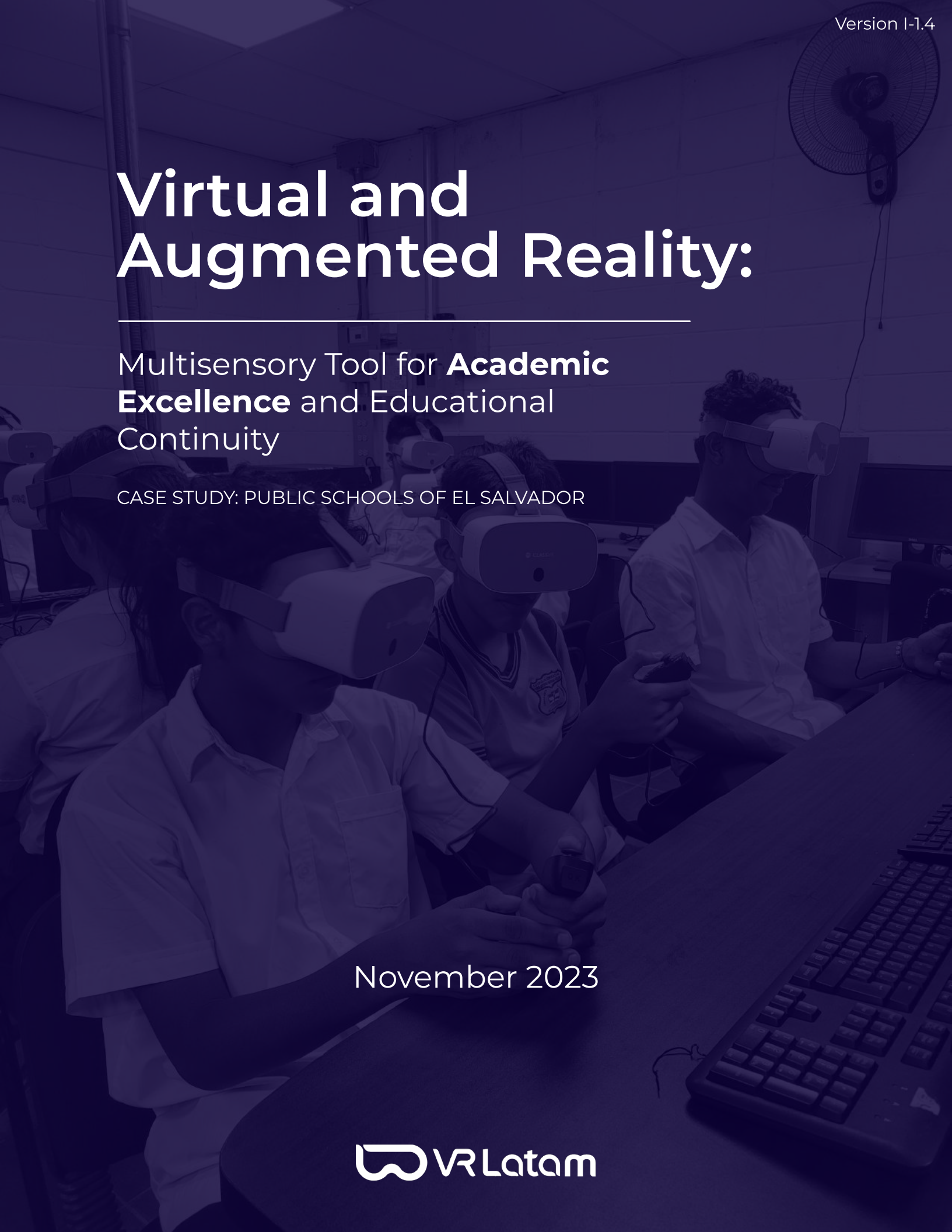
Version I-1.4

# Virtual and Augmented Reality:

## Multisensory Tool for **Academic Excellence** and Educational Continuity

CASE STUDY: PUBLIC SCHOOLS OF EL SALVADOR



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VR Latam

Research conducted by:


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# ABSTRACT

This research describes the impact of including virtual and augmented reality as a teaching tool, in schools placed in vulnerable sectors of El Salvador. The purpose of the experiment was to measure the incidence of this technology in two different fundamental variables of education: retention and motivation. The studied subjects were 297 students from ninth grade that belong to 13 different schools of limited resources. Two-groups pretest-posttest experimental design was used. The treatment group received Science and Social Studies classes with virtual reality. Results revealed an increase of 6.7% in knowledge retention in all the students exposed to the technology, with more incidence in subjects such as Social Sciences and a trend towards better results on retention with longer interventions. Related to the motivation variable, an increase of 21% was achieved in commitment, expectation and affectivity from the treatment group that received classes with VR, but the most significant finding is the gap between both groups in conduct dimension (+31%). The research allows to state, based on experimental evidence, that virtual reality stimulates different cognitive processes linked with academic development. The multisensorial aspect of technology allows students to recall more information and commit to their own learning process, improving the key indicators of quality and educational outcomes.

**Keywords:** immersion, virtual reality, extended reality, technology, educational innovation.

# 1. INTRODUCTION

Public education in Latin America faces three major challenges: reducing technological gaps, maximizing the educational trajectory of the most vulnerable students, and ensuring that education generates employable and productive learning outcomes.

Each of these mentioned challenges implies a tremendous effort by policymakers to create cost-effective plans that cover the basic functioning of massive bureaucratic structures while aiming to improve educational quality and continuity indicators.

The incorporation of technology as a tool to enhance education is a globally discussed topic that has gained even more relevance in Latin America due to increasingly marked technological disparities compared to industrialized and economically developed countries.

According to a study by the Inter-American Dialogue[1], as of November 2021, **only 33% of the region's schools had access to high-speed internet**, contrasting with a Gallup study revealing that by 2019, 78% of public school teachers in the United States used digital tools at least twice a week as a pedagogical aid[2].

Within the spectrum of technologies aimed at improving educational indicators, 'meaningful connectivity,' a term used by the Alliance for Affordable Internet, is prioritized, necessitating the convergence of three elements in schools:

[1] Grupo de Trabajo sobre Tecnología e Innovación en la Educación. (2021). El Estado de la Conectividad Educativa en América Latina: Noviembre de 2021. Desafíos y oportunidades estratégicas. Recuperado de: https://www.thedialogue.org/wp-content/uploads/2021/11/El-estado-de-la-conectividad-educativa-en-America-Latina-Desafios-y-oportunidades-estrategicas-1.pdf

[2] Dick, E. (2021). The Promise of Immersive Learning: Augmented and Virtual Reality's Potential in Education. Information Technology and Innovation Foundation.

access to stable and sufficient internet, availability of smart devices, and teacher training[3]. Subsequently, various comprehensive solutions have emerged, aiming to transform the educational experience by incorporating elements of science and engineering to encourage cognitive development and critical thinking, such as STEAM methodologies that employ robotics, programming, and other information technologies.

Extended reality, XR for short, has emerged in recent years as the technological promise to enhance educational quality across all levels of teaching, from basic to professional education, owing to its immersive and experiential nature[4]. Added to these benefits is the multisensory component, which, according to studies by the Games For Change association, reduces cognitive load in learning by utilizing technology as a teaching tool in the classroom[5].

This research is an experimental study seeking to identify and analyze the impact of extended reality (virtual and augmented reality) on two key education indicators, retention, and motivation, in schools located in vulnerable sectors of Central America, specifically in El Salvador.

Building upon previous experiments conducted by the research team and based on the guided use methodology of technology, 10 rural schools from different vulnerable communities in El Salvador, part of the “Educar y Convivir” project by USAID implemented by FEPADE, were selected. Each school was equipped with a lab comprising 16 virtual reality devices, utilizing the educational platform Class VR by the British company Avantis Education.

Teachers underwent a 12-hour in-person training endorsed by the Technology Department and Teacher Training Directorate of the Ministry of Education, Science and Technology of El Salvador. The goal was to have the same teachers from beneficiary schools conduct the virtual and augmented reality classes. Finally, the pedagogical adaptation of Science and Social Studies subjects corresponding to the last month of the academic year for ninth-grade students was carried out to be taught using extended reality.

This article is organized into five sections. The first section, the theoretical framework, describes the most important definitions of extended reality technologies and previous research, both from the authors and third parties, which led to the conceptual design of the experiment. The second part contains the research methods, leading to the results obtained after a month of intervention in the beneficiary schools. Finally, the analysis of results, conclusions, and key findings are presented, summarizing the identified contribution of this technology to the key education indicators for Latin America.

[3] A4AI (2022). Advancing MeaningfulConnectivity: Towards Active & Participatory Digital Societies. Alliance for Affordable Internet. Recuperado de: https://a4ai.org/report/advancing-meaningful-connectivity-towards-active-and-participatory-digital-societies/

[4] Dick, E. (2021). The Promise of Immersive Learning: Augmented and Virtual Reality’s Potential in Education. Information Technology and Innovation Foundation.

[5] Games for Change. (2020). XR for Social Impact: A Landscape Review. Recuperado de: https://static1.squarespace.com/static/5a3c7a6e8a02c7c479b86829/t/5e3f7d7d7c5f8d4c8d7d7f5c/1581096846075/XR_for_Social_Impact_Landscape_Review.pdf

# 2. THEORETICAL FRAMEWORK

## 2.1 Virtual and Augmented Reality as a Pedagogical Tool

At a global level, society is immersed in a reality characterized by constant technological changes that have given rise to new paradigms, expanding exponentially across the world. The educational sphere has also undergone significant transformations due to these advancements, particularly in the teaching and learning processes, which now exhibit substantially different characteristics from traditional conceptions. These dynamic and revolutionary processes have led to a redefinition of educational paradigms across all levels and modalities, marking a fundamental shift in how education is conceptualized

In this context, new educational models associated with technology have emerged to revolutionize teaching paradigms[6]. The inclusion of technologies such as Virtual Reality (VR) and Augmented Reality (AR) has transformed the way classes are conducted turning them into powerful teaching tools for educators. Numerous studies demonstrate that this technology goes beyond its recreational application and significantly contributes to the development of cognitive skills such as retention, comprehension, perception, attention, memory, motivation, etc [7][8].

**Virtual Reality offers an immersive experience where students can engage with all their senses: sight, smell, touch, taste, and hearing.**

In the educational realm, for instance, simulations of historical contexts or interactions with natural resources can be employed, making the student the primary protagonist of their own learning process [9].

[6] Montoya, M. S. R. (2009). Recursos tecnológicos para el aprendizaje móvil (mlearning) y su relación con los ambientes de educación a distancia: implementaciones e investigaciones. RIED. Revista iberoamericana de educación a distancia, 12(2), 57-82. http://e-spacio.uned.es/fez/view/bibliuned:revistaRied-2009-12-2-2040

[7] Wu, H. K., Lee, S. W. Y., Chang, H. Y., y Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. Computers & Education, 62, 41-49. https://doi.org/10.1016/j.compedu.2012.10.024

[8] Krokos, E., Plaisant, C., & Varshney, A. (2018). Virtual memory palaces: immersion aids recall. Virtual Reality, 23(1), 1–15. https://doi.org/10.1007/s10055-018-0346-3

[9] Rodrigo-Yanguas M, Martin-Moratinos M, Menendez-Garcia A, Gonzalez-Tardon C, Sanchez-Sanchez F, Royuela A, Blasco-Fontecilla H. (2021). A Virtual Reality Serious Videogame Versus Online Chess Augmentation in Patients with Attention Deficit Hyperactivity Disorder: A Randomized Clinical Trial. Games Health J. 2021 Aug;10(4):283-292. doi: 10.1089/g4h.2021.0073

Based on the aforementioned aspects, the integration of Virtual Reality for educational purposes enables the creation of a participatory, collaborative, practical, and immersive learning environment that potentially enhances learning indicators and educational continuity.

## 2.2 Retention

Retention, as a memory process, has been extensively studied in the educational field as it's fundamental for learning. Among prevalent theoretical frameworks, retention is understood as an individual's ability to maintain and recall learned information or skills over an extended period[10].

Emerging trends in education emphasize learning as a collaborative construction between teachers and students, a significant factor influencing retention. When students take an active role in their learning process, higher levels of information and content retention are observed[11].

Studies indicate that teaching with VR impacts knowledge retention because students engage in interactive, practical, and innovative learning experiences. Given that newer generations are highly accustomed to interactive environments, it's presumed that VR would be highly beneficial for cognitive processes like retention[12].

In this regard, the REDEM platform (2023)[13] states the following:

> *The premise is as simple as it is didactically perfect: learning in interactive environments that feel real, where mistakes can be made without suffering consequences, thus enhancing the effectiveness of learning. Virtual Reality (VR) has evolved from a futuristic concept to providing immersive experiences with immersive images and surround sound, enabling students to experience each situation from various perspectives, analyze the consequences of their decisions, and even observe the time taken to respond to each question.*

Importantly, meaningful learning occurs when the learning object is functional or interactive, as it integrates in a simple way while the participant develops the necessary cognitive structures, enabling them to establish connections with the new knowledge.

## 2.3 Motivation

Motivation is a key element in learning and is also considered one of the determining variables, alongside retention, for academic success. In this sense, educators should seek technological alternatives to capture students' attention in order to enhance motivation and improve academic performance. Students must

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[10] Soderstrom, N. C., Kerr, T. K., & Bjork, R. A. (2016). The Critical Importance Of Retrieval—And Spacing—For Learning. Psychological Science, 27 (2), 223-230.

[11] Hermann Acosta, Andrés (2015). Narrativas digitales como didácticas y estrategias de aprendizaje en los procesos de asimilación y retención del conocimiento. Sophia: colección de Filosofía de la Educación, 19(2), pp. 253-270.

[12] Wu, H. K., Lee, S. W. Y., Chang, H. Y., y Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. Computers & Education, 62, 41-49. https://doi.org/10.1016/j.compedu.2012.10.024

[13] Tomado de REDEM Alfabetización Digital Recuperado el 12 11 2023 https://alfabetizaciondigital.redem.org/la-ensenanza-con-realidad-virtual-puede-multiplicar-por-cuatro-la-retencion-de-conocimientos/

maintain a positive attitude towards new learning, which translates into greater interest, ultimately driving their engagement in learning. Carrillo, Padilla et al. (2009)[14] suggest that 'Motivation is that internal, positive attitude towards new learning; it is, therefore, an endogenous process. Undoubtedly, motivation plays a fundamental role in this process'. This process is primarily generated by the participant's interest in the subject matter. A topic of interest sparks motivation and undoubtedly aids in facilitating learning.

Within the multiple lines of research on motivation, the work of Pintrich[15] stands out, primarily integrating motivational and cognitive variables to gain a comprehensive view of the learning process within the school context. He indicates that learning is regulated by three components or dimensions directly linked to motivation: Cognition, Emotion, and Behavior.

The primary insights related to motivation research in the field of education have been condensed into the Motivated Strategies for Learning Questionnaire (MSLQ), one of the most widely accepted instruments globally. It has been adapted for highly diverse populations due to its robust structure[16]. Students characterized by high levels of motivation display personal involvement in their learning and demonstrate the ability to persist and exert effort in tasks to achieve their set goals.

Certainly, the use of VR in the classroom allows for, among other advantages, the development of cognitive, spatial, perceptual-motor, and affective skills. In students, it enhances attention, retention, and learning. These are significant advantages, as suggested by Marín-Díaz et al. [17]:

- Provides an effective communication environment for educational work by reducing uncertainty about knowledge concerning an object.
- Increases students' positive attitude towards learning and their motivation or interest in the subject matter, reinforcing abilities and competencies.

## 2.4 Vulnerable Schools (Previous Experiment)

One of the key objectives of educational training is universal access to information and knowledge. For these reasons, governments must promote and ensure inclusive and quality education, providing technology in schools, especially in more deprived sectors where access to information and innovative technology becomes critical. Vulnerable schools (hereafter referred to as VS) are characterized by experiencing a series of difficulties influenced by context and resources, hindering students from benefiting fully from the curriculum and classroom teachings throughout their school journey[18]. VS commonly exhibit high dropout rates[19].

[14] Carrillo, M., Padilla, J., Rosero, T., & Villagómez, M. S. (2009). La motivación y el aprendizaje. Alteridad. Revista de Educación, 4(2), 20-32.
[15] Pintrich, P. R. (2000b). Multiple goals, multiple pathways: The role of goal orientation in learning and achievement. Journal of Educational Psychology, 92, 544-555.
[16] Pintrich, P., Smith, D.; García, T. & McKechie, W. (1991). A Manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ). Ann Arbor: University of Michigan
[17] Verónica Marín-Díaz, Julio Cabero-Almenara y Oscar Manuel Gallego-Pérez (2018) Motivación y realidad aumentada: alumnos como consumidores y productores de objetos de aprendizaje. En: Aula Abierta, volumen 47, nº 3, julio-septiembre, 2018, págs. 337-346
[18] Díaz, C., & Pinto, M. (2017). Educational Vulnerability: A study from the socio-critical paradigm. Universidad Nacional de La Pampa. Praxis Educativa (Arg), vol. 21, núm. 1, pp. 46-54, 2017. Recuperado de: https://doi.org/http://dx.doi.org/10.19137/praxiseducativa-2017-210105
[19] Otero, A., & Flores, J. (2011). Realidad virtual: Un medio de comunicación de contenidos. Aplicación como herramienta educativa y factores de diseño e implantación en museos y espacios públicos. Revista ICONO14. Revista Científica de Comunicación y Tecnologías Emergentes, 9(2), 185. https://doi.org/10.7195/ri14.v9i2.28

In marginalized areas, educational quality is compromised by various factors, including the limited provision of educational resources.

For this reason, an experiment was conducted in partnership with the “Fundación Salvador del Mundo” (FUSALMO), involving students from 12 educational institutions in vulnerable sectors through an educational reinforcement program.

Nine science classes were adapted to be delivered through VR, and subsequently, knowledge retention and motivation (engagement) were measured. The same measurements were conducted for a group of students not exposed to VR. Among a total of 550 students, it was found that the VR-exposed group:

Produced **10.4% more passing students** than the non-VR group.

Produced **8.7% more correct answers** than the non-VR group.

Rated their classes **9.1% better in terms of interactivity and dynamism.**

Rated their classes **9% better in terms of enjoyment**

Selected the highest option to **describe the class as more fun 14.59%** more often.

This study helps to understand VR as a pedagogical tool that drives knowledge retention and therefore positively impacts students' academic performance. Due to its immersive, playful, and multisensory nature, it enhances students' motivation and engagement with their learning process. It becomes crucial to operationally define these latter two variables, which are key to predicting educational success and continuity.

# 3. METHODS

## 3.1 Research Objective:

- To measure the impact of using virtual and augmented reality as a pedagogical support tool on retention and motivation variables in schools within vulnerable sectors of El Salvador.

## 3.2 Study Participants:

- The study consists of 297 ninth-grade students from schools located in rural areas of El Salvador, ranging in age from 14 to 19 years old.

- A stratified sampling technique was employed, which divides the population into homogeneous subgroups or strata before selecting samples[20]. In this case, each school was considered as a stratum to ensure a proportional representation of different schools in the sample.

- Additionally, a purposive approach was implemented, intentionally selecting participants based on specific criteria[21], facilitating the inclusion of key individuals for the research objectives and enhancing the quality of the collected data in each educational context. Ninth-grade students were chosen as this grade represents a critical point for school dropout rates in El Salvador[22].

## 3.3 Variables

**Retention:**

A five-question questionnaire for each Science and Social Studies class was designed. These assessments encompass the content that will be taught in each class, addressing the predetermined performance indicators in the national educational curriculum. A higher score on the questionnaire indicates a higher level of retention of the recently taught class.

[20] Creswell, J. W., & Creswell, J. D. (2017). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (4th ed.). Sage Publications.

[21] Fraenkel, J. R., & Wallen, N. E. (2006). How to Design and Evaluate Research in Education (6th ed.). McGraw-Hill.

[22] Hernández Medrano, W. A., & Montano de Cortés, C. Y. (2020). Análisis de la Deserción Escolar desde un Enfoque Cualitativo: Qué Ocurre en el Tránsito del Noveno Grado a Bachillerato en el Sistema Educativo Público; Así Como Sus Factores Vinculantes. Tesis preparada para la Facultad de Postgrados, Universidad Centroamericana José Simeón Cañas.

**Motivation:**
The Motivated Strategies for Learning Questionnaire (MSLQ)[23], a self-report instrument designed to assess students' motivational orientations, was used. The MSLQ is based on a broad cognitive perspective of motivation and learning strategies. In this study, the questions were adapted to fit the educational level of the treatment population (ninth grade), and only the items related to the motivational aspect of the questionnaire were included.

The adaptation of the MSLQ maintained the five-point Likert scale, where participants rate their level of agreement or disagreement (ranging from 1 = completely disagree, 2 = disagree, 3 = neutral, 4 = agree, to 5 = completely agree) with six statements related to three psychological dimensions:

- Dimension of expectations: based on the student's beliefs regarding whether they find the classes useful or not.

- Dimension of affectivity: focused on the student's concerns and rejection towards the classes.

- Behavioral dimension: centered on the student's willingness or unwillingness to attend classes.

## 3.4 Research design

Two methodological designs were conducted, one for each variable under study: retention and motivation.

**Retention:**
An experimental pretest-posttest design was carried out with both a treatment and a control group, with students being randomly assigned to these groups. The following outlines the characteristics of the groups:

- **Treatment Group:** Students who received Science and Social Studies classes using virtual and augmented reality as an immersive pedagogical support tool.

- **Control Group:** Students who received Science and Social Studies classes through a standard class format taught using a PowerPoint presentation.

Both the treatment and control groups were given the retention test before the class to determine the level of understanding of the concepts to be addressed in the academic session. Both groups were re-evaluated using the same test one week after receiving the class, in virtual reality for the treatment group and in the traditional way for the control.

For the purposes of this study and to standardize the control group, a traditional class is defined as delivering the didactic sequence of the topic using PowerPoint slides as a supporting tool for presenting the content

Sixteen academic sessions were conducted for Science (10 sessions) and Social Studies (6 sessions), adapted from the national curriculum program. These sessions were conducted during the months of September and October at the participating schools involved in the research. Both interventions, the treatment and control groups, were led by the respective school's teachers who underwent training on delivering classes in virtual reality. They were certified by the Teacher Training Ministry of Education's Directorate.

[23] Pintrich, P., Smith, D., Garcia T. & McKeachie, W. (1991). A Manual for the Use of the Motivated Strategies for Learning Questionnaire (MSLQ). National Center for Research to Improve Postsecondary Teaching and Learning, Ann Arbor, MI. NCRIPTAL-91-B-004

**Motivation:**
A pre-experimental design of pretest-posttest for the treatment group and a measurement for the control group was conducted. Below are the characteristics of the groups::

- **Treatment Group:** Students involved in the project "Incorporation of Virtual Reality as a tool to enhance the quality and educational continuity" (IVR-TEQC), part of the “Educar y Convivir” program by USAID, implemented by FEPADE. They received Science and Social Studies classes utilizing virtual and augmented reality as an immersive pedagogical support tool.

- **Control Group:** Students from schools situated in rural sectors of El Salvador who are not part of the "Incorporation of Virtual Reality as a tool to enhance quality and educational continuity" project, located in areas adjacent to those of the treatment group.

For the treatment group, the initial MSLQ measurement was conducted in the first week of the experiment's implementation, and a posttest was done in the final week of the intervention. For the control group, the instrument was administered during the last week of the project.

Both measurements, for both the treatment and control groups, were administered by the school's own teachers, consistent figures within the students' learning process.

## 3.5 Theory of change:

The exposure of students to science and social classes using virtual reality enhances the level of **knowledge retention** compared to those students who received the same content through the traditional method (PowerPoint presentation).

Similarly, conducting classes using virtual and augmented reality methodologies enhances the **commitment and willingness to study** among the beneficiaries.

## 3.6 Data processing:

The data was collected through self-administered printed questionnaires (retention test and MSLQ questionnaire) by the students without any assistance, over a period of five weeks (September 21 - October 26, 2023). Additional requested information included: date, institution, gender, and age; all administered surveys were anonymous.

The questionnaire results were organized using SPSS version 25 software, manually inputting the data into two databases, one for the Retention variable and another for the Motivation variable. In both cases, an exploratory data analysis was conducted to identify outliers and missing information.

Among the statistical analyses performed, a one-way ANOVA was used for the Retention variable. This helped control variability between the experimental and control groups, allowing us to identify if the observed differences were attributable to the intervention and not external factors. This approach helps determine if the impact can be attributed to the VR intervention.

For the Motivation variable, the means between the treatment group, pretest and posttest, and the control group were compared. Multiple Student's t-tests were used, a robust and effective parametric test even with small samples, to verify if there were significant differences between the two groups. It's a useful significance test in situations with limited sample sizes.

# 4. RESULTS

## 4.1 Demographic Data

Sample of the treatment group consisted of 130 students, from 5 out of the 10 participating schools in the 'Incorporation of Virtual Reality as a Multisensory Tool to Enhance Educational Quality' program, with an equal gender distribution (see Table 1), and ages ranging from 14 to 19 years old (see Chart 1), all attending the ninth grade.

### Gender:

| Groups | Male | Female | Total |
|---|---|---|---|
| Control Group | 57.14% | 55.38% | 164 |
| Treatment Group | 42.86% | 44.62% | 125[24] |

**Table 1.** Percentage of male and female students per study groups.

### Age:

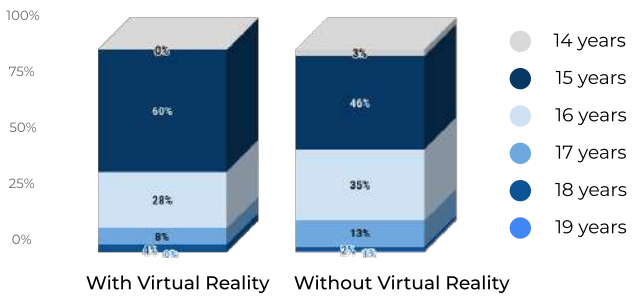


**Chart 1.** Age distribution per study group (treatment group=With Virtual Reality | control group=Without Virtual Reality)

For this study, the sample was obtained from 13 educational institutions located in different rural areas of El Salvador. The distribution per school is detailed in Tables 2 and 3.

### Schools:

| Treatment Group | | | |
|---|---|---|---|
| Schools | Pretest | Posttest | Population |
| Mano Amiga | 37 | 40 | 40 |
| Caliachura | 20 | 19 | 20 |
| Bedout | 25 | 25 | 25 |
| Fe y Alegría | 19 | 19 | 19 |
| Escobar Guillén | 25 | 26 | 26 |
| | | **Total** | 130 |

**Table 2.** Number of students per evaluation moment per school

| Control Group | |
|---|---|
| Schools | Population |
| La Reforma | 23 |
| Soldado Óscar Ortiz | 52 |
| San Juan de las Minas | 14 |
| Caserio Santa Rita | 14 |
| El Pedregal | 10 |
| Juan Pablo Rodríguez | 16 |
| Cosme Spessotto | 17 |
| Gesuina Melzi | 21 |
| **Total** | 167 |

**Table 3.** Number of students per school (control group)

[24] Five respondents did not report their gender.

## 4.2 Results per Variable

### Retention

The data collected in the retention tests show averages above the minimum passing score (>= 5 points) for both the treatment group and the control group (see Table 4). Similarly, there are similar averages between the control group and the treatment group (TG=6.73 vs CG=6.63) before the implementation of the intervention. As a result of the intervention, there is an increase in the average scores of both groups at the time of the second measurement (TG=6.7% vs CG=4.1%) (see Chart2).

| Group | Pretest | Posttest | Pretest | Posttest |
|---|---|---|---|---|
| Treatment | X=6.73 | X=7.18 | S=2.56 | S=2.36 |
| Control | X=6.63 | X=6.9 | S=2.63 | S=2.54 |

**Table 4.** Average retention levels and standard deviation (0-10) for the treatment group and control group (Pretest and Posttest)

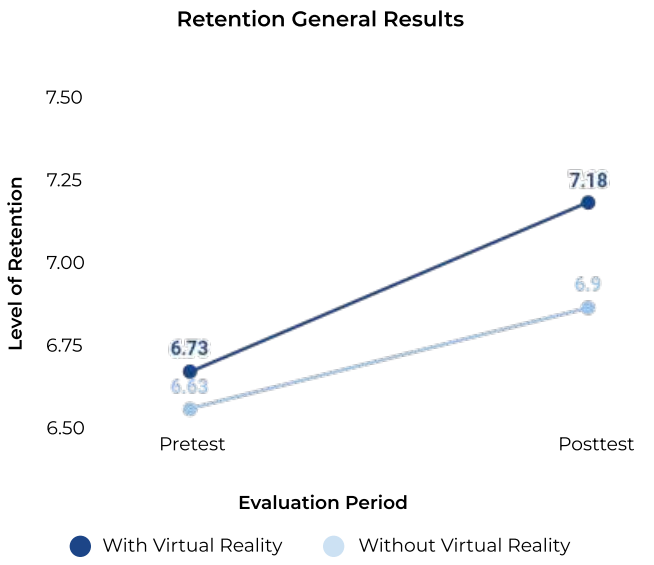


**Chart 2.** Average retention level (0-10) for the treatment and control groups (Pretest and Posttest)

### Retention by subject:

On the other hand, it was also relevant to consider the results regarding the retention variable when we isolate the subjects of Science and Social Studies.

Chart 3 details the average obtained by each group, treatment and control, in the pre and post-intervention measurements for Science classes

The treatment group achieves a higher score than the control group in both measurements

| | Treatment G. | | Control G. |
|---|---|---|---|
| Pretest | 6.31 | > | 6.03 |
| Posttest | 6.76 | > | 6.54 |

Similarly, **the increase in retention for the treatment group is 7.1%**

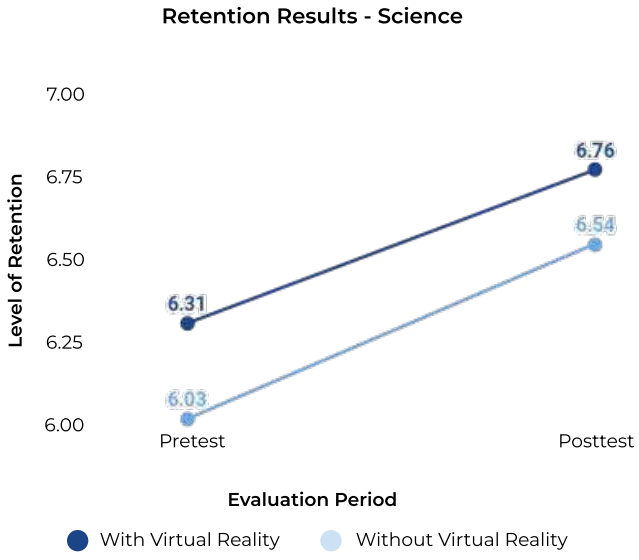


**Chart 3.** Average retention level (0-10) for the treatment and control groups (Pretest and Posttest) in Science subject

Chart 4 displays the results for the treatment and control groups regarding retention in the pretest and posttest for the Social Studies subject, indicating a tendency to increase retention levels for the treatment group (X=7.41 < X=7.87), while the control group tends to decrease its levels (X=7.55 > X=7.49). The percentage variation for the treatment group is 6.20%

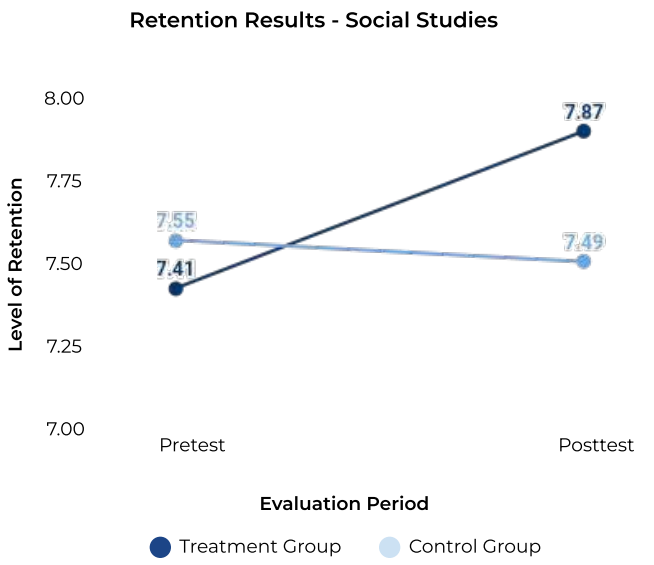


**Chart 4.** Average retention level (0-10) for the treatment and control groups (Pretest and Posttest) in Social Studies subject

## Retention by classes:

Here are the results of the treatment and control groups in each of the science classes (see table 5) and social studies classes (see table 6); in 10 out of the 16 classes, the treatment group had higher average retention scores than the control group.

| | Treatment Group | | Control Group | |
|---|---|---|---|---|
| Class | Pre | Post | Pre | Post |
| Class 1 | 8.00 | 9.00 | 8.89 | 8.44 |
| Class 2 | 8.74 | 8.85 | 8.41 | 8.88 |
| Class 3 | 7.64 | 7.25 | 7.65 | 7.94 |
| Class 4 | 8.64 | 8.43 | 8.36 | 8.07 |
| Class 5 | 6.04 | 7.23 | 6.45 | 6.47 |
| Class 6 | 3.13 | 4.37 | 2.36 | 3.72 |
| Class 7 | 4.54 | 5.51 | 4.70 | 5.27 |
| Class 8 | 6.48 | 6.21 | 5.03 | 7.03 |
| Class 9 | 3.52 | 4.69 | 4.29 | 4.40 |
| Class 10 | 4.67 | 4.44 | 3.88 | 5.09 |

**Table 5.** Average motivation level (0-5) for the treatment group (Pretest and Posttest) and control group

| | Treatment Group | | Control Group | |
|---|---|---|---|---|
| Class | Pre | Post | Pre | Post |
| Class 1 | 8.46 | 8.00 | 8.77 | 4.60 |
| Class 2 | 6.82 | 7.43 | 8.38 | 7.62 |
| Class 3 | 7.82 | 8.73 | 8.38 | 8.11 |
| Class 4 | 8.38 | 8.38 | 8.03 | 8.61 |
| Class 5 | 6.81 | 6.97 | 6.00 | 6.56 |
| Class 6 | 6.60 | 7.11 | 6.56 | 6.50 |

**Table 6.** Average retention for the treatment and control groups for Social Studies class

## Motivation

For the motivation variable, the treatment group had a 19% change between their pretest and posttest (X1=3.67 < X2=4.37), in the final outcome of the MSLQ questionnaire adaptation, using a 5-point Likert scale. The control group, which served as a contrast to compare the results, obtained an average motivation of X=3.56 with a standard deviation of S=0.8. The difference between the average of the treatment group (posttest) and the control group was 23%.

| Group | Pretest | Posttest | Pretest | Posttest |
|---|---|---|---|---|
| Treatment | X=3.67 | X=4.37 | S=0.60 | S=0.37 |
| Control | | X=3.56 | | S=0.87 |

**Table 7.** Average motivation levels and standard deviation (0-5) for the treatment group (Pretest and Posttest) and control group

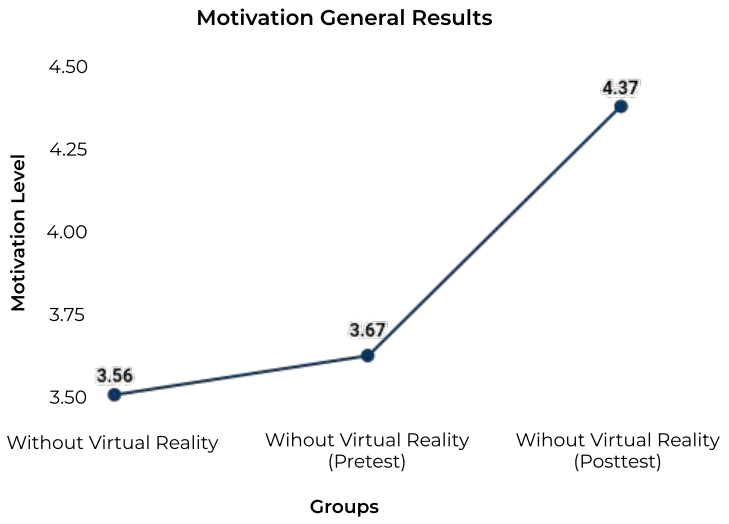


**Chart 5.** Average motivation level (0-5) for the treatment group (Pretest and Posttest) and control group

**Motivation Dimensions:**

When reviewing the results separately for each dimension of the motivation variable, it is evident that the highest levels are found in the behavioral dimension for the treatment group (X=4.6), and in the dimension of expectations for the control group (X=3.69), as shown in tables 9 and 8 respectively. For the control group, the dimensions of affectivity and behavior had an average of X=3.48 and X=3.52 respectively.

In the case of the treatment group, the dimension of expectations had an average of X=4.29, and the affectivity dimension had an average of X=4.22. When analyzing the percentage difference, it shows that the group with VR surpasses the group without VR by 16% in the dimension of expectations, 27% in affectivity, and 31% in behavioral aspects (see chart 6)

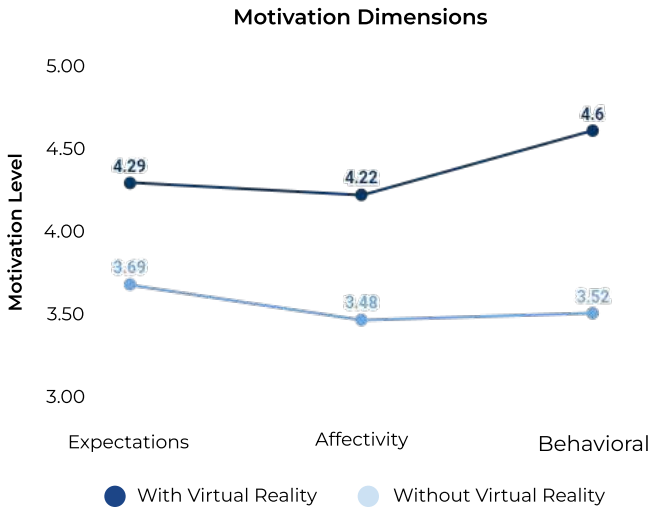


**Chart 6.** Comparison of results in the 3 dimensions of the Motivation variable (0-5 pts) for the treatment and control groups

| Control Group | | | |
|---|---|---|---|
| **Dimension** | **N** | **Average** | **Standard Deviation** |
| Expectations | 167 | 3.69 | 0.94 |
| Affectivity | 167 | 3.48 | 0.98 |
| Behavioral | 167 | 3.52 | 1.03 |

**Table 8.** Results in the 3 dimensions of the Motivation variable (0-5 pts) for the control group

| Treatment Group | | | |
|---|---|---|---|
| **Dimension** | **N** | **Average** | **Standard Deviation** |
| Expectations | 130 | 4.29 | 0.62 |
| Affectivity | 130 | 4.22 | 0.52 |
| Behavioral | 130 | 4.60 | 0.52 |

**Table 9.** Results in the 3 dimensions of the Motivation variable (0-5 pts) for the treatment group

# 5. RESULTS ANALYSIS

### 5.1 Improvement in retention with a tendency towards a wide gap:

Table 4 and chart 2 reveal that the average retention results (both in sciences and social studies) improved by 2.6% more in the group exposed to classes in virtual and augmented reality compared to the control group.

While larger gaps in the retention variable were expected between the group exposed to virtual reality classes, based on previous experiments conducted through the VR HUB in FUSALMO - Soyapango, the results are satisfactory, considering that the intervention lasted only four weeks, corresponding to the last month of the academic year.

Furthermore, the slope of the curves in Chart 2, comparing the retention variable results between the group exposed to virtual reality and the control group, indicates that with more implementation time, the differences will be greater, and the impact on knowledge retention will be better.

Likewise, in 62.66% of the classes taught, irrespective of the subject (see tables 8 and 9), the results for the retention variable were better in the group that received virtual reality classes than the group that wasn't exposed to VR. It's worth noting that by using a different intervention in the control group, such as classes through a PowerPoint presentation with a multimedia video projector, the scores obtained were higher than in a class with no participation. This positive effect in the non-VR group (positive control group[25]) is largely due to this intervention, as various studies affirm that the use of multimedia projectors significantly enhances academic performance in students[26].

[25] Shuttleworth, M. (2010). Grupo de control científico. Nov 21, 2023. Recuperado de: https://explorable.com/es/grupo-de-control-cientifico
[26] Lloccallasi Castro, R., & Pari Apaza, L. E. (2019). El uso del proyector multimedia contribuye a la mejora del rendimiento escolar del área de comunicación de los estudiantes del primer grado de secundaria del colegio Rafael Loayza Guevara del distrito de Mariano Melgar provincia-Arequipa, (2018) (Tesis de licenciatura). Universidad Nacional de San Agustín de Arequipa, Facultad de Ciencias de la Educación. Arequipa, Perú.


## 5.2 Greater and highly positive impact on retention in subjects associated with social studies:

Contrary to some previous assumptions before the experiment, when discriminating the retention variable by the subject taught, better results were obtained in Social studies classes, showing an increase of 6.2%. One possible explanation is the indirect effect that motivation has on knowledge retention results.

Social studies classes, particularly those within the study period, tend to be less interesting for students. Therefore, by incorporating the immersive and multisensory component offered by virtual reality, greater engagement is triggered, impacting attention and consequently knowledge retention[27].

## 5.3 Motivation and interest in attending classes show a 23% improvement in the VR-exposed group:

The results of the MSLQ questionnaire administered to students demonstrate that the group exposed to classes delivered through Virtual Reality achieves significantly higher levels of motivation than those who received traditional classes (see Chart 5). **Specifically, students in the treatment group reported a 19% improvement in the aggregated MSLQ score (without discriminating between the dimensions that constitute the variable).** The difference between the means of the treatment group and the control group is also statistically significant, indicating that the results are due to the intervention and not by chance (at a significance level of 5%; the Student's t-test provides a p-value of 0.000), with a 23% difference between both groups.

These results highlight the impact of Virtual Reality on student motivation. Exposure to this type of technology serves as an extra incentive for students, especially those from schools with limited resources and vulnerable areas, where incentives to study and attend classes are lower. Therefore, integrating classes with virtual and augmented reality increases the level of interest and desire to attend classes among students[28].

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[27] Calderón, S., Bournissen, J. M., & Tumino, M. C. (2019). La Realidad Virtual y su impacto en el aprendizaje. Universidad Adventista del Plata, Libertador San Martín, Entre Ríos, Argentina.

[28] Díaz, C., & Pinto, M. (2017). Educational Vulnerability: A study from the socio-critical paradigm. Universidad Nacional de La Pampa. Praxis Educativa (Arg), vol. 21, núm. 1, pp. 46-54, 2017. Recuperado de: https://doi.org/http://dx.doi.org/10.19137/praxiseducativa-2017-210105

### 5.4 Positive effect on all three dimensions of motivation, increasing their commitment to the educational process by 31%:

This result was the most significant and relevant, both statistically and in terms of the contribution of virtual reality to educational continuity indicators.

As described in the framework, motivation can be estimated in three dimensions: the first being expectations, understood as the student's beliefs and ideas associated with performance and the usefulness of studying. In this aspect, the treatment group obtained a significant 16% difference compared to the control group (see Chart 6). This allows us to indicate that exposure to VR establishes new and better frames of reference in which the student can value classes and the learning process as a useful aspect for their academic development.

On the other hand, there is the dimension of affectivity, which refers to the degree of rejection and emotion that classes can generate. In this regard, the treatment group surpasses the control group by 27%. This difference implies a change in perception, rejection, and fear that the student may have about the classes. As a ludic-educational tool, the class is emotionally approached from a more positive perspective and with a lower degree of concern. This consequence is also linked to the result obtained in the retention for Social Studies classes, where the subject receives a more attractive appreciation when VR is used.

Finally, the behavioral dimension refers to the student's willingness to act, execute actions, and make specific decisions aimed at attending classes.

Chart 6 shows a 31% difference in the behavioral dimension of the motivation variable between students who had virtual reality classes and those who received classes through PowerPoint presentations.

This result shows that the use of these immersive, multisensory, and experiential experiences has a positive impact on the commitment shown by the student towards their educational process. **This translates into concrete actions aimed at greater involvement in attending classes and studying, enhancing their academic performance, and reducing the risk of student dropout.**

# 6. CONCLUSIONS

### 6.1 Impact of Virtual Reality:

The positive impact of Virtual Reality (VR) on knowledge retention and engagement with studies is directly linked to its multisensory and immersive nature. Being an immersive experience, VR stimulates attention to details, providing students with the ability to assimilate and retain key information necessary for learning more effectively. The playful-educational blend of the tool grants students superior capacity to memorize, retain, and comprehend abstract and complex content[29]. This phenomenon is evident in the retention results in areas like social studies, where understanding complex definitions and terms is favored by immersion in virtual environments (see Chart 6 in the results analysis section). VR, by simplifying abstract and complex concepts, becomes an invaluable educational tool, making complex ideas more accessible and understandable for students[30]. The connection between the multisensory experience of VR and the improvement in knowledge retention reinforces its potential to positively transform education.

The above suggests that with increased intervention and measurement time, the gap in retention between the VR-exposed group and the non-VR group could be much wider, resulting in a more decisive impact. Extended exposure to this multisensory tool would imply a significant improvement in student success, harnessing the benefits of Virtual Reality in an extended manner. These results support the premise that **VR is not only an innovative tool but an essential educational resource for addressing challenges associated with academic performance and meaningful learning**.

[29] Krokos, E., Plaisant, C., & Varshney, A. (2018). Virtual memory palaces: immersion aids recall. Virtual Reality, 23(1), 1–15. https://doi.org/10.1007/s10055-018-0346-3

[30] Games for Change. (2020). XR for Social Impact: A Landscape Review. Retrieved from https://static1.squarespace.com/static/5a3c7a6e8a02c7c479b86829/t/5e3f7d7d7c5f8d4c8d7d7f5c/1581096846075/XR_for_Social_Impact_Landscape_Review.pdf

## 6.2 Prediction of success and school continuity

In the analysis of predicting academic success and school continuity, it has been observed that Virtual Reality displays its maximum impact on subjects that traditionally are less appealing to students. In this context, VR emerges as an innovative and sophisticated tool that transforms the way content is delivered, turning less stimulating subjects into engaging educational experiences. VR not only complements but revolutionizes teaching by providing a fresh and captivating approach, crucial factors in the development of academic motivation.

The results obtained reinforce the notion that VR can help create a positive image of the educational process, especially due to the value attributed by students to the classes, their perception of their own performance, and how engaging they find actively participating in their learning process. By providing a fresh and immersive approach, it stands as a significant catalyst for enhancing motivation and, consequently, improving academic performance[31].

Virtual Reality not only serves as a driver of academic success[32] but also plays a crucial role in promoting school continuity by offering extraordinary educational experiences that influence students' willingness to attend classes. The opportunity to engage in fun and stimulating learning experiences not only reduces levels of fear and rejection toward classes but also fosters active participation, contributing to the creation of a more inclusive educational environment less prone to student dropout.

Consequently, the findings suggest that the effective integration of VR in education not only benefits the academic sphere but also stands as a valuable strategy to address challenges associated with motivation, academic performance, and student retention.

The results of this research pave the way for broader implementations that allow for further evidence to support the initially proposed theory of change, confirmed by experimental findings: virtual and augmented reality are among the technologies with the most significant impact on educational quality and continuity indicators.

[31] Calderón, S., Bournissen, J. M., & Tumino, M. C. (2019). La Realidad Virtual y su impacto en el aprendizaje. Universidad Adventista del Plata, Libertador San Martín, Entre Ríos, Argentina.
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