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Integration of Immersive Technologies in Hybrid Classrooms: Evaluation of their Pedagogical Effectiveness and Student Participation

Remy Felipe Barreda Medina[1]

Abstract

This article analyzes the integration of immersive technologies—such as virtual reality (VR), augmented reality (AR), and 3D virtual environments—in hybrid classrooms, evaluating their impact on pedagogical effectiveness and student engagement. Using a mixed methodology, data was collected from university students who participated in hybrid educational experiences with immersive technologies for one semester. The results indicate significant improvements in student motivation, conceptual comprehension, and active participation. The conclusions suggest that immersive technologies not only enrich the teaching-learning process, but also transform the role of the student towards a more autonomous and collaborative participation.

Keywords: *Immersive Technologies, Hybrid Classrooms, Virtual Reality, Student Participation, Pedagogical Effectiveness.*

Introduction

The advancement of digital technology has profoundly transformed the way education is conceived and practiced at all levels. In particular, the emergence of hybrid classrooms has led to a flexible environment that combines face-to-face and virtual learning experiences. This model, accelerated by the COVID-19 pandemic, has generated deep reflection on the most effective pedagogical strategies to promote meaningful learning in technology-mediated contexts (Trust & Whalen, 2021). Within this evolution, **immersive technologies**, such as **virtual reality (VR), augmented reality (AR)** and **mixed reality (MR),** have gained prominence for their ability to create more engaging, interactive and sensory-enriched educational experiences.

These technologies make it possible to generate interactive three-dimensional environments that simulate real-world situations or project virtual objects into the student's physical space, thus facilitating experiential learning (Tang et al., 2021). Recent studies have shown that the incorporation of immersive technologies can improve conceptual understanding, foster curiosity, and facilitate knowledge retention by allowing a visual and experiential representation of content (Lindner et al., 2022). In addition, these environments have been observed to promote more active student engagement, by motivating them to explore, problem-solve, and collaborate in simulated scenarios in a more meaningful way than traditional methods (Shin, 2023).

However, the implementation of these technologies also poses important challenges, such as the need for specialized teacher training, pedagogical design adapted to immersive environments,

[1] Universidad del Pacífico Lima, Peru, Email: rf.barredam@alum.up.edu.pe, https://orcid.org/0009-0005-5320-6170.

and the evaluation of their true impact in terms of academic results and student participation. It is essential, therefore, to empirically evaluate their pedagogical effectiveness, as well as to analyze the changes they produce in the dynamics of the hybrid classroom, where students move between physical and virtual learning spaces (Radianti et al., 2020; Lee & Lim, 2022).

This study seeks to contribute to this emerging field of research by evaluating the impact of the integration of immersive technologies in hybrid university classrooms in Colombia, paying special attention to two fundamental dimensions: pedagogical effectiveness and student participation. The research is framed in the need to adapt educational processes to the demands of a digital generation, which expects not only connectivity, but also meaningful, immersive and interactive training experiences.

Theoretical Framework

1. Immersive Technologies in Education

Immersive technologies have emerged as disruptive tools in the field of education, transforming the way content is presented, perceived, and understood. These technologies mainly include **virtual reality (VR), augmented reality (AR),** and **mixed reality (MR),** each with different interaction characteristics, degree of immersion, and technical requirements (Radianti et al., 2020).

Type of technology	Definition	Immersion level	Educational examples
Virtual Reality (VR)	Complete digital simulation of an interactive three-dimensional environment.	High	Lab simulators, historical virtual tours.
Augmented Reality (AR)	Superimposition of digital objects on the physical environment.	Middle	Mobile apps to explore anatomy, art, or engineering.
Mixed Reality (MRI)	Interactive integration between real and virtual elements.	High	Collaborative projects in shared digital environments.

These technologies allow the development of multisensory experiences that stimulate visual, spatial, and procedural memory, promoting active learning and student autonomy (Lee & Lim, 2022). According to a recent meta-analysis, the use of VR in educational contexts significantly improves conceptual understanding compared to traditional methods (Lindner et al., 2022).

2. Hybrid Classrooms and Transformation of the Educational Space

The concept of a hybrid classroom refers to a teaching-learning environment that combines face-to-face and virtual elements, allowing students to participate from diverse locations and with varying degrees of synchronous and asynchronous interaction (Tang et al., 2021). This model is supported by digital platforms, constant connectivity and personal devices, creating a flexible ecosystem that transcends the physical barriers of the traditional classroom.

Feature	Face-to-face classroom	Hybrid class
Interaction	Predominantly face-to-face	Combination of face-to-face and virtual
Access to Resources	Limited to class time	Permanent, cross-platform
Role of the teacher	Process Center	Facilitator and Experience Designer

Student Engagement	Passive or moderate	Active, autonomous and collaborative

In this context, immersive technologies act as **facilitators of social and cognitive presence**, essential aspects to generate meaningful learning in technologically mediated environments (Trust & Whalen, 2021).

3. Student Participation: Dimensions and Factors

Student participation is a fundamental indicator of the student's commitment and motivation to the educational process. Fredricks et al. (2004) distinguish three key dimensions of participation:

- **Cognitive**: mental effort and self-regulation strategies.
- **Emotional**: feelings of belonging, interest and enthusiasm.
- **Behavioral**: attendance, class participation, homework fulfillment.

Recent studies show that immersive technologies enhance these dimensions by offering rich, interactive, and customizable contexts that stimulate critical thinking and collaboration (Shin, 2023; Parong & Mayer, 2020).

Participation dimension	Example of immersive stimulus
Cognitive	Simulation of complex scientific experiments in VR.
Emotional	Empathic exploration of historical or social environments.
Behavioral	Active interaction in gamified AR challenges.

In addition, pedagogical design must consider motivational aspects, such as **self-determination**, **immediate feedback**, and the possibility of personalizing the educational path, factors that have been shown to increase student involvement in these environments (Makransky & Petersen, 2021).

Methodology

1. Research Approach and Design

This study was developed under a **mixed approach** (quantitative-qualitative), with a **quasi-experimental pretest-posttest design** accompanied by an interpretative qualitative analysis. The mixed approach was chosen for its ability to offer a more complete view of the phenomenon investigated, integrating statistical data with participants' perceptions and experiences (Creswell & Plano Clark, 2018; Molina-Azorín, 2021).

Element	Description
Approach	Mixed (quantitative + qualitative)
Design Type	Quasi-experimental pretest-posttest with single group
Temporality	Longitudinal (1 academic semester)
Qualitative strategy	Case study and thematic analysis

This design allowed to evaluate the changes in student participation and academic performance before and after the implementation of immersive technologies in hybrid environments, as well as to explore the perceptions of students and teachers involved.

2. Participants

The sample was **intentional non-probabilistic**, composed of **120 university students** from programs in education, engineering and communication, and **9 teachers** from three Colombian institutions. All participated in hybrid academic activities enriched with immersive technologies during the 2023-2 semester.

Variable	Detail
Total students	120
Gender	58% female, 42% male
Middle Ages	21.6 years
Participating Institutions	University A, University B, University C
Previous experience with immersive technologies	73% no previous experience

The diversity of careers and levels made it possible to analyze how these technologies affect participation and academic performance in a transversal way.

3. Data Collection Techniques and Instruments

Different adapted and validated instruments were used to guarantee reliability and validity in the results, both in the quantitative and qualitative components:

Instrument	Guy	Objective	Fountain
Student Engagement Questionnaire	Likert scale (pre-post)	Measure changes in cognitive, emotional, and behavioral dimensions	Adapted from Fredricks et al. (2004)
Academic evaluation rubric	Quantitative	Measure performance before and after the intervention	Own elaboration
Semi-structured interviews	Qualitative	Exploring student and teacher perceptions	Structured guide validated by experts
Focus groups	Qualitative	Deepening collective experiences	Moderated by external researchers

The reliability of the questionnaire reached a **Cronbach α index = 0.88**, considered high according to psychometric reliability criteria (Field, 2020).

4. Procedure

1. **Diagnosis phase**: application of a pre-test of participation and collection of initial data on academic performance.

2. **Intervention phase**: implementation of immersive activities (simulations, virtual tours, interactive AR) in hybrid sessions for 12 weeks.

3. **Evaluation phase**: application of post-test, interviews and analysis of academic products generated in immersive environments.

The technologies used included platforms such as **CoSpaces Edu**, **Google Expeditions,** and **Merge EDU,** selected for their accessibility and compatibility with hybrid environments.

5. Data Analysis

- **Quantitative**: descriptive and inferential analysis using **SPSS v27 software**. Student's t-tests were applied for related samples with a significance level of 95% ($p < .05$).
- **Qualitative**: open coding and thematic analysis using **Atlas.ti**, following the model of Braun and Clarke (2019), with triangulation between researchers to guarantee interpretative validity.

Type of analysis	Technique	Software
Statistical	Pretest vs Posttest, Average Comparison	SPSS v27
Interpretative	Inductive thematic análisis	Atlas.ti 23

Results

The integration of immersive technologies in hybrid classrooms generated positive effects on student engagement and academic performance. The findings obtained from the analysis of the instruments applied during the pre- and post-intervention phases are reported below.

1. Quantitative Results: Student Participation

The three dimensions of student engagement (behavioral, emotional, and cognitive) were evaluated before and after the implementation of immersive technologies. A 5-point Likert scale was used (1 = very low, 5 = very high).

Dimension	Pretest (M ± DE)	Postest (M ± DE)	t (119)	P-Value
Behavioral	3.02 ± 0.55	3.84 ± 0.47	-11.32	<.001
Emotional	2.88 ± 0.64	3.71 ± 0.58	-10.96	<.001
Cognitive	3.14 ± 0.52	3.92 ± 0.50	-12.03	<.001

Table 1. Pretest–Posttest Comparison in Student Engagement (N = 120)

Source: Authors' elaboration based on field data (2023–2024).

The results indicate a statistically significant improvement ($p < .001$) in all dimensions of student participation. The cognitive dimension presented the greatest gain, coinciding with recent studies on the effect of immersion on deep information processing (Shin, 2023; Makransky & Petersen, 2021).

2. Quantitative Results: Academic Performance

Academic performance was assessed using standardized rubrics. Scores out of 100 were measured in equivalent activities carried out before and after the intervention.

Variable	Pre-intervention	Post-intervention	Increase (%)
Overall average	72.4	85.3	+17.9%
Students with ≥ 80 pts	34%	78%	+44%
Standard deviation	8.6	6.2	—

Table 2. Pre- And Post-Intervention Grade Point Average

The results show a significant improvement in the overall average, as well as a considerable

increase in the proportion of students who exceeded the 80-point threshold. This finding aligns with studies where virtual and augmented reality improve conceptual understanding and motivation (Lindner et al., 2022; Parong & Mayer, 2020).

3. Qualitative Results: Perceptions of Students and Teachers

From the thematic analysis of interviews and focus groups, three main categories were identified:

Category	Summary Description	Representative Quotes
Motivation and emotion	Students expressed greater enthusiasm and commitment.	"I felt like it wasn't just a class, it was an experience..."
Meaningful Learning	The simulations helped to understand abstract concepts.	"For the first time, I understood how that system works because I saw it in 3D."
Collaborative participation	Increased peer-to-peer interaction, including online.	"We organized ourselves better because we all wanted to explore together."

These perceptions coincide with what was reported by Lee and Lim (2022), who state that immersive technologies favor a participatory and dynamic climate in hybrid contexts.

4. Identified Difficulties

Although the results were positive, some challenges were identified:

- **Unequal access to devices and connectivity** (25% of students reported technical difficulties).
- **Teaching learning curve** in the use of immersive platforms.
- **Additional preparation time** to adapt content (expressed by 67% of teachers).

These challenges are consistent with the caveats raised by Radianti et al. (2020) about the sustainable implementation of VR/AR in university settings.

Conclusions

The incorporation of **immersive technologies** in hybrid classrooms represents a significant advance in pedagogical innovation and in the way students relate to knowledge. The findings of this study reveal that **virtual reality (VR), augmented reality (AR)** and other immersive platforms not only enrich educational content, but also transform the role of the student, the teacher and the learning environment itself.

1. Impact on Student Engagement

The results show a clear and significant improvement in the behavioral**, emotional,** and **cognitive** dimensions of student participation after the implementation of immersive technologies. This transformation aligns with recent research that highlights the power of immersion to generate greater involvement, concentration, and a sense of belonging (Shin, 2023; Lindner et al., 2022).

The possibility of actively interacting with visual and three-dimensional content motivated students to take on a more autonomous, collaborative, and reflective role. Accordingly, studies

by Makransky and Petersen (2021) have shown that well-designed immersive environments stimulate self-regulation, curiosity, and active exploration of knowledge.

2. Pedagogical Effectiveness and Performance Improvement

The improvement in academic performance by 17.9% validates the hypothesis that immersive environments can generate **more meaningful learning**, by allowing students to **"experience"** concepts instead of limiting them to theoretical abstraction. This finding is supported by Parong and Mayer (2020), who argue that VR learning facilitates deep and multisensory coding of content.

In addition, the increased understanding of complex concepts in disciplines such as science, communication, and technology suggests that these tools are especially useful in subjects that require **dynamic visualization**, **process simulation**, or **contextualized analysis**.

3. Implications for Teaching Practice

Although the benefits of immersive technologies are evident, their implementation requires a change in **pedagogical planning**, as well as in the **digital skills of teachers**. Teachers are no longer positioned as transmitters of content, but as **facilitators of meaningful learning experiences**, which implies taking on new roles in design, mediation, and evaluation (Lee & Lim, 2022).

Training teachers in the critical and didactic use of these technologies becomes an institutional priority, since the success of their integration into curricular plans will depend on their appropriation (Radianti et al., 2020).

4. Limitations and Future Recommendations

This study was limited to the use of commercially available technologies and to a specific sample of university students in Colombia. It is recommended to extend the research to other educational levels (secondary, technical training), as well as to institutions with different technological infrastructure.

Likewise, it will be essential to explore new metrics of pedagogical impact in immersive environments, including aspects such as **critical thinking**, **creativity**, **intercultural interaction**, or **complex problem solving**, key dimensions for education in the twenty-first century (Tang et al., 2021).

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