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Augmented Reality as a Tool for Cultural Learning in Educational Institutions in Peru

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Abstract. Within the context of basic education, one of the persistent challenges is the low academic performance and limited student engagement in the Social Studies course. This issue is further exacerbated by the lack of innovative pedagogical tools that promote active learning. In response to this situation, the objective of this study was to evaluate the impact of Augmented Reality (AR), implemented through the SCRUM methodology, on four key indicators: academic performance, number of participations, number of assignments submitted, and learning time. The research employed a true experimental design with a control group and an experimental group, both composed of students from the Angelita Bohórquez Moreno Educational Institution. Normality tests and inferential statistical analysis using the Student's t-test were applied. The results showed statistically significant differences in favor of the experimental group across all four evaluated indicators. An increase in academic achievement, student participation, and assignment submission was observed, along with a reduction in the time required for learning. It is concluded that the use of AR, integrated with SCRUM, constitutes an effective strategy for optimizing teaching-learning processes in school contexts. This technological and methodological approach offers transformative potential for Peruvian basic education.

Keywords. Augmented reality, Vuforia, unity, learning, scrum, cultures.

1 Introduction

The outbreak of the pandemic and the resulting lockdown measures forced educational institutions to modernize their processes and incorporate digital platforms. Both teachers and students faced the challenge of adapting to these new virtual teaching-learning environments. The limited familiarity with digital technologies became a significant obstacle to educational continuity, as did the lack of appropriate resources for teaching cultural content. This scenario led to a gradual decline in student interest in learning about other cultures.

Over time, the repeated use of conventional pedagogical methods has prevented a meaningful improvement in academic performance, while the time required to teach has increased due to the absence of innovative tools that enable educators to effectively capture students' attention and interest. Montenegro and Fernández [1] highlighted the need to expand the field of learning related to Augmented Reality (AR) and teacher training in educational settings. Their proposal also seeks a deeper understanding of the knowledge structure in the scientific domain of AR applied to education. In the same vein, Añapa and Ruah [2] emphasized the implementation of this technology as an effective strategy to promote in students those skills that are difficult to develop in traditional educational settings, such as problem-solving, collaborative work, creativity, and critical thinking.

Likewise, Valero and Berns [3] showed that the use of digital tools in language instruction has yielded results aligned with recent digital trends in education, facilitating the progressive incorporation of technological resources that enhance the acquisition of linguistic competencies. On the other hand, Aquino et al. [4] pointed out that, although technological resources are widely available for various purposes, their educational potential has been underestimated, which represents a critical opportunity for their effective integration into learning processes.

Similarly, Concepción et al. [5] assessed student acceptance of interactive educational environments through a mobile application based on Augmented Reality aimed at teaching natural sciences to children with Autism uuSpectrum Disorder (ASD). In turn, Alonso et al. [6] noted that the introduction of emerging technologies into the classroom has historically posed a challenge for both teachers and students. However, the ongoing advancement of the digital era is becoming overwhelming, making their integration into educational settings inevitable.

According to the authors, the real challenge lies in equitable access to these technologies for educational stakeholders, which in some cases constitutes a structural difficulty. Likewise, Díaz et al. [7] highlighted the transformative potential of mobile Augmented Reality in education, especially in the field of health.

This technology, which integrates real and computer-generated virtual elements, allows health science students to immerse themselves in simulated clinical environments. Using mobile devices such as smartphones and tablets, students can interact with clinical scenarios, visualize 3D anatomical structures, and practice medical procedures in safe and controlled environments. Lancheros and Vesga [8] conducted a systematic review examining the use of digital technologies in secondary education, with emphasis on the application of Augmented Reality, Virtual Reality, and Artificial Intelligence during the 2019–2023 period.

Furthermore, Ruiz [9] analyzed the impact and application of Augmented Reality (AR) as a pedagogical tool in the context of Primary Education. Subsequently, Cárdenas et al. [10] proposed the development of mobile applications based on AR to support student learning in the Information Technology program at the Technological University of Nayarit. As demonstrated in previous studies, this technology has begun to be implemented in various state research centers promoted by the National Council for Humanities, Science, and Technology. Complementarily, Pujos et al. [11] highlighted the development of a didactic guide aimed at facilitating the download, installation, and use of tools such as SketchUp and Aumentaty, to reinforce learning of content related to geometry, calculus, and measurement of geometric figures and bodies. Castro-Espichan et al. [12] argued that AR has positioned itself as the most widely used technology by the research community, given the favorable results obtained in the analysis of 92 empirical studies.

Likewise, Viveros and Terán [13] indicated that this technology has the potential to enhance motivation and a sense of responsibility among students. Consequently, they recommended future longitudinal and comparative research focused on analyzing emerging AR applications, particularly in chemistry education, aiming to enrich disciplinary knowledge. Finally, Minaya-Isique et al. [14] identified strong collaboration among authors in the field of virtual reality, reflected in co-authorship networks that underscore the relevance of interdisciplinary partnerships in advancing and consolidating this research area.

The forced virtualization of education exposed limitations in teaching cultural content, worsened by teachers' low digital literacy and a lack of engaging tools. Although several studies report benefits of Augmented Reality (AR) in areas such as mathematics, health, and science, there remains a notable gap in its use for intercultural learning. Most research focuses on disciplinary content and lacks longitudinal approaches or specific proposals that address cultural diversity and inclusion. In response, this study proposes an AR-based educational solution aimed at strengthening cultural learning, overcoming current limitations, and promoting more inclusive and contextualized practices.

This paper is structured as follows: Section 2 addresses the fundamentals of Augmented Reality and its key components. Section 3 describes the methodology used in the development of this research. Section 4 details the AR implementation process using the agile SCRUM framework. Section 5 presents the results obtained from this implementation. Finally, Section 6 outlines the study's conclusions and directions for future research.

2 Theoretical Background

2.1 Augmented Reality

An initial approach to Augmented Reality is presented by Ortí [15], who argues that both AR and Virtual Reality contribute to improved academic performance in university-level mathematics by offering inclusive and personalized learning experiences. However, the author warns about the need to overcome technical challenges and enhance teacher training to achieve effective implementation.

In the study conducted by Hurtado et al. [16], the impact of using 2D digital storytelling versus Augmented Reality was compared among

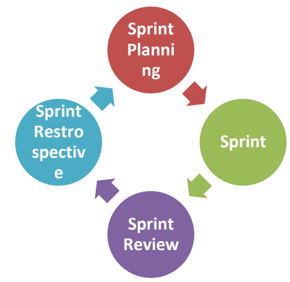

Fig. 1. Stages of the SCRUM methodology

preschool students. They concluded that both modalities foster creativity, although the effects were more significant with the use of AR.

Similarly, Sensu and Erogan [17] carried out a review on the state of pathology teaching in medical schools, highlighting the growth of digital learning and Augmented Reality after the COVID-19 pandemic, as well as the increasing role that artificial intelligence will play in this educational domain.

2.2 Learning

Kumar et al. [18] conducted an analysis of gamification in higher education, emphasizing its integration with technologies such as Virtual Reality and Augmented Reality. They identified emerging trends such as E-learning and serious games, while also underscoring the need to expand research in this area.

Likewise, Putra et al. [19] examined the impact of online learning and immersive technologies in primary education during the COVID-19 pandemic in Indonesia, revealing a 24% increase in students' understanding of scientific content.

Similarly, Weijia and Hao [20] reviewed the use of Augmented Reality in physical education instruction, highlighting its benefits in terms of interactive and ubiquitous learning, as well as the advancements, challenges, and future directions in its implementation and assessment.

3 Research Method

This section provides a detailed explanation of the methodology adopted in this study, aiming to present the applied approach with clarity and rigor,

Table 1. Operationalization of the Dependent Variable

Indicator	Índex	Unit of Measure-ment	Unit of Observation
Academic Performance	[0-20]	points	Direct Observation
Number of Participations	[0 - 30]	participations	Direct Observation
Number of Submitted Assignments	[0 - 30]	submissions	Direct Observation
Learning Time	[0 - 190]	minutes	Direct Observation

thereby ensuring the validity and reliability of the results obtained.

3.1 SCRUM Methodology

SCRUM is an agile framework aimed at managing and developing complex projects, with particular application in the field of software development. This approach is based on principles such as effective collaboration, adaptability to change, and continuous process improvement (see Figure 1).

A concise description of the fundamental stages that comprise the SCRUM methodology is provided below:

Sprint Planning: This stage begins with a meeting in which the Product Owner presents the prioritized items from the product backlog to the team, establishing which ones will be addressed in the upcoming Sprint.

Sprint: This refers to the iterative and continuous work period during which the development team implements the selected tasks. During this phase, daily meetings (daily SCRUM) are held to coordinate progress, identify obstacles, and adjust the work.

Sprint Review: At the end of the Sprint, a review session is conducted where the team presents the developed product increment. During this session, both the Product Owner and stakeholders provide feedback and suggestions to guide future improvements.

Sprint Retrospective: Finally, the team critically reflects on the process carried out. Achievements and challenges are identified, and concrete actions are proposed to optimize performance.

3.2 Applied Research Method

This section presents in detail the methodological approach of the study, including the operationalization of variables, the research design, the sampling strategy, the data collection procedure, and the formulation of hypotheses, with the aim of ensuring a precise and well-founded understanding of the research process.

A. Operationalization of the Dependent Variable

This section presents the table corresponding to the operationalization of the dependent variable, specifying its indicators for proper measurement (see Table 1).

B. Research Design

This study follows an applied research approach, with a true experimental design aimed at evaluating the impact of the intervention under controlled conditions:

$$\mathbf{RG_e \quad X \quad O_1}$$

$$\mathbf{RG_c \quad -- \quad O_2}$$

An experimental group (Ge) received the independent variable intervention, while a control group (Gc) did not receive such intervention. Both groups were composed of randomly selected subjects (R), thus ensuring the internal validity of the study. The experimental group received a specific stimulus (X), corresponding to the proposed treatment.

C. Population and Sample

The study population comprises learning processes related to cultures within the Social

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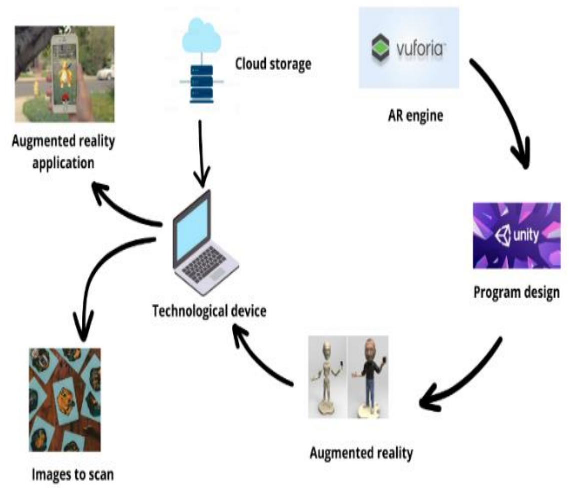

Fig. 2. System architecture

Studies course offered in educational institutions nationwide; in this case, the population size is considered undetermined (N = undetermined). The sample specifically includes the learning processes of the aforementioned course at the Angelita Bohórquez Moreno Educational Institution, involving a total of 30 students (n = 30).

D. Data Collection Procedure

For this study, the direct observation technique was employed using structured forms specifically designed to systematically record evidence related to learning processes.

E. Hypothesis Statement

The following hypotheses were proposed in this study:

H1: The use of Augmented Reality, implemented through the SCRUM methodology, increases academic performance in the learning process at the Angelita Bohórquez Moreno Educational Institution.

H2: The application of Augmented Reality using the SCRUM approach increases the number of student participations during the learning process.

H3: The use of Augmented Reality in combination with the SCRUM methodology increases the frequency of assignment submissions by students.

H4: The incorporation of Augmented Reality, implemented through the SCRUM methodology, reduces the time required to achieve learning at the Angelita Bohórquez Moreno Educational Institution.

To test the proposed hypotheses, the following comparative scheme based on the evaluated indicators was established:

$\mu1$=Population mean (I1, I2, I3, I4) for the Post-Test Gc

$\mu2$=Population mean (I1, I2, I3, I4) for the Post-Test Ge

Where: Ho: $\mu1 \geq \mu2$ y Ha: $\mu1 < \mu2$

In addition:

$\mu1$=Population mean (I4) for the Post-Test Gc

$\mu2$=Population mean (H4) for the Post-Test Ge

where: H0: $\mu1 \leq \mu2$ y Ha: $\mu1 > \mu2$.

Finally, a normality test was applied to the collected data, followed by descriptive statistical analysis. The validation of hypotheses H1, H2, H3, and H4 was conducted using the Student's t-test, considering the comparison of means between the experimental and control groups.

4 Case Study

In the development of the Augmented Reality-based solution, the SCRUM methodology was applied, which comprises four main stages that structure the iterative development process.

4.1 Sprint Planning

In this phase, the system architecture and functional requirements were established, defining the technical and pedagogical objectives to be achieved during the corresponding development cycle.

A. System Architecture

The environment in which the project is developed is outlined in order to meet the functional requirements that enhance learning through Augmented Reality (see Figure 2).

ISSN 2007-9737

Table 2. Functional Requirements

Id	Requirements	Stories
RF01	The system can identify and track real-world objects, allowing for precise overlay of Augmented Reality content	H1
RF02	Users will be able to interact intuitively with other Augmented Reality elements	H2
RF03	The system facilitates the customization of Augmented Reality content, tailoring it to the specific needs of students and learning objectives.	H3
RF04	The system has the capability to integrate various types of media, such as images, 3D models, and sound, into the Augmented Reality experience to enrich learning.	H4
RF05	The system allows students to explore different cultural aspects of various societies through Augmented Reality experiences.	H5
RF06	The system offers interactive simulations that allow students to experience specific cultural situations.	H5

Table 3. User Stories

Stories	Description
H1	As a system administrator, I want the system to be able to identify and track real-world objects to precisely overlay Augmented Reality content.
H2	Users will be able to interact intuitively with the Augmented Reality elements
H3	The system allows for the customization of Augmented Reality content to fit the specific needs of students and learning objectives.
H4	The system has the capability to integrate various types of media, such as images, videos, and 3D models, into the Augmented Reality experience to enhance learning.
H5	The system allows students to explore various cultural aspects of different societies through Augmented Reality experiences.
H6	The system has the capability to provide interactive simulations that enable students to experience specific cultural situations.

Tabla 4. Product Backlog

Id	Description	Sprint
1	As a system administrator, I want the system to have the capability to identify and track real-world objects to precisely overlay Augmented Reality content.	Sprint 1
2	The system allows for the customization of Augmented Reality content to adapt to the particular needs of students and learning objectives.	
3	The system has the capability to integrate various types of media, such as images, 3D models, and sound, into the Augmented Reality experience to enrich learning.	Sprint 2
4	The system allows students to explore various cultural aspects of different societies through Augmented Reality experiences.	
5	The system has the capability to offer interactive simulations that provide students the opportunity to experience specific cultural scenarios.	Sprint 3

ISSN 2007-9737

For I1: Academic Performance

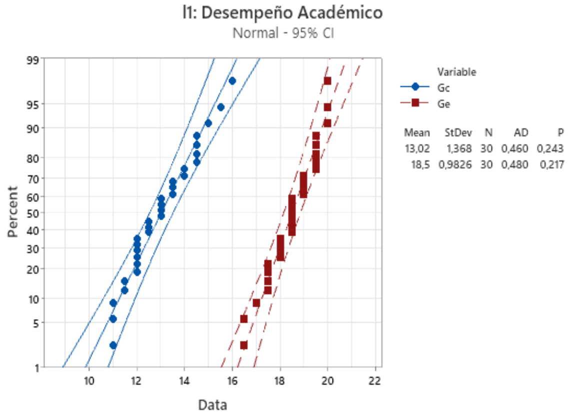

Fig. 5. Normality Test for I1

For I2: Number of Participations

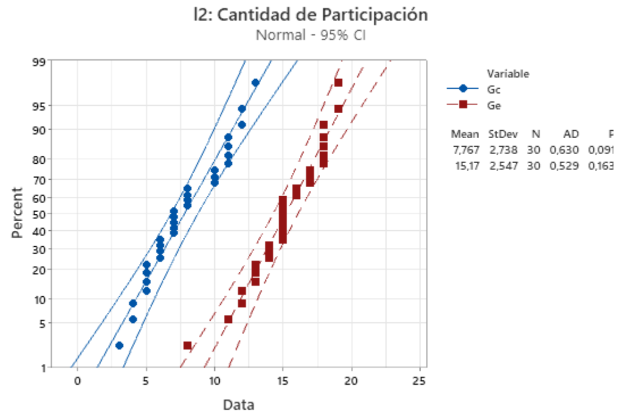

Fig. 6. Normality Test for I2

For I3: Number of Submitted Assignments

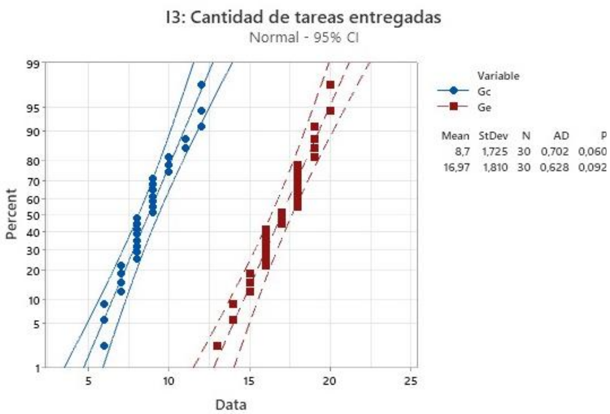

Fig. 7. Normality Test for I3

For I4: Learning Time

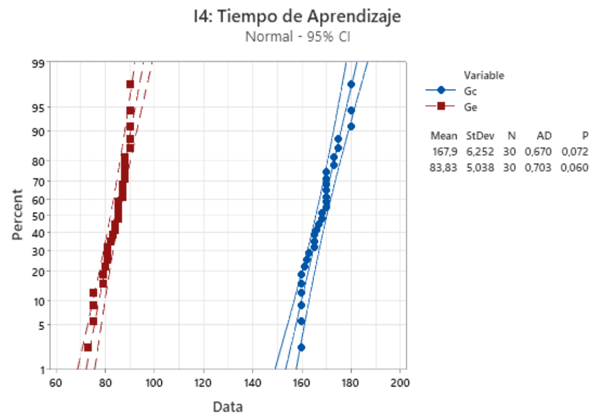

Fig. 8. Normality Test for I4

B. Functional Requirements

This section describes the functional requirements defined for the developed system (see Table 2).

4.2 Sprint

In this stage, the user stories derived from the previously defined functional requirements are identified.

A. User Stories

This section describes the user stories linked to the defined functional requirements (see Table 3).

4.3 Sprint Review

In this phase, the elements of the Product Backlog identified for the system development are presented.

A. Product Backlog

The initial Product Backlog is shown in the table below and was developed over the course of three sprints (see Table 4).

Fig. 3. Evidence from Sprint 1 and Sprint 2

Fig. 4. Evidence from Sprint 3

Table 5. Gc and Ge Values for I1

I1: Academic Performance (points)					
Gc Test			**Ge Test**		
16	13,5	12	20	19	18
15,5	13,5	12	20	19	18
15	13	12	20	18,5	18
14,5	13	12	19,5	18,5	17,5
14,5	13	12	19,5	18,5	17,5
14,5	13	11,5	19,5	18,5	17,5
14,5	12,5	11,5	19,5	18,5	17,5
14	12,5	11	19,5	18,5	17
14	12,5	11	19	18,5	16,5
13,5	12	11	19	18	16,5

Table 6. Gc and Ge Values for I2

I2: Number of Participations (participations)					
Gc Test			**Ge Test**		
13	8	6	19	16	14
12	8	6	19	16	14
12	8	6	18	15	14
11	8	5	18	15	13
11	7	5	18	15	13
11	7	5	18	15	13
11	7	5	18	15	12
10	7	4	17	15	12
10	7	4	17	15	11
10	6	3	17	15	8

4.4 Retrospective

In this case, the retrospective of the process is visually represented through images (see Figures 3 and 4).

5 Results and Discussion

5.1 Experimental Results

The experimental results obtained demonstrated an increase in academic performance, a rise in the

Table 9. Results with Descriptive Statistics

I1: Academic Performance		
	Post-Test (Gc)	**Post-Test (Ge)**
N	30	
Mean	13.02	18.5
StDev	1.368	0.9826
AD	0.460	0.480
p-value	0.243	0.217
I2: Number of Participations		
	Post-Test (Gc)	**Post-Test (Ge)**
N	30	
Mean	7.767	15.17
StDev	2.738	2.547
AD	0.460	0.480
p-value	0.091	0.163
I3: Number of Submitted Assignments		
	Post-Test (Gc)	**Post-Test (Ge)**
N	30	
Mean	8.7	16.97
StDev	1.725	1.810
AD	0.702	0.628
p-value	0.060	0.092
I4: Learning Time		
	Post-Test (Gc)	**Post-Test (Ge)**
N	30	
Mean	167.9	83.83
StDev	6.252	5.038
AD	0.670	0.703
p-value	0.072	0.060

number of participations, a greater number of submitted assignments, a reduction in learning time, and an increase in satisfaction levels (see Tables 5, 6, 7, and 8).

It can be observed that the indicators (I1, I2, I3, and I4) present values higher than the significance level $\alpha = 0.05$, allowing us to conclude that the data associated with each indicator follow a normal distribution.

5.2 Normality Test

This test is used to verify whether the collected data follow a normal distribution, which is essential for the validity of the statistical analyses applied (see Figures 5, 6, 7, and 8).

5.3 Discussion of Results

This section presents a descriptive and inferential analysis of the data obtained, aiming to interpret the significance and scope of the findings in relation to the hypotheses formulated at the beginning of the study.

5.3.1 With Descriptive Statistics

The preliminary descriptive analysis of the data clearly reveals several relevant trends in the results obtained (see Tables 9 and 10).

For I1: Academic Performance

The experimental group (Ge) obtained a significantly higher mean (18.5) compared to the

ISSN 2007-9737

Table 10. Summary of Results for the Indicators

I1: Academic Performance	
N	**30**
Confidence Interval (95%)	18 – 19 (points)
Kurtosis	-0.527472
Skewness	-0.321277
Q_3	19.5
I2: Number of Participations	
N	**30**
Intervalo de confianza (95%)	14.229 – 16.771 (participations)
Kurtosis	0.694070
Asimetría	-0.655458
Q_3	17.250
I3: Number of Submitted Assignments	
N	**30**
Confidence Interval (95%)	16 – 18 (submissions)
Kurtosis	-0.567167
Skewness	-0.283686
Q_3	18
I4: Learning Time	
N	**30**
Confidence Interval (95%)	81.229 – 87 (minutes)
Kurtosis	-0.553037
Skewness	-0.616089
Q_3	88

control group (13.02), with lower dispersion (StDev = 0.98 vs. 1.37), indicating better and more consistent academic performance.

This supports the application of parametric tests to compare the effects of Augmented Reality on academic achievement.

It suggests that immersive technological tools can be effective in enhancing students' understanding and mastery of curricular content. This promotes institutional decisions to integrate agile methodologies and emerging technologies into formal teaching.

For I2: Number of Participations

The experimental group recorded nearly double the number of participations (15.17) compared to the control group (7.77), with similar standard deviations. This reflects that the AR environment fostered active student participation.

This increase suggests higher motivation and engagement in the experimental group. It encourages the design of pedagogical experiences where students play a more active and constructive role.

For I3: Number of Submitted Assignments

Students in the experimental group submitted significantly more assignments (mean = 16.97) than those in the control group (mean = 8.7), maintaining low variability.

This reinforces the importance of integrating motivational technologies that foster greater student involvement outside the classroom. It provides evidence to justify investment in digital resources that promote student autonomy and responsibility.

For I4: Learning Time

ISSN 2007-9737

The experimental group required less time to learn (mean = 83.83 minutes) than the control group (167.9 minutes), with lower dispersion.

This is particularly relevant in contexts with time constraints or dense curricula. It justifies the adoption of technologies that improve not only results but also the efficiency of the educational process.

For I1: Academic Performance

The confidence interval (18–19 points) indicates high and stable academic performance in the experimental group. The negative kurtosis (-0.527) suggests a flatter and less concentrated distribution around the mean. The negative skewness (-0.321) and Q3 of 19.5 indicate a slight tendency toward lower scores, although results remain high.

The results exceed those reported by Pantoja [21] in his study "Academic Performance Indicators as Predictors of Financial Resource Acquisition," which showed an increase in academic performance of 30% to 45%. However, Castro et al. [22] reported an increase of 95% in their research, and Redondo & Jiménez [23] indicated a 51% improvement. Finally, Sucari et al. [24] reported an increase equivalent to a score of 19 points.

The proposed system supports robust and generalizable learning among students. This outcome reinforces the integration of AR in courses aimed at uniformly improving academic performance.

For I2: Number of Participations

The confidence interval (14.229–16.771) reflects sustained high participation in the experimental group. The positive kurtosis (0.694) indicates a slight central concentration. The negative skewness (-0.655) and Q3 = 17.25 reveal that most students participated frequently.

Huanca et al. [25] reported an increase to 85 participations, reflecting a 57.4% rise. Similarly, Díaz et al. [7] indicated that participations rose from 40 to 78, a 95% increase.

The interactive environment promotes inclusion and reduces passivity in the classroom. This finding supports the design of AR-based activities to foster student dialogue and collaboration.

For I3: Number of Submitted Assignments

The confidence interval (16–18 submissions) confirms consistent task completion after the intervention. The negative kurtosis (-0.567) shows a less concentrated, more spread-out distribution. The negative skewness (-0.283) and Q3 of 18 indicate that most students submitted nearly all assignments.

Gil et al. [26] reported a 56.9% increase in submitted assignments. Similarly, Vera et al. [27] found a 36.8% increase.

This behavior can be key to improving study habits and course follow-up. The use of immersive technology should be considered to enhance student productivity in various areas.

For I4: Learning Time

The confidence interval (81.229–87 minutes) shows a significant reduction in learning time. The negative kurtosis (-0.553) suggests a flatter distribution. The negative skewness (-0.616) and Q3 of 88 indicate that most students required less than 90 minutes to learn.

Franco & Ruiz [28] reported a reduction in learning time from 210 to 130 minutes (38.1% reduction). García et al. [33] noted a drop from 150 to 70 minutes (53.3% reduction), while Mendoza [29] found a decrease from 220 to 120 minutes (40% reduction).

This positively impacts time management in the classroom, benefiting both teachers and students. The finding supports the use of AR as an efficient tool to improve the cognitive economy of learning.

5.3.2 With Inferential Statistics: Hypothesis Testing

The following are the results from the application of statistical tests used for hypothesis testing (see Tables 11).

For I1: Academic Performance

With n = 30 and a null hypothesis H_0: $\mu_1 > \mu_2$, the t-value = -17.85 and p = 0.000 indicate a statistically significant difference in favor of the experimental group (Ge). Since $p < 0.05$, H_0 is rejected, confirming that the AR intervention increased academic performance.

Pantoja [21] also reported positive results, concluding that the use of technologies such as

Table 11. Hypothesis Testing for Parametric Indicators

Sample	n	H0	t-value	p-value
I_1: Gc **I_1: Ge**	30	$\mu_1 > \mu_2$	-17.85	0.000
I_2: Gc **I_2: Ge**	30	$\mu_1 > \mu_2$	-10.84	0.000
I_3: Gc **I_3: Ge**	30	$\mu_1 > \mu_2$	-18.11	0.000
I_4: Gc **I_4: Ge**	30	$\mu_1 < \mu_2$	57,32	0.000

Augmented Reality enhances Academic Performance.

These results provide empirical evidence to support the adoption of AR in the school curriculum. They reinforce the need to invest in educational technologies that directly impact academic achievement.

For I2: Number of Participations

With n = 30 and H_0: $\mu_1 > \mu_2$, the t-value = -10.84 and p = 0.000 indicate a significant difference in favor of the experimental group. Since $p \leq 0.05$, the null hypothesis is rejected, validating the positive effect on student participation.

According to Cañadas et al. [31], the use of technological tools such as Augmented Reality increases student interest, resulting in high levels of participation. In their study, a p-value = 0.000 supported the acceptance of the alternative hypothesis (Ha) and rejection of the null (H_0).

Augmented Reality enhances not only content but also classroom participation dynamics. Teachers can use AR as a strategy to promote active student engagement.

For I3: Number of Submitted Assignments

With n = 30 and H_0: $\mu_1 > \mu_2$, the result t = -18.11 and p = 0.000 indicates a significant difference favoring the experimental group. The p-value reinforces the validity of the finding, rejecting H_0 and confirming the positive impact of AR on academic commitment.

Cañadas et al. [31] reported excellent results with a p-value = 0.000, rejecting the null hypothesis (H_0) and accepting the alternative (Ha), concluding that the number of assignments submitted increased significantly.

This result suggests that AR can strengthen habits of responsibility and academic compliance. It is advisable to incorporate AR in subjects where task tracking is critical to learning outcomes.

For I4: Learning Time

With n = 30 and H_0: $\mu_1 < \mu_2$, the t-value = 57.32 and p = 0.000 indicate a significant difference in the opposite direction of H_0. The mean of the experimental group is lower, contradicting H_0 and demonstrating that AR reduced learning time.

Papakostas et al. [32] also reported positive results, concluding that the use of Augmented Reality reduces learning time.

AR enables learning objectives to be achieved in less time than traditional methods.

This represents a significant advantage in educational contexts with time constraints or a heavy curriculum load.

6 Conclusions and Future Research

The experimental results show that Augmented Reality, applied through the SCRUM methodology, had a statistically significant effect on the evaluated indicators. For I1 (Academic Performance), the experimental group significantly outperformed the control group, with lower dispersion and greater consistency. In I2 (Number of Participations), a substantial increase in student interaction was observed, reinforcing motivation. I3 (Number of Submitted Assignments) showed a clear improvement in academic commitment and task completion, with notably higher values in the experimental group. Finally, I4 (Learning Time) was considerably reduced, demonstrating that the use of AR not only enhances performance but also improves the efficiency of knowledge acquisition. All obtained p-values were below 0.05, statistically validating these improvements.

Future studies could explore the impact of Augmented Reality in multicultural or rural contexts, where resources are limited. Additionally, it is recommended to incorporate longitudinal evaluations to assess the sustainability of learning. Finally, it would be relevant to analyze the effect of AR on socio-emotional variables such as self-esteem or collaboration.

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