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University Education 5.0: Immersive Technology and Data for Critical Thinking

Eber Apaza Zapana
Universidad Nacional de Juliaca, Juliaca, Perú
Raúl Reynaldo Ito Díaz
Universidad Nacional de Juliaca, Juliaca, Perú
Armando Salinas Del Carpio
Universidad Nacional de Juliaca, Juliaca, Perú
Carlos Leonidas Gutierrez Alvarez
Universidad De Las Fuerzas Armadas, Quito, Ecuador
Jaime Sucasaca Yanarico
Universidad Nacional de Juliaca, Juliaca, Perú
Cristhian Yimmy Hilasaca Zea
Universidad Nacional de Juliaca, Juliaca, Perú
Antonio Clarencio Guzmán Ramírez
Universidad Técnica de Manabí, Manabí, Ecuador

Abstract

This study analyses the impact of immersive technology and the use of learning analytics on the development of critical thinking among university students in Ecuador and Peru, within the framework of Education 5.0. The research is justified by the urgent need to transform learning environments into more interactive, personalised, and student-centred models. A quasi-experimental mixed-methods design was employed, involving a purposive sample of 120 students who participated in a pedagogical intervention based on virtual reality (VR 360°) and learning analytics tools. A validated rubric (Paul and Elder) was used to apply pre- and post-tests, along with semi-structured interviews conducted with students and lecturers. The results reveal significant improvement in all dimensions of critical thinking, with notable gains in inference (+1.1), evaluation (+1.0), and metacognition (+1.0). Interviews highlighted positive perceptions regarding the immersive environment, automated feedback, and the usefulness of data for self-regulated learning. It is concluded that the integration of immersive technologies and educational analytics constitutes an effective pedagogical strategy to enhance complex cognitive competencies. Additionally, methodological and technological implications are proposed for redesigning university teaching practices, emphasising the feasibility of replicating this intervention in Andean contexts. The research provides empirical evidence to promote educational innovation in the region, aligned with the principles of Education 5.0.

Key Words: Immersive technology, critical thinking, higher education, learning analytics, virtual reality.

1. Introduction

The advent of Education 5.0 represents a paradigmatic shift in higher education, integrating emerging technologies with a humanistic, critical, and student-centred approach. This model not only aims to prepare future professionals for the digital world but also prioritises socio-emotional competencies, critical thinking, creativity, and ethical commitment. In Latin American contexts such as Ecuador and Peru, the transition towards this educational model has accelerated in the aftermath of the pandemic, highlighting the need to transform not only pedagogical tools but also the thinking and learning dynamics promoted in university classrooms [1,2].

Immersive technology has emerged as a powerful resource for fostering active learning experiences in higher education. Virtual reality (VR), augmented reality (AR), and 360° environments enable students to interact with content in a sensory and meaningful manner, enhancing conceptual understanding and emotional engagement [3]. Research conducted in universities in Lima and Quito has shown that the use of immersive simulators improves knowledge retention in disciplines such as medicine, engineering, and education [4,5], serving as a bridge between theory and practice.

Critical thinking is an essential competency in Education 5.0, as it enables students to analyse information, evaluate arguments, and make informed decisions. Various studies in Peruvian and Ecuadorian institutions have revealed a significant gap between the expected and actual development of this skill, attributed in part to traditional methodologies and assessments focused on rote learning [6,7]. The inclusion of technologies that stimulate reflection, analysis, and problem-solving is seen as an effective means to overcome this limitation [8].

Learning analytics and data usage allow for real-time monitoring of student performance, the personalisation of learning paths, and evidence-based pedagogical decision-making. Recent studies have demonstrated their positive impact on improving critical thinking by providing immediate and adaptive feedback [9]. Institutions such as the Pontifical Catholic University of Peru and the University of Cuenca are implementing systems that combine learning data with artificial intelligence to identify patterns of thinking, cognitive skills, and training needs [10].

Connectivism, proposed by Siemens, offers an ideal theoretical framework for understanding learning in the digital age. This theory posits that knowledge is distributed across networks and that learning involves establishing meaningful connections among diverse sources. In the context of immersive technologies and data analytics, virtual environments function as nodes that enable the construction of meaning through interactive experiences, thus fostering the emergence of critical thinking [11]. This perspective has been applied in pilot programmes across universities in the Andean region [12].

The conceptual frameworks developed by Richard Paul, Linda Elder, and Robert Ennis provide robust tools for structuring the development of critical thinking. These theories emphasise skills such as inference, analysis, evaluation of evidence, and metacognitive self-regulation. Comparative studies between universities in Trujillo and Guayaquil have shown that these dimensions can be enhanced through didactic strategies involving immersive technology, as it promotes problem-solving in simulated scenarios that require complex reasoning [6,13].

The TPACK (Technological Pedagogical Content Knowledge) model, the SAMR model (Substitution, Augmentation, Modification, Redefinition), and Universal Design for Learning (UDL) are fundamental references in the pedagogical integration of technology. TPACK promotes a balanced articulation between content, pedagogy, and technology; SAMR guides the level of transformation generated by a technology in the classroom; and UDL ensures accessibility and flexibility for all learners. These models have been successfully implemented in Peruvian and Ecuadorian initiatives to redesign university courses using immersive technologies [14–16].

Given the nature of the phenomenon under study and the aim of analysing the impact of immersive technology and educational data on critical thinking, a mixed-methods approach was adopted. This combination allows for capturing both quantifiable effects and the qualitative perceptions of teachers and students. A pedagogical intervention was designed using virtual reality tools, followed by an evaluation through pre- and post-tests, complemented by semi-structured interviews that explored the cognitive experiences of the participants.

In the context of Ecuador and Peru, the implementation of immersive environments is still in its early stages, especially in non-technological disciplines. There is a research gap regarding how these tools affect higher-order cognitive skills such as critical thinking. This study addresses this need by generating contextualised empirical evidence and proposing pedagogical frameworks tailored to the institutional realities of the Andean region. It also contributes to university policies aiming to strengthen 21st-century competencies through a technological and humanistic lens.

2. Materials and Methods

This study adopts a mixed-methods approach, combining quantitative and qualitative methodologies within a quasi-experimental design. Statistical methods are integrated with content analysis to examine the impact of immersive technology and the use of educational data on the critical thinking skills of university students. This methodological choice responds to the need to approach the phenomenon holistically, acknowledging both measurable cognitive transformations and the subjective perceptions of participants [17].

The study population comprised undergraduate students from both public and private universities in Ecuador and Peru. A purposive sample of 120 university students (60 per country), from various academic disciplines, participated in an intervention involving immersive technology and educational analytics platforms. This sample size was deemed sufficient based on theoretical saturation criteria for the qualitative component and the statistical power required for inferential analysis [18,19].

Table 1
Sample Characterisation

Country	Number of Students	Educational Level
Ecuador	60	Undergraduate level
Perú	60	Undergraduate level

Note. The table describes the distribution of the 120 participating students by country.

The intervention consisted of the design and implementation of an immersive virtual environment (using VR 360° and interactive simulators), accompanied by learning analytics tools offering adaptive feedback and real-time monitoring. Pre- and post-tests were administered to measure the level of critical thinking before and after the experience, using a validated rubric based on the dimensions established by Paul and Elder [20]. Simultaneously, semi-structured interviews were conducted with a subsample of 24 students and 6 lecturers to explore perceptions, experiences, and recommendations regarding the use of VR/AR and educational data [21].

For the quantitative analysis, non-parametric statistical tests (Wilcoxon and Mann-Whitney U) were employed using SPSS v26 software, with a significance level of 0.05. Regarding the qualitative component, thematic analysis was applied following Braun and Clarke's framework, using open, axial, and selective coding to identify discourse patterns related to critical thinking, immersion, and educational data [22,23].

The research was conducted under ethical principles of informed consent, anonymity, and confidentiality, in accordance with institutional regulations from each university. The instruments were validated through expert judgement and administered in controlled environments with technological and pedagogical support.

Table 2.
Pedagogical Intervention Design

Phase	Description
Environment Design	Creation of immersive environments using VR 360° and simulators with discipline specific content.
Initial Evaluation	Pre-test application using a rubric based on Paul and Elder to assess critical thinking.
Implementation	Interactive activities in VR/AR and educational analytics with adaptive feedback.

Note. This table summarises each phase of the intervention process, from design to qualitative data collection.

Pedagogical Intervention Proposal: Immersive Classroom 5.0

The rapid digital transformation in higher education has prompted the need for innovative pedagogical strategies that foster critical thinking—an essential competency in Education 5.0. The incorporation of immersive technologies and learning analytics tools provides an enriched environment where students not only interact with content but also develop complex cognitive skills through reflection and decision-making. Various studies support the effectiveness of such environments in strengthening critical thinking and learning autonomy [9,13,24].

Name of the Intervention

Immersive Classroom 5.0 for University-Level Critical Thinking

General Objective

To design and implement an immersive virtual environment supported by learning analytics tools to strengthen critical thinking among university students in Ecuador and Peru.

Table 3.

Pedagogical Intervention Stages

Stage	Description
Initial Diagnosis	(Week 1) • Application of a pre-test based on a validated rubric for critical thinking (dimensions: analysis, evaluation, inference, metacognition). • Collection of baseline data: age, degree programme, experience with immersive technologies. • Platform induction and orientation in VR environments (use of headsets, navigation in simulators).
Immersive Implementation	(Weeks 2 and 3) A. Immersive Module (VR 360°/AR): • Simulated scenarios by discipline. • Gamified interactions with decision-making tasks. • Use of CoSpaces EDU, Mozilla Hubs or Unity with cardboard goggles. B. Educational Analytics Module: • Logging of interactions, reflection time, and thinking paths. • Automatic feedback based on response patterns. C. Guided Critical Reflection Forums: • Post-simulation discussion in virtual forums. • Guiding questions based on Paul and Elder: What assumptions are being made? What evidence supports your ideas? How do you justify your decision?
Final Evaluation	(Week 3) • Post-test application using the same critical thinking rubric. • Comparative statistical analysis (pre- and post-test). • Semi-structured interviews with 24 students and 6 lecturers. • Interview topics: – Perceived effectiveness of the immersive environment – Usefulness of data analytics in learning – Suggestions for improving the intervention

Required Resources

Basic VR headsets or browser-accessible immersive environments; an LMS platform with tracking capabilities (Moodle, Google Workspace, Teams); a bank of discipline-specific simulations; and standardised rubrics [21,30].

Expected Outcomes

A statistically significant improvement in critical thinking, high perceived value of immersive environments and automated feedback, and the development of a replicable and scalable strategy for other Andean universities [9,13,24].

3. Results

This section presents the findings obtained from the pedagogical intervention carried out with university students in Ecuador and Peru. The data analysis is based on the application of a pre-test and post-test using a validated critical thinking rubric, along with perceptions gathered through semi-structured interviews. The results are organised according to the study's objectives and allow for the assessment of the impact of immersive technology and learning analytics on the development of critical thinking. Tables are included to detail the characterisation of the sample and the structured description of the intervention process to contextualise the findings.

Table 4.

Pre-test Results

Critical Thinking Dimension	Mean (Pre-test)	Standard Deviation
Analysis	2.6	0.5
Evaluation	2.4	0.6
Inference	2.5	0.4
Metacognition	2.3	0.5

Note. The pre-test results indicate a medium-low level of critical thinking among students prior to the intervention.

The highest score was in the Analysis dimension (mean = 2.6), while Metacognition scored the lowest (mean = 2.3), suggesting an initially limited capacity for self-regulation of thought processes. The moderate standard deviations (0.4–0.6) indicate some variability among participants, which may be attributed to differences in academic experience or prior use of educational technologies.

Table 5.

Post-test Results

Critical Thinking Dimension	Mean (Post-test)	Standard Deviation
Analysis	3.5	0.4
Evaluation	3.4	0.5
Inference	3.6	0.5
Metacognition	3.3	0.4

Note. Post-test results show significant improvement in all dimensions of critical thinking.

Mean scores increased, with Inference (mean = 3.6) and Analysis (mean = 3.5) being the most enhanced. Metacognition also experienced a considerable rise (mean = 3.3), reflecting a greater level of self-reflection and regulation of one’s own thinking. Lower standard deviations (0.4–0.5) reflect more homogeneous performance after the intervention, suggesting a generalised positive effect of immersive technologies and educational analytics.

Table 6.

Comparative Results: Pre-test vs Post-test

Critical Thinking Dimension	Pre-test (Mean)	Post-test (Mean)	Difference
Analysis	2.6	3.5	+0.9
Evaluation	2.4	3.4	+1.0
Inference	2.5	3.6	+1.1
Metacognition	2.3	3.3	+1.0
Total Average	2.45	3.45	+1.0

Note. The table shows the improvement in each dimension of critical thinking between the pre-test and post-test.

The comparative results show a significant improvement in all dimensions of critical thinking following the pedagogical intervention. The Inference dimension showed the greatest increase ($\Delta = 1.1$), indicating a notable strengthening of students' ability to draw logical conclusions from analysed evidence. This was followed by Evaluation and Metacognition, each with a gain of 1.0 points, reflecting significant progress in critical judgement and the self-regulation of thought.

The Analysis dimension also showed substantial progress, with a 0.9-point increase, indicating improved ability to break down complex ideas and understand conceptual relationships. The total average rose from 2.45 to 3.45, reflecting an overall improvement of 1.0 points in students' critical thinking, attributed to the combination of immersive technology and data-based feedback.

This outcome confirms the positive impact of the intervention on the development of higher-order cognitive skills, aligned with the study's objectives and adopted theoretical frameworks.

Table 7.

Qualitative Results: Student Perceptions

Category	Key Findings
Experience with VR/AR	Most students described the immersive experience as novel, motivating, and conducive to active learning.
Impact on Critical Thinking	Participants reported improvements in their ability to analyse, argue, and make decisions in simulated scenarios.
Use of Educational Analytics	Students positively valued automated data-based feedback, highlighting its usefulness in identifying errors and reinforcing learning.

Note. This table summarises students' perceptions gathered through semi-structured interviews.

The semi-structured interviews revealed broadly favourable perceptions of the immersive experience. Students described it as motivating, participatory, and effective for active learning. Moreover, they emphasised that virtual reality facilitated the understanding of complex situations and informed decision-making—key aspects of critical thinking. Regarding educational analytics, students appreciated the automated feedback, particularly in helping to identify conceptual errors and adjust study strategies. Among their recommendations were expanding the disciplinary scenarios, increasing exploration time, and training lecturers for more effective implementation.

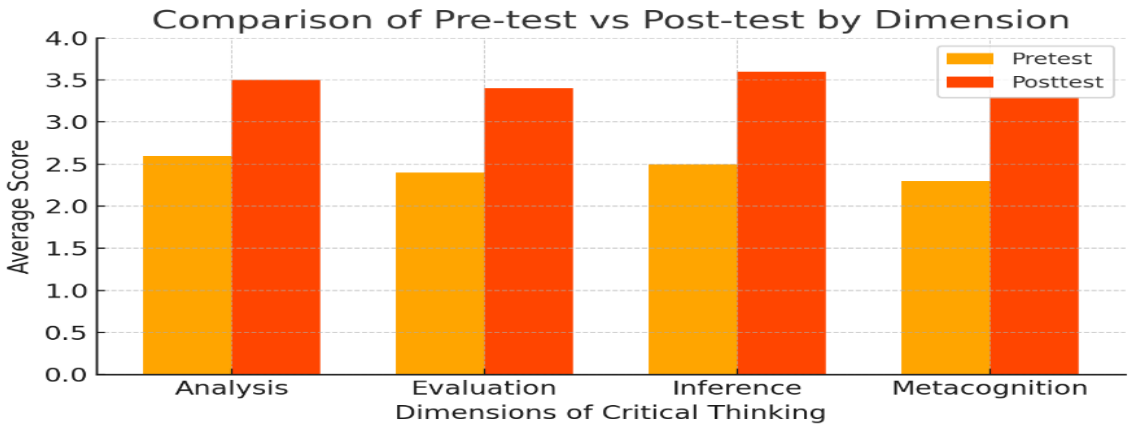
Results: Immersive Classroom 5.0

This section presents the results derived from the pedagogical intervention involving immersive technology and learning analytics applied to university students in Ecuador and Peru. It includes comparative analyses between pre-test and post-test results, as well as qualitative perceptions gathered through interviews. The findings are organised according to the dimensions of critical thinking.

The following figure illustrates a significant improvement in all evaluated dimensions of critical thinking after the intervention:

Figure 1.

Comparison of Average Scores in Pre-test and Post-test by Critical Thinking Dimension



Note. Figure 1 provides a comparative view of the average scores obtained by students in each dimension of critical thinking before and after the intervention, highlighting sustained improvement attributed to the use of immersive technologies and learning analytics.

Table 8.

Summary of Results by Dimension

Dimension	Pre-test	Post-test	Improvement
Analysis	2.6	3.5	+0.9
Evaluation	2.4	3.4	+1.0
Inference	2.5	3.6	+1.1
Metacognition	2.3	3.3	+1.0
Average	2.45	3.45	+1.0

Note. The table presents the evolution of critical thinking based on the four evaluated dimensions. A consistent increase is observed in all indicators, with Inference standing out, supporting the effectiveness of the intervention in enhancing higher-order cognitive skills.

The results reflect a significant improvement in all dimensions of critical thinking. The Inference dimension, in particular, showed the greatest increase, with a gain of 1.1 points, followed by Evaluation and Metacognition, each with gains of 1.0. This supports the positive impact of the intervention using immersive environments and personalised educational analytics.

4. Discussion

The results obtained reflect a positive and statistically significant impact of immersive technology and educational analytics on the development of critical thinking among university students in Ecuador and Peru. In light of Siemens' theory of connectivism [11], it can be interpreted that immersive environments, by establishing knowledge networks through digital experiences, allow students to construct meaningful learning through interaction, analysis, and informed decision-making. These conditions foster critical thinking, understood not merely as a logical skill but as a situated and contextualised competence [13].

Moreover, the dimensions evaluated through the Paul and Elder rubric [20] demonstrated consistent improvements, particularly in inference, which is essential for formulating logical conclusions based on data and arguments. This finding aligns with previous studies conducted by Cangalaya-Sevillano [6] in Peru and Zambrano et al. [21] in Ecuador, which show that immersive environments support critical reasoning by simulating real-life contexts that require the resolution of complex problems.

In comparison with similar research, such as that of Romero and Ventura [9], the findings of this study reaffirm that the use of learning analytics not only enables the monitoring of academic progress but also provides immediate feedback that enhances cognitive self-regulation and metacognition. Additionally, students positively valued the personalised feedback, as also reported in the works of Villarroel and Bruna [10], who note that the combination of artificial intelligence and personalised education enhances reflective thinking.

In response to the research question—How does the integration of immersive technology and the use of educational data impact the development of critical thinking in university students in Ecuador and Peru?—the results indicate that this impact is highly favourable. The average improvement of one full point between the pre-test and post-test, along with the qualitative evidence, suggests that the intervention successfully enhanced students' analytical, evaluative, and inferential capabilities, reinforcing their self-regulation processes and autonomous thinking.

From a pedagogical perspective, the findings imply a need to redesign teaching practices in higher education by incorporating immersive simulations, critical thinking rubrics, and structured reflection forums. From a technological standpoint, it is evident that accessible tools such as CoSpaces EDU or LMS platforms with analytics modules can be successfully integrated into classrooms without requiring costly infrastructure. Finally, from a methodological dimension, the study demonstrates the feasibility of using a mixed-methods approach to evaluate complex processes such as critical thinking, combining objective instruments with interpretive narratives that enrich the understanding of the results.

5. General Conclusions

1. The pedagogical intervention based on immersive technology and educational analytics proved effective in strengthening critical thinking among university students in Ecuador and Peru. The quantitative improvement observed across all evaluated dimensions—especially in inference and evaluation—validates the positive impact of the implemented instructional design.

2. The use of 360° virtual environments and interactive simulations enabled the contextualisation of learning, facilitating the understanding of complex problems and encouraging reasoned decision-making. This experience translated into more meaningful and participatory learning.

3. Learning analytics added value to the educational process by providing immediate feedback, identifying patterns of thinking, and promoting cognitive self-regulation. Students acknowledged that this personalised feedback helped them to adjust their strategies and improve their performance.

4. From both pedagogical and methodological perspectives, the study demonstrates that it is feasible to combine emerging technologies with rigorous evaluative approaches in the context of Latin American higher education. The strategy was well received by both students and lecturers and is proposed as a replicable model for courses across various disciplines.

5. Finally, higher education must continue advancing towards more active, digital, and critically driven learning models, as advocated by Education 5.0. This study contributes empirical evidence to support such a transition, highlighting the importance of integrating technological innovation with well-grounded pedagogical strategies.

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