Exploring Technological Education: An Augmented Reality Sandbox

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Abstract

Extended reality (EX) is permeating the Education aim, but it is still a field to explore. In this paper, a first developed by the University of California Sandbox based on Augmented Reality for the users to interact with graphics that are modified following the users' sands interplay, was presented at a Festival for elementary school students. With the purpose of spreading the use of extended reality for education, the Festival assistants were asked for possible applications at their scholar programs. Sixty-three participants who tried the device answered a three-question brief questionnaire. All of them expressed enjoyed using the Augmented Reality Sandbox. The answers on how to apply the device for learning range from recreational and artistic activities to scientific and technological ones. It is important to consider that the incorporation of these technologies in the classroom is no longer as expensive and difficult as it was in the past.

Keywords

AR, Extended Reality, elementary school students, active learning

1. Introduction

Those technologies that merge reality with virtual environments were described by Milgram and Kishino [1] as a continuum of Mixed Reality (MR) that goes from the real environment on one end to Virtual Reality (VR) on the other, passing through Augmented Reality (AR) and Augmented Virtuality (AV). MR is then the real world with virtual items within a single displayed representation, anywhere between reality and virtuality [2]. MR has become a complex concept that fluctuates across time following technological trends, linguistic meanings, and narratives [3]. These technologies are now gathered under the term Extended Reality (XR) which encompasses the spectrum of realities assisted by immersive technologies, they are intended to extend our sense of reality by blending it with a computer environment.

However, the different XR technologies present specific features:

VR's purpose is to immerse the user into a virtual world.

AR enhances the virtual world with digital or virtual elements.

AV can be understood as the virtual world enhanced by the real world, using, for example, physical objects for digital feedback.

Conversely, interacting with the world is fundamental to the learning process [4]. Although this isnot always possible, and therefore an appropriate way to generate a context based on authentic learning activity can benefit from XR. The XR can be a valuable substitute for a real situation, providing a first-person experience and allowing the spontaneous acquisition of knowledge that requires less cognitive effort compared to traditional educational practices [5].

CISETC 2023: International Congress on Education and Technology in Sciences 2023, December 04–06, 2023, Zacatecas, Mexico
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Educational XR may provide students with visual, experimental, and self-directed learning to directly experience some physical properties of objects and events, changing the point of view to access new and/or unusual perspectives or interact with objects to discover or study hidden elements and evaluate the effects of different manipulations on objects [6].

Back in 2002, Winn described two special characteristics with which XR technologies can contribute to learning, that is, reification and inscription. Reification is the process through which a phenomenon that cannot be directly perceived and experienced in the real world, due to specific qualities of the objects, can be perceived and interacted with in XR for learning. This empowers students to experiment in a virtual learning environment something they might not be able to experience in the real world, probably the most important contribution of XR technology to learning. And, the word inscription, represents an alternative to referring to external representations instead of internal ones such as images or mental models [7], aspects that provide understanding and facilitatethe learning process.

1.1. Augmented Reality on Education

In recent decades, the integration of AR into educational applications has significantly growth, particularly since the advent of mobile devices. [8] sated that while early challenges such as high costs hindered its widespread adoption, the subsequent integration of AR into mobile platforms has fueledits use in education, leading to numerous applications designed to enhance teaching and learning. Qualitative reviews highlight the positive impact of AR on students' learning achievements and motivation; however, according to [8] a limited number of quantitative meta-analyses have been conducted, indicating the overall effectiveness of AR in education, where the role of technology in learning underscores the need to consider both technical aspects and pedagogical strategies for optimal student learning.

A study conducted by [9] focuses on the perceptual characteristics of AR from a user's perspective: contextuality, interactivity, and spatiality, derived from Azuma's definition of AR [10]. Contextuality emphasizes the integration of virtual and real elements allowing the overlay of digital information onto the real world. This contextuality, unique to AR, offers opportunities for situated scaffolding. For learning, AR's contextuality can enhance authenticity and grounding in reality. The second characteristic, interactivity, highlights the real-time responsiveness of AR elements to user input, fostering intuitive and natural interactions with virtual objects. This interactivity not only supports individual learning outcomes but also facilitates collaborative learning, enabling users to observe and interact with virtual elements collectively. And, the spatiality characteristic of AR, emphasizes the registration of virtual elements within the 3D real world, offering advantages for learning spatial structures and relationships. This study identifies research questions related to each characteristic, to deepen the impact of AR on learning experiences. Overall, it underscores the user-centric perspective in exploring the educational potential of AR and advocates for comprehensive empirical studies to address the identified research gaps.

In [11] it is recognized the AR dual nature of combining digital and physical information in real-timethrough electronic devices. As the authors stated, AR has demonstrated its effectiveness in facilitatingstudent learning and creating meaningful experiences, generating different benefits, such as increased motivation, improved academic performance, active student engagement, autonomy, and the promotion of digital competence. Their study introduces an approach by employing bibliometric analysis, scientific mapping, and co-word analysis to explore the state of affairs in AR within the educational field, specifically using the Web of Science database. The justification lies in addressing the existing gap in this particular bibliometric perspective and contributing to the literature's understanding. The study's objectives encompass assessing scientific production, determining the evolution of AR in education, identifying prevalent topics, and recognizing influential authors. The research is exploratory, aiming to reveal insights and guide future studies, ultimately representing progress in scientific understanding and providing a foundation for subsequent research endeavors.

The incessant search for innovative and effective methods must be a constant in Education, this paper describes the experience of an AR prototype presented at a festival for elementary school students

2. Augmented Reality Sandbox

Augmented Reality Sandbox is a dynamic and transformative tool, designed to elucidate concepts of watershed hydrology and topography, often abstract for students. It consists of a video projector, an Xbox Kinect sensor, and open-source software — a product of efforts from the University of Californiaat Davis, W.M. Keck Center [12]— the sandbox projects a topographic map onto a sandy surface, thatgets adapted to real-time modifications made by users. While museums and introductory geoscienceclasses are the primary beneficiaries, the simulations allow for a deeper understanding of hydrogeological phenomena.

The University of Vermont (UVM) has taken this tool a step further, introducing enhancements such as digital visualization of bathymetry, additional climate varieties, and precise climate simulation controls [13]. Moreover, thanks to 3D printing based on LiDAR data, it is possible to accurately replicate specific topographies, giving students a clear perspective on particular hydrological processes. In courses like Applied River Engineering at UVM, understanding of topographic map constructions, drainage patterns, and the impacts of climatic events on topographies is enhanced [14].

The AR sandbox was constructed, Figure 1 depicts a sketch of the structure and measurements, on the left and a partially constructed sandbox on the right in which can be seen the actual sand in the box

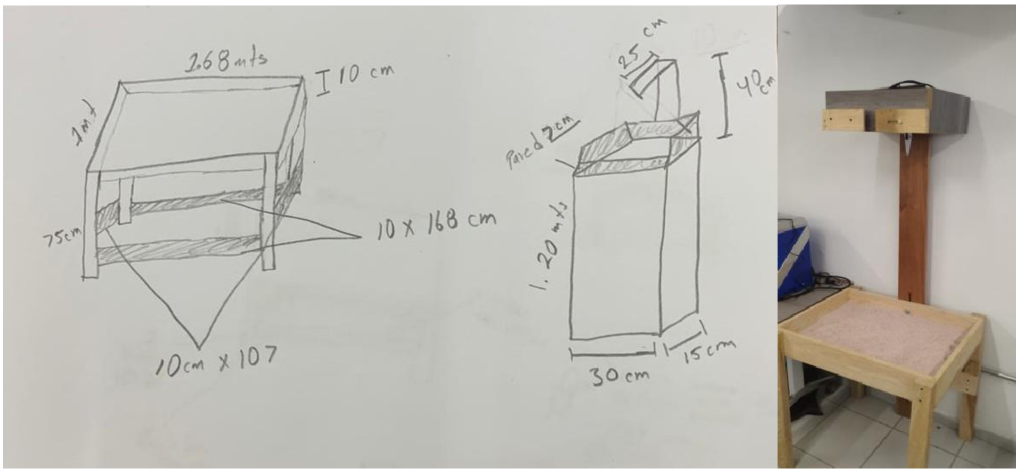

Figure 1: AR sandbox sketch and a partially constructed one

Studies like that of Wu et al. [15] reinforce the idea that AR can facilitate learning by offering meaningful experiences. AR in the educational realm, although promising, is not without challenges, including teacher training and curriculum adaptability. Therefore, we decided to place the sandbox ata festival aimed at primary school students and directly ask them where to apply it.

2.1. AR sandbox in the Papirolas Festival

The AR sandbox constructed intended to use three-dimensional models to observe conceptual changes like erosion in real-time, and educational models. It was presented at the "Papirolas Festival 2023" which stood out by introducing groundbreaking technology, promising to reshape primary students' interaction with knowledge.

The Papirolas Festival is a multicultural, educational, and innovative space that takes place annually in the city of Guadalajara, Mexico, and as an extension in some cities in the interior of the state of Jalisco since 1995, 28 years ago. It lasts five days in which take place workshops, shows, exhibitions, thematic pavilions, contests, awards, activities and special guests, training conferences for teachers and parents, as well as an area of stands and sponsor pavilions, are held. Its mission is to contribute to cultural, creative, educational, intellectual, and physical development and universal human values, to promote social awareness in boys, girls, young people, and their environment [16].

Therefore, AR was selected because it permeates the educational world, while the focus should remain on the student, this technology should be adapted to the context and the learner [17]. Next is a list of suggestions for the AR sandbox application [18]:

- Terrain Modeling: Users can shape mountains, valleys, and rivers in the sand, which are identified by sensors and visually projected with realistic effects.
- Water Simulation: Creating depressions in the sand can simulate water, including rivers and lakes, showing flow and movement in real time.
- Weather Interactivity: Potential rain or snow effects on the terrain, altering the landscape interactively with hands.
- Geography: Teaching about geographical concepts such as watersheds, topography, and ecosystems.
- Collaboration: Multiple people can work together to build and modify landscapes, encouraging teamwork.
- Games and Challenges: It may include games or challenges that require modifying the terrain to achieve specific objectives.
- Science Exploration: It allows users to experiment with physical concepts like gravity, erosion, and mass conservation.
- Dynamic Visualizations: The projection changes dynamically as users interact with the sand, offering immediate feedback.
- Environmental Education: It can be used to teach about environmental impacts and sustainability.
- Events and Presentations: It is ideal for museums, science fairs, and educational events to demonstrate interactive technology and teachings.

Figure 2 shows the displayed starting image in the AR sandbox with rabbits on the land and fisheson the water, and Figure 3 elementary school students interacting with it. Some of the interactants answered a very short just three-question questionnaire.

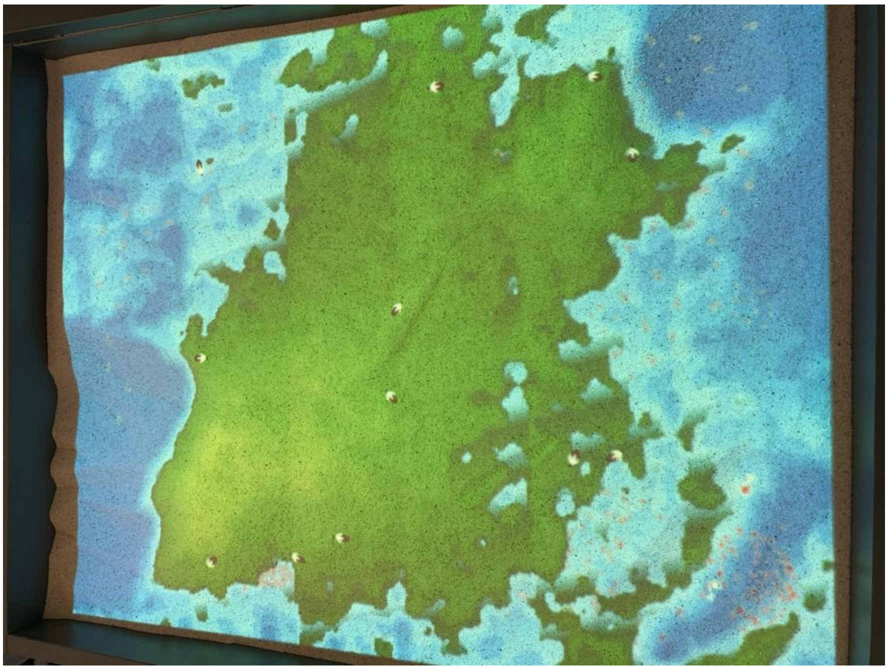

Figure 2: Starting image at the AR sandbox

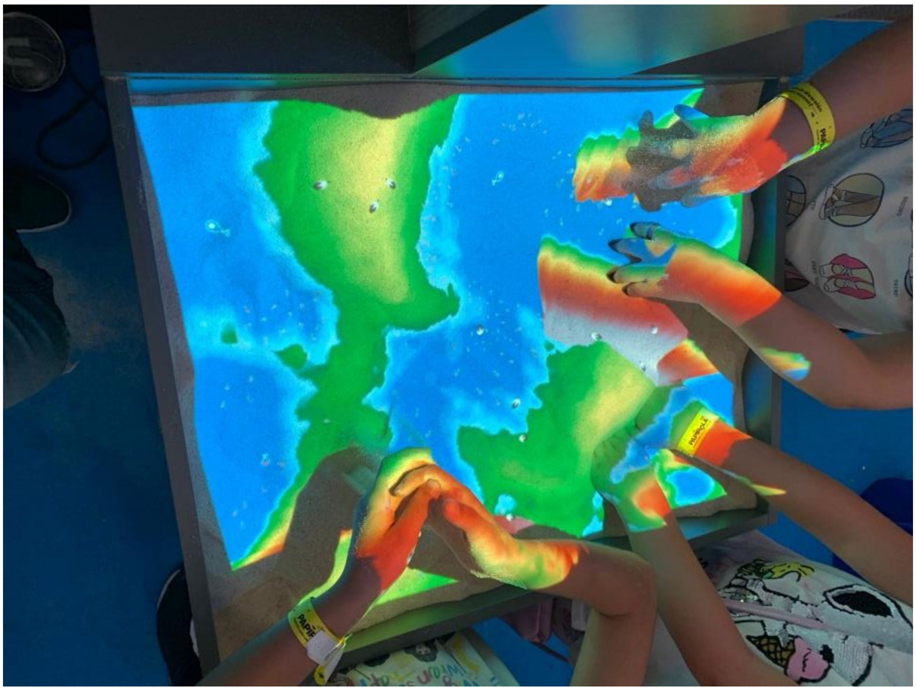

Figure 3: Elementary school students interacting with the AR sandbox at the Papirolas Festival 2023**.**

2.2. Questionnaire

The questionnaire had only six questions, three of them to establish the age, gender, and scholarship of the participant, one to see if they enjoyed the experience, and two more to understand how they would use it in the classroom. The last three questions were:

1. Did you like the device? Yes, or not
2. In what subject at your school would you use it? With open answers, and
3. For what topic? Also, with an open answer.

2.3. Participants

Sixty-three participants answered the questionnaire. Twenty-four were not elementary school students, most of them were undergraduate students (i.e., 22), one Ph.D. and one professor, with anaverage age of 24 years old, 14 males and nine females. There was also a kinder garden 4-year-old female participant. The rest of them (i.e., 38) were in elementary school, 17 females and 21 males, with an average age of 9 years old as follows:

- Six in the first year
- Four in the second year
- Seven in the third year
- Five in fourth year
- Six on fifth year
- Three in the sixth year
- Four in the first year of the second level
- Two in the second year of the second level, and
- One of the third year of the second level.

Two participants, one of kinder and one in the first year of elementary school could not come outwith an answer for the subject or topic to use the AR sandbox.

2.4. Results

All the participants expressed that they liked the device. Table 1 shows the answers of the adults about the subject and the topic they would use it in their school program. And Table 2 shows those students from elementary school.

Table 1
Subjects and topics suggested by adults

Number	Subject	Topics
1	Arts	Everything in general
2	Science	Ecosystems
		Animals and nature
1	Natural science	Temperature changes in the atmosphere
1	Physics	Gravity
8	Geography	The earth and plants
		Ecosystems and regions
		The earth surface
		The ocean
		Terrains
1	Anatomy	Body parts
2	Meteorology	Atmospheric pressure
		Tides
		Subsoil
3	None of them	None
1	Psychology	Relaxation for autistics
2	Chemistry	Periodic table of elements
		For metal identification
1	Technology	Devices
1	Topography	Soil

Table 2
Subjects and topics suggested by elementary school students

Number	Subject	Topics
1	Arts	Drawing
16	Science	The ocean
		Earth surface
		Weather
		Plants and woods
		Drawing mountains
		To play
		For animals' identification
		To play with fishes
		Drawing ecosystems
		Earth planet
		Natural phenomena
1	Drawing	Drawing
3	Spanish	The alphabet
12	Geography	The continents
		Countries and capitals
		Layers of the Earth
		The Earth
		Earth temperature
		The relief of the earth
		To create maps
2	History	Commercial routes
		War places
1	Play	Playing with sand
1	Mathematics	Addition

As can be observed, not surprisingly because it was its first intentional use, Geography seems to be the subject with more topics to explore in the device, as well as subjects and topics related to nature.

As can be seen by comparing both tables, elementary school students refer to various topics witha generic name of science. However, despite the age difference and experiences, both groups propose practically the same topics, showing the possibilities of the use of the AR sandbox. From both Tables,the most mentioned subjects were Geography mentioned 20 times, and Science 18 times, most of them of the elementary school students.

3. Conclusions and Future Work

In this paper, we explored the possibilities of constructing devices that use AR to enhance the real world for a better comprehension of certain phenomena from the real world. An interactive and attractive alternative that nowadays does not represent a great cost for its implementation.

In the future we plan to include learning purposes within the AR sandbox, to compare this learningapproach with the traditional one.

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