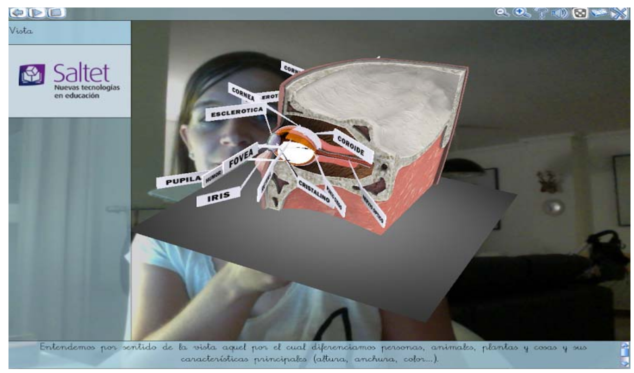

Figure 4. Content of Senses

TABLE 1. SIGNIFICANCE LEVEL AND EFFECT IN EXPERIMENTAL AND CONTROL GROUPS AFTER INTERVENTION

	Mean (max score = 10)	
	experimental	***control***
Midterm	5.5	5.52
Final	7.57	5.55

experimental + control			
within group		***between group***	
sign.	eta	sign.	η^2_{part}
0.0	.481	0.0	.139

With respect to the between-group dimension, we observed that significant differences exist between the experimental and control groups $F_{(1,86)}$=13.854 (p=0.000). These differences explain 13.9% of the total (η^2_{part}=0.139), which also represents a large effect. This indicates differences between the groups (pre, post) within the two dependent variables.

As shown in Table 2, the assumption of homoscedasticity was met in all measures of the intervention process (p>0.05). However, it was not possible to perform post hoc tests because there are fewer than 3 groups.

TABLE 2. LEVENE CONTRAST ON EQUALITY OF VARIANCES

	F	**df1**	**df2**	**Sig.**
Midterm	.016	1	86	.901
Final	.220	1	86	.640

By examining Figure 5, we observe that before the intervention, both groups performed at approximately the same level (on average, both groups' science grades were around 5.5 (out of 10)). After the intervention, the experimental group's performance increased significantly (2.3 points) while the control group's remained constant.

Finally, pre and post tests regarding student interest in the content and motivation are discussed. In terms of student perception of the content, augmented reality materials were generally preferred to a traditional textbook (see Figure 6). Participants confirmed they engaged with the AR material in a more stimulating and exciting manner.

Regarding motivation, results suggest that interest in learning as well as active participation, confidence to face more complex content, and general attitude towards learning also increased (see Figure 7).

The overall results of the intervention with AR have been positive. Critical aspects of the teaching-learning process such as learning outcomes, interest in the content, and motivation have significantly improved.

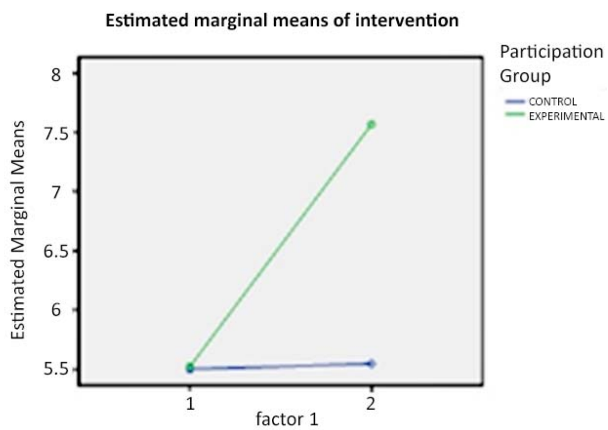

Figure 5. Average participation in intervention group

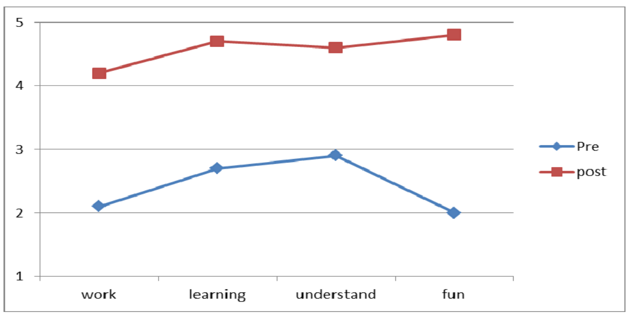

Figure 6. Student perception of learning contents (Dimensions: Working, Learning, Understanding, Enjoying)

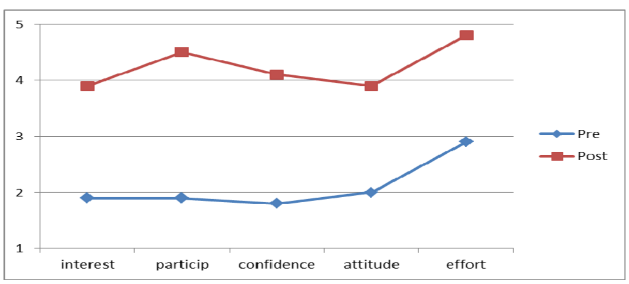

Figure 7. Student motivation before and after intervention (Dimensions: Interest, Participation, Confidence, Attitude, and Effort)

IV. Conclusions

In this paper, we described a study aimed at evaluating the educational value of AR technology in a classroom with middle school special-needs students. Some of the variables considered in our analysis include student performance, motivation, and perception of contents.

The results of this educational experience reveal an improvement in the overall academic performance of the experimental group (with AR materials). The control group (no AR materials) showed no comparable results. Additionally, an increase in motivation and interest in the learning contents were also observed after the intervention, which validates previous studies in similar environments [6, 16, 29, 30]. The study suggests that AR promotes cognitive development in students with special educational needs by fostering a more active learning which leads to higher levels of motivation and student engagement.

A number of variables that influence student learning and academic performance were observed during the experiment. Although many are intrinsic to the individual, such as personal interests, expectations, previous experience, etc, there may be some where the teaching staff has certain control in terms of learning contents, methodology, or assessment [31, 32].

Augmented reality has the potential to become an effective tool to enhance traditional teaching materials and transform instruction, particularly in special education. Many educators have already ventured to successfully incorporate this type of technology into the classroom, and research in this area is ongoing. In the future, more AR materials, tools, and easier and more intuitive methods to create AR content are expected.

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