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INCIDENCE OF AUGMENTED REALITY IN LEARNING ON EARLY CHILDHOOD

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Abstract. This research analyzed the association between the achievement of learning in early childhood, the level of understanding and augmented reality (AR) in an ICT-mediated environment. To meet the proposed objective, a mixed, participatory, quasi-experimental study was structured with two groups, A and B, that used AR in alternative phases of the study. This included 27 transition students from the IED Colegio República de Colombia from Bogota. For this study, a social experiment that develops the practical empirical component was carried out; in this, AR is used in didactic units, designed, developed, and evaluated in the conceptual framework of teaching for understanding, in environments that combine the physical world with the virtual world, to identify, analyze and explain the changes that occur in learning and the level of understanding of students. The results showed that the implementation of AR resources statistically affect the growth of levels of understanding for each of the dimensions considered in the conceptual framework of understanding. In the execution of the didactic units, the potential of AR to promote student understanding was evidenced, especially in the dimension of forms of communication.

Keywords: educational technology, motivation, didactic technique, educational environment, comprehension, augmented reality.

INCIDENCIA DE LA REALIDAD AUMENTADA EN EL APRENDIZAJE DE LA PRIMERA INFANCIA

Resumen. Esta investigación analizó la asociación entre el logro del aprendizaje en la primera infancia, el nivel de comprensión y la realidad aumentada (RA) en un ambiente mediado por las TIC. Para cumplir con el objetivo propuesto, se estructuró un estudio mixto de corte participativo, cuasi experimental, con dos grupos, A y B, que utilizaron RA en fases alternativas del estudio. En este, participaron 27 estudiantes de transición de la Institución Educativa Distrital (IED) Colegio República de Colombia de Bogotá (Colombia). Para este estudio, se llevó a cabo un experimento social que desarrolló el componente empírico práctico, en el cual se utilizó la RA en unidades didácticas, diseñadas, desarrolladas y evaluadas en el marco conceptual de la enseñanza para la comprensión en ambientes que combinan el mundo físico con el mundo virtual, para identificar, analizar y explicar los cambios que se presentan en el aprendizaje y el nivel de comprensión de los estudiantes. Los resultados demostraron que la implementación de los recursos de RA

incide estadísticamente en el crecimiento de los niveles de comprensión para cada una de las dimensiones consideradas en el marco conceptual de la comprensión. Se evidenció en la ejecución de las unidades didácticas la potencialidad de la RA para promover la comprensión de los estudiantes, especialmente en la dimensión de las formas de comunicación.

Palabras clave: tecnología educacional, motivación, técnica didáctica, ambiente educacional, comprensión, realidad aumentada.

Introduction

In recent years, Information and Communication Technologies (ICTs) have approached educational institutions with technological advances that allow experimenting with new devices, resources, and applications. These have opened a wide range of opportunities in the teaching-learning process. Within these advances, emerging technologies emerge, such as augmented reality (AR); this is the one that "allows adding an unreal object to a real context" (Cabero et al., 2018, para. 1) that can be used in educational institutions in the service of various purposes related to education, which new educational challenges can be raised.

One characteristic of augmented reality that favors its inclusion in the educational world is that it allows "complementing" the real world with a virtual object without replacing it (Vidal, Febrero López and Casal Otero, 2021). This technology helps to considerably reduce the time needed to understand complex subjects since it enables motivating and attractive learning for both students and teachers.

According to studies carried out in the educational field, AR is a tool that can be very useful at all stages, helping students to have a more experiential, real, and close learning process. Some studies already endorse this success using AR, for example, in the case of its use for learning the foreign language: English, in the primary stage, has been proven that this tool facilitates the development of classes and improves the acquisition of the contents of the students (Bezares, 2020).

In the infant stage, there are studies such as the one by López-Belmonte et al. entitled “The Effectiveness of Augmented Reality in the Early Childhood Classroom”; which presents a study conducted in an infant classroom, specifically in the 3rd year of the 2nd cycle, when the students are between 5 and 6 years old, whose results indicate that those students who had used the technological tool mentioned obtained "significantly superior" results than those who did not use it (López-Belmonte et al., 2019).

On the other hand, articles such as the one by Márquez (2018) studies the relationship between didactic games and AR and tells us how "the use of this technology improves the use of knowledge" (p. 1). Or that of Prendes (2015), who points out that "Augmented Reality is a promising technology (...), which can help improve the teaching-learning process" (p. 187).

Some of the conclusions of these studies yield information such as that AR allows these resources to be "contextualized to the needs and tastes of their users and can provide better facilities and motivation within their learning" (Bezares et al. 2020, p.88), in addition it is specified that "all students who have worked with AR have acquired more knowledge (...), and that such knowledge lasts longer in time" (Cascales, 2015, p.12). On the other hand, López et al. point out *that* "the use of AR resources improves the grade obtained, participation, autonomy, attitude, motivation, interest, attention and promotes collaborative, ubiquitous, meaningful and constructivist learning in young learners″ (López et al. 2019, p.157).

> In the case of more global studies investigating how this technology has influenced education in general, the results point out that ″logical changes stand out, such as greater and different access to information, together with transcendent innovations, such as the increase in informal and playful activities, insertion in iconic virtual environments, belonging to specific groups and networks of friendly interaction within new scales of values" (Fombona et al, 2017, p. 63).
>
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A thorough review of different sources (books, articles, research, theses, etc.) that deal with the study of educational technologies reveals an infinite number of innovative technological resources and the implementation of programs. The question arises when looking for research that focuses its efforts on determining the relationship between technology and learning; that is, to compare to what extent technological resources influence student learning, especially in early childhood. Among the advantages pointed out in the different review sources, "there is the increase in motivation and interest of students when using AR" (Gavilanes et al., 2018, p. 16); however, novelty is also pointed out as a disadvantage. This awakens students' motivation but decreases over time.

> The technological resources most commonly used in the development of the experimental phase of the studies reviewed were mobile devices, desktop computers, HMD, and 3D glasses. Among the disadvantages of the use of educational resources with AR, problems of usability and access to technological resources, excessive reading time requirements, and slight fatigue in students are pointed out. (Gavilanes et al., 2018, p. 17).

Another of the fundamental aspects to point out in the studies reviewed is the need for methodologies to integrate AR in educational processes, so that the incorporation of AR does not become a technological problem but rather an educational and pedagogical contribution. Among the lines to be developed are analyzing the potential of AR for students with special needs and early childhood; determining the new roles of teachers and students; and establishing elements for the design and implementation of AR applications by identifying technological and pedagogical resources in the classroom.

Digital resources are additional instruments present in the context of current childhood development; it is not the same to interact with a tool that arrives when one is already in the world as it is to be born into it when such a tool already exists (Ferreiro, 2011). This leads to questioning the pedagogical potential of ICTs in education and how they impact student learning and improve the quality of teaching. It is important to determine whether augmented and enriched technological environments offer new possibilities for learning, and to what extent AR is a promising technology in education to become a motivational system capable of maximizing student understanding and learning.

This doctoral thesis is situated in this context, focusing on the analysis of the impact of AR on early childhood students' learning, thus yielding results on the extent to which such technology improves the quality of learning.

Method

This mixed, participatory, and quasi-experimental study seeks to establish changes in students' learning and level of understanding by analyzing particular variables. Accordingly, the dependent variable is learning; and the didactic units with and without AR activities are the independent variable.

The design of the study is quasi-experimental since the intervention takes place in a natural situation, without random assignment of the groups. Specifically, there are two experimental groups, A and B, and the didactic units are applied to both, so that they benefit from the methodological resource. They should use AR in alternative phases of the study.

The adapted design scheme (Table 1) shows the five didactic units that were applied in three quarters. In the first quarter, groups A and B worked with AR; in the second quarter, group A worked with AR and group B without AR, teaching units 2 and 4, respectively; and finally, in the third quarter, group A worked without AR and group B with AR, teaching units 3 and 5, respectively. Finally, comparisons were established for both groups with the measurements obtained from the rubric of each of the didactic units.

Table 1
Study design scheme

2019 quarter	Transition group 3	Didactic unit	AR	Heading
1	A AND B	UD1	YES	RUD1
2	A	UD2	YES	RUD2
	B	UD4	NO	RUD4
3	A	UD3	NO	RUD3
	B	UD5	YES	RUD5

Note: own elaboration

For each didactic unit worked with and without the AR resource, the students' level of comprehension is evaluated; four levels are differentiated: naïve, beginner, learner, and mastery. This evaluation is carried out five times by the teacher, which makes it coincide with the development of each of the didactic units.

The question is to know and explain the changes in learning in the transition students of Colegio República de Colombia. For this purpose, an evaluation rubric is used for each of the five didactic units implemented in the students' learning environment in which the use of AR resources is considered. Each evaluation rubric, designed within the framework of teaching for understanding (TEQ), considers 16 qualitative quadrants, product of the crossing of the "four dimensions of understanding: content, purpose, method, and forms of expression; with four levels of understanding: naïve, beginner, learner, mastery " (Wiske, 1999, p. 230). These make it possible to determine and locate the student's level of comprehension according to each dimension, to perform a comparative analysis of the results, and to determine changes in learning based on the continuous diagnostic assessment of the student's performance.

The categories established for the organization and analysis of the data are based on the dimensions and levels of comprehension that were defined based on the conceptual model of comprehension, according to which the qualities of comprehension can be known from the assessment of the students' performance (Wiske, 1999, p. 227). The categories defined to evaluate and know the changes in learning and comprehension are:

"content, method, purpose, and forms of communication, in their levels of naïve, beginner, learner, and mastery " (Rivera, 2014, p. 80).

The conceptual framework of the CPE is summarized below (Table 2). The four dimensions and the four levels of comprehension for the elaboration of the evaluation rubrics and instruments used to assess the level of comprehension achieved for the performances defined in the planning of each of the didactic units with and without AR designed and applied in the study are shown.

Table 2
Outline of the conceptual framework for understanding

DIMENSIONS	Content	Methods	Purposes	Form of communication
	A. Transformed intuitive beliefs B. Conceptual, coherent, and rich networks	A. Healthy skepticism B. Building domain knowledge C. Validate domain knowledge	A. Awareness of the purposes of knowledge B. Uses of knowledge C. Autonomy management	A. Good management of performance genres B. Effective use of symbol systems C. Consideration of audience and context
LEVELS	Mastery	Learner	Beginner	Naïve
	Integrative, creative, and critical. They use knowledge to interpret the world.	Flexible use of concepts. With support, they detect the relationship in everyday situations.	Mechanical procedures. The validation of the work depends on external authority.	Intuitive and not very reflective knowledge. Unstructured knowledge.

Note: own elaboration

The changes in learning and understanding on the part of the students are recorded with the information obtained from the application of the evaluation rubric of the didactic units managed. Thus, results and conclusions are generated. The creation of the resources for this research, the AR applications, and the didactic units has been a multidisciplinary process in which professionals with different profiles, experiences and points of view on how didactic materials should be and should be created have participated. These have been teachers, experts in early childhood education, graphic designers, engineers, and pedagogues.

For the research, three AR applications are designed, whose topics are recycling, healthy eating, and school garden. As for the didactic units, two models of guides are designed for students who work with AR and for those who work without AR. Each is based on the pedagogical model of teaching for understanding. In conclusion, the design of the present study is framed in the mixed approach; it is a participatory research with a practical and quasi-experimental approach. Figure 1 describes the information process in the study.

Figure 1. Diagram of the information process in the study.

Population and sample

The target population of the proposed research corresponds to 125 students from five transition grades of the Colegio República de Colombia, whose ages range between 5 and 6 years old. The distribution of the participating students by gender and by group is shown in Tables 3 and 4, respectively.

Table 3
Distribution of participating students according to gender

Genre	Number of students	Percentage
Boys	13	48,14 %
Girls	14	51,85 %

Note: own elaboration

Table 4
Distribution of participating students by group and gender

Group	Boys	Girls	Total
A	7	7	14
B	6	7	13

Note: own elaboration

The sample is made up of 27 transition 3 students corresponding to 20.8% of the population. These children are part of the same study group that, from the concept of sample composition, is statistically representative to observe, analyze, and validate the information obtained and to issue with a good level of reliability the judgments in relation to the verification of the formulated hypotheses.

Results

The dimensions and levels of comprehension obtained in each of the didactic units with and without AR allow for a comparative analysis of the results in the levels of comprehension for each of the dimensions. In didactic unit 1 with AR, groups A and B participated; in didactic unit 2 with AR, group A participated and, simultaneously, group B worked on didactic unit 4 without AR; finally, in unit 3 with AR, group B participated and, simultaneously, group A worked on didactic unit 5 without AR. Based on this information, the radiography of the comprehension of the transition course 3 in the five didactic units implemented and the results in each of the dimensions of comprehension were consolidated, which is presented in Table 5.

Table 5
Consolidated outline of course comprehension transition 3

Dimensions	**Unit didactics 1 with AR groups a and b**	**Unit didactic 2 with AR group a**	**Unit didactic 3 with AR group b**	**Unit didactic 4 without AR group b**	**Unit didactic 5 without AR group a**
Contents	**Level of understanding** mastery 44 % learner 41 % beginner 0 % naïve 0 %	**Level of understanding** mastery 50 % learner 29 % beginner 7 % naïve 14 %	**Level of understanding** mastery 69 % learner 31 % beginner 0 % naïve 0 %	**Level of understanding** mastery 38 % learner 62 % beginner 0 % naïve 0 %	**Level of understanding** mastery 7 % learner 64 % beginner 22 % naïve 7 %
Methods	**Level of understanding** mastery 41 % learner 26 % beginner 19 % naïve 15 %	**Level of understanding** mastery 43 % learner 29 % beginner 14 % naïve 14 %	**Level of understanding** mastery 61 % learner 31 % beginner 8 % naïve 0 %	**Level of understanding** mastery 38 % learner 54 % beginner 8 % naïve 0 %	**Level of understanding** mastery 7 % learner 57 % beginner 36 % naïve 0 %
Purpose	**Level of understanding** mastery 48 % learner 19 % beginner 18 % naïve 15 %	**Level of understanding** mastery 36 % learner 36 % beginner 14 % naïve 14 %	**Level of understanding** mastery 69 % learner 23 % beginner 8 % naïve 0 %	**Level of understanding** mastery 38 % learner 46 % beginner 8 % naïve 8 %	**Level of understanding** mastery 7 % learner 64 % beginner 22 % naïve 7 %
Communication	**Level of understanding** mastery 37 % learner 33 % beginner 30 % naïve 0 %	**Level of understanding** mastery 36 % learner 21 % beginner 29 % naïve 14 %	**Level of understanding** mastery 46 % learner 46 % beginner 8 % naïve 0 %	**Level of understanding** mastery 15 % learner 62 % beginner 23 % naïve 0 %	**Level of understanding** mastery 14 % learner 43 % beginner 29 % naïve 14 %

Note: own elaboration

Analysis of results by dimension

Content dimension**:** Figure 2 shows the levels obtained by the students in this dimension.

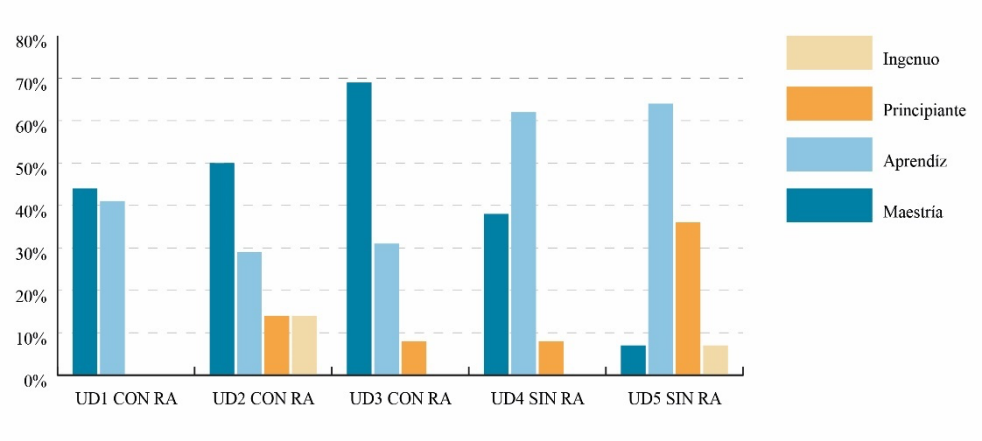

Figure 2. Percentage of levels obtained in the content dimension.

Analysis of the content dimension

The content dimension of comprehension focuses on students' conceptual knowledge. The mastery level is the one that concentrates in each of the didactic units with AR the highest number of performances in this dimension, with percentages of 44%, 50%, and 69%, respectively. This ratifies that students, in the didactic units worked with AR, evidenced knowledge of the subject treated, responded to the forms of intervention and understood what it is done for. Students were critical, creative, and used the knowledge acquired to solve situations and reinterpret their environment.

Method dimension: Figure 3 shows the levels obtained by the students in this dimension.

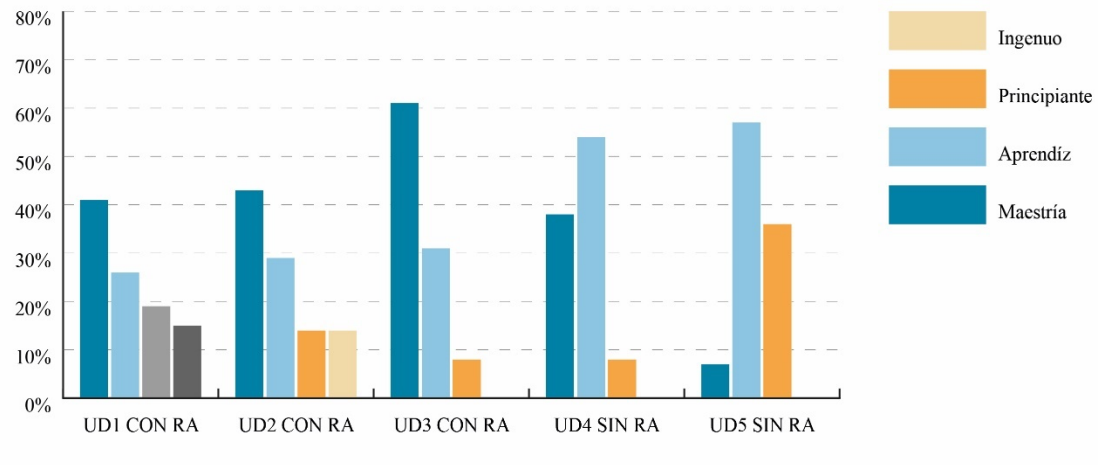

Figure 3. Percentage of levels obtained in the method dimension.

Analysis of the method dimension

The method dimension of understanding focuses on finding how to generate and construct knowledge by using and validating formal sources and questioning one's own with a healthy skepticism. This is complex for anyone, even generating knowledge methodically from instructions and with available resources has a degree of difficulty.

The mastery level is the one that concentrates in each of the didactic units with AR the highest number of performances in this dimension, with percentages of 41%, 43%, and 61%, respectively. This confirms that students, in the didactic units that worked with AR, maintained a healthy skepticism about what they know and what they were told, and used reliable methods to construct and validate statements and works.

Purpose dimension: Figure 4 shows the levels obtained by students in this dimension.

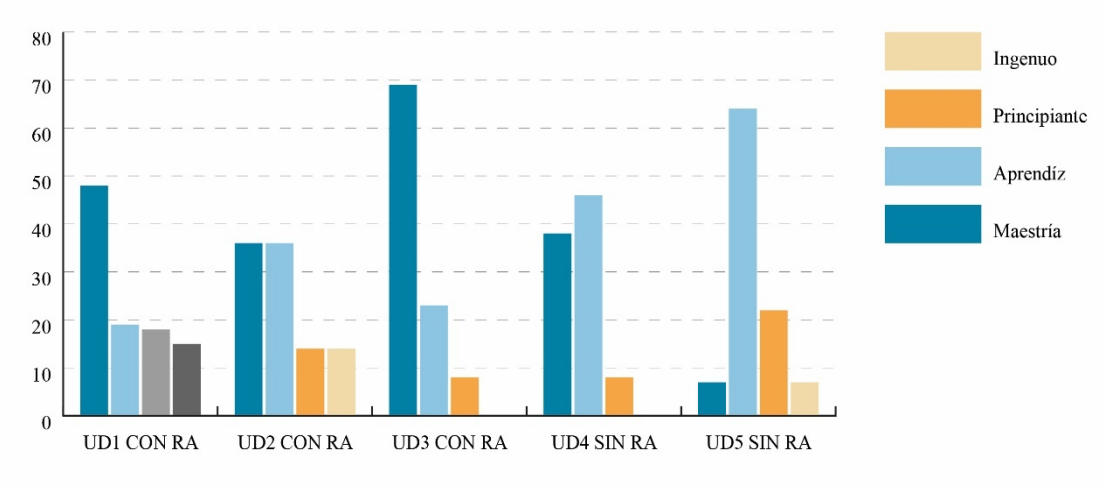

Figure 4. Percentage of levels obtained in the purpose dimension.

Analysis of the purpose dimension

The purpose dimension of understanding focuses on students demonstrating that they know and use knowledge of principles and values; that they identify the use and application of knowledge in the context; that they make use of good management and conceptual and behavioral autonomy in the development of the activity; and that they are consistent with what they are working on, as they prove it in their activities and attitude.

The mastery level is the one that concentrates in each of the didactic units with AR the highest number of performances in this dimension, with percentages of 48%, 36%, and 69%, respectively. This ratifies that students, in the didactic units worked with AR, had clear purposes and interests that guided the construction of knowledge, used it in different situations and knew the consequences of doing so.

Communication forms dimension: Figure 5 shows the levels obtained by the students in this dimension.

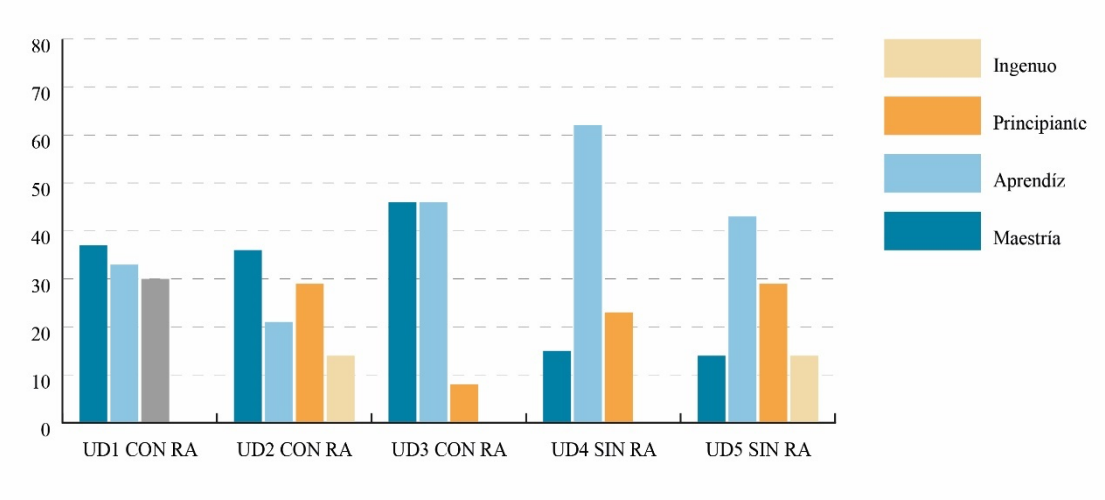

Figure 5. Percentage of levels obtained in the dimension of forms of communication.

Analysis of the dimension of forms of communication

The mastery level is the one that concentrates in each of the didactic units with AR the highest number of performances in this dimension, with percentages of 33%, 36%, and 46%, respectively. This ratifies that the students, in the didactic units worked with AR, managed to master the types of communication and were facilitated to express what they knew in different contexts and in different ways. The dimension of forms of communication deals with the understanding in which ICTs naturally find their development environment. Here, technological resources offer the best and greatest support in the generation of understanding, where students develop in a comfortable way.

In the didactic units with AR, the number of students at the mastery level prevails in the four dimensions of comprehension; and in the didactic units without AR, the learner level prevails over the mastery level. This allows us to affirm that, in the didactic units with AR, the transition students achieved a higher level of comprehension. For Ausubel (1963), learning is synonymous with understanding, which implies meaningful learning; this is not only the process of relating knowledge but of actively and personally controlling it, so that new knowledge is related to existing knowledge in order to give it functionality.

Content dimension analysis with AR and without AR

The comparative analysis of each of the dimensions of comprehension is carried out by giving a numerical value to each of the levels, as shown in Table 6 below.

Table 6
Numerical value of comprehension levels

Level of understanding	Numerical value
Naïve	1
Beginner	2
Learner	3
Mastery	4

Note: own elaboration

Unit 2 with AR and unit 5 without AR

Table 7
Comparative analysis of content dimension UD2 with AR and UD5 without AR

		U2 with AR content	U5 without AR content
N	Valid	14	14
Mean		3,14	2,71
Median		3,50	3,00
Standard deviation		1,099	,726
Minimum		1	1
Maximum		4	4

Note: own elaboration

When analyzing the data obtained in didactic unit 2 with AR in Table 7, it is observed that the average is 3.14, and that, in didactic unit 5 without AR, it is 2.71. This means that by using AR the average number of students shifts towards the maximum value, which implies a higher number of students between the mastery and apprentice levels in the dimension of content comprehension. On the other hand, the increase in the standard deviation reflects that there is a percentage of students in group A, who are at the naïve level; therefore, there are still difficulties in their comprehension. This is positive insofar as it allows us to identify more easily the cases in which students present comprehension deficiencies; thus, these cases can be attended to in a particular way. Regarding Figures 6 and 7, it can be observed that the number of students at the mastery level increases significantly when AR is used in the implementation of the didactic unit.

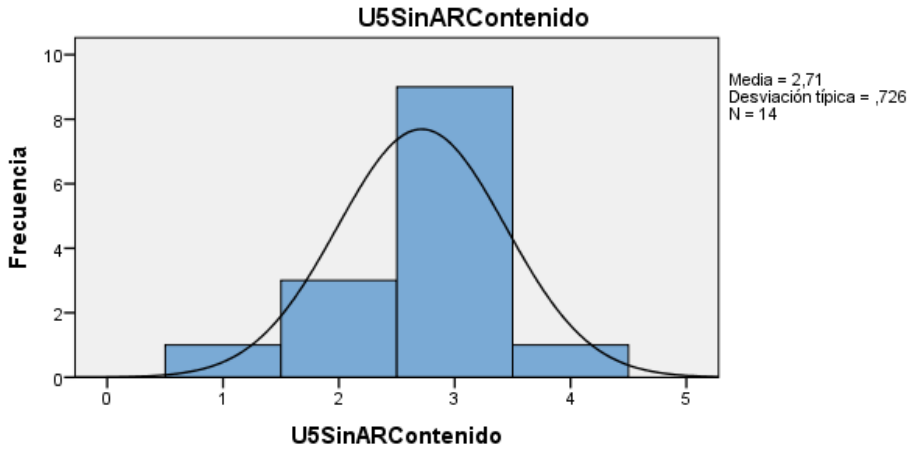

Figure 6. UD5 content dimension without AR

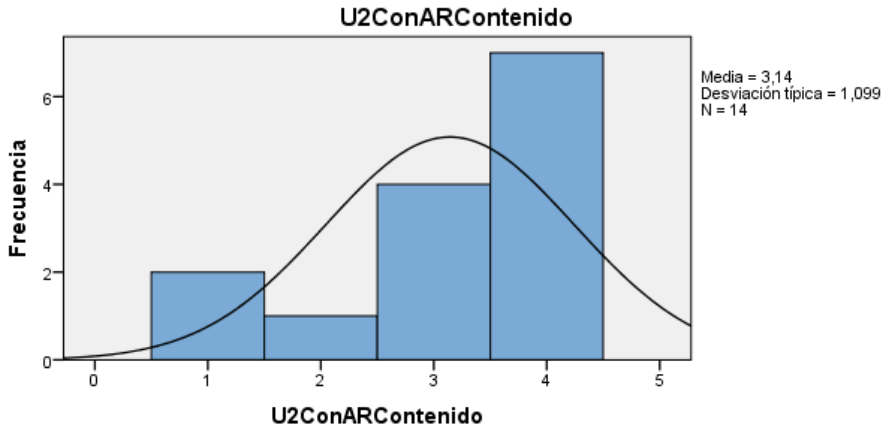

Figure 7. UD2 content dimension with RA

Unit 3 with AR and unit 4 without AR

Table 8
Content dimension analysis UD3 with AR and UD4 without AR

		U3 with AR content	U4 without AR content
N	Valid	13	13
Mean		3,69	3,38
Median		4,00	3,00
Standard deviation		,480	,506
Minimum		3	3
Maximum		4	4

Note: own elaboration

When analyzing the data obtained in didactic unit 3 with AR in Table 8, it is observed that the mean is 3.69, and that in didactic unit 4 without AR it is 3.38. This points out that when using AR, the average number of students shifts towards the maximum value, which implies a higher number of students between the mastery and learner levels in the dimension of content comprehension. On the other hand, the decrease in the standard deviation reflects that there are no students from group A in the lower levels; therefore, there are no comprehension difficulties. Regarding Figures 8 and 9, it is observed that the number of students in mastery level grows significantly when AR is used in the implementation of the didactic unit.

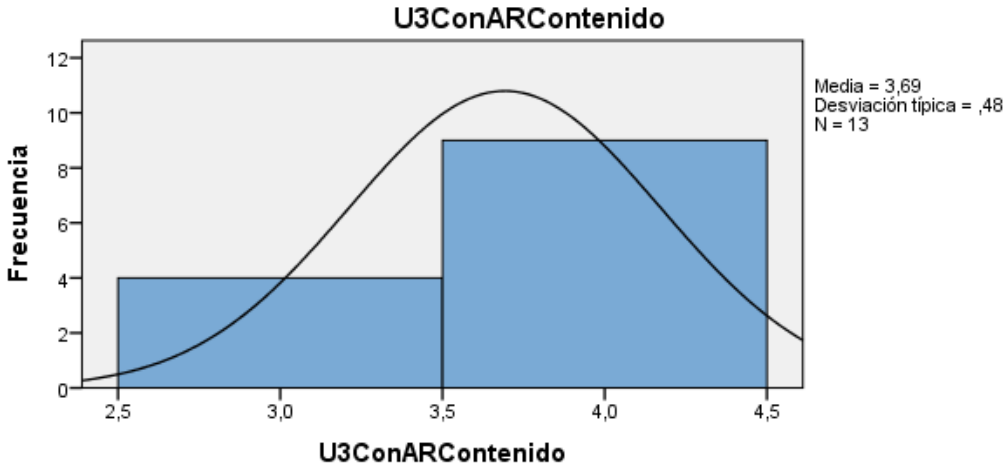

Figure 8. UD3 content dimension with R

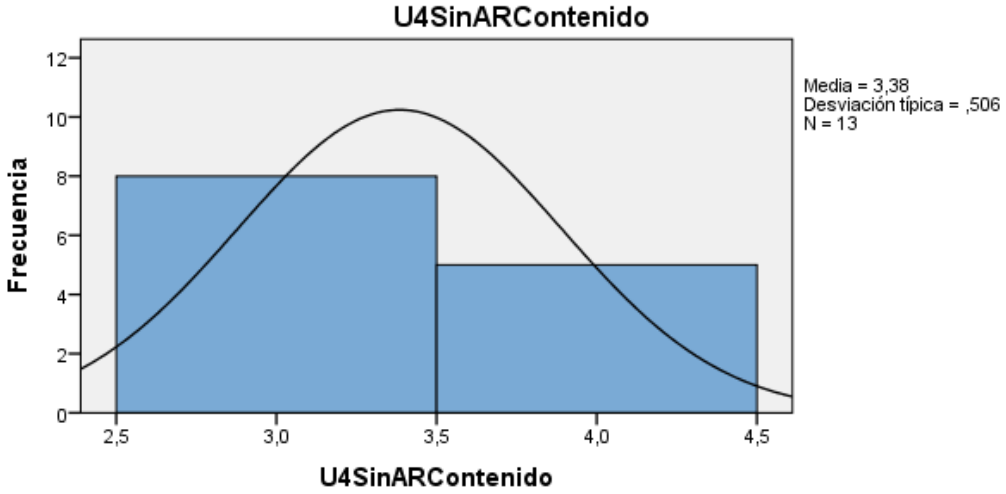

Figure 9. UD4 content dimension without RA

Dimensional analysis of AR and non-AR methods

Unit 2 with AR and unit 5 without AR

Table 9
Analysis dimension of UD2 with AR and UD5 without AR methods

		U2 with AR methods	U5 without AR methods
N	Valid	14	14
Mean		3,00	2,71
Median		3,00	3,00
Standard deviation		1,109	,611
Minimum		1	2
Maximum		4	4

Note: own elaboration

When analyzing the data obtained in didactic unit 2 with AR in Table 9, it is observed that the mean is 3.00, and that in didactic unit 5 without AR it is 2.71. This shows that when using AR, the average number of students shifts towards the maximum value, which implies a higher number of students between the mastery and learner levels in the dimension of understanding methods. On the other hand, the increase in the standard deviation reflects that there is a percentage of the student group that is in the lower levels; therefore, difficulties are present. This is positive insofar as it allows us to identify more easily the cases in which students show shortcomings in comprehension, and these can be addressed in a particular way.

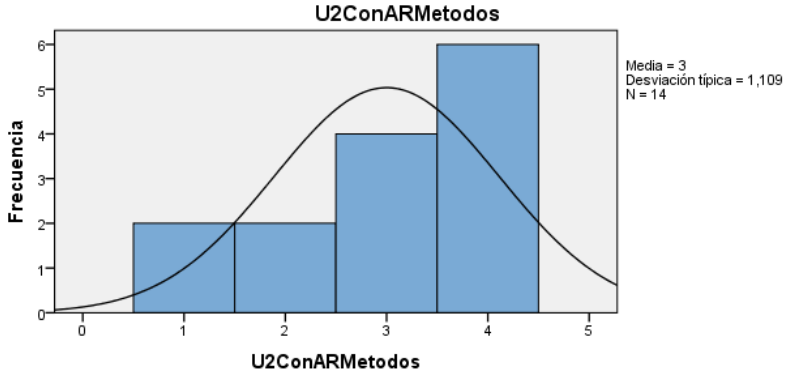

Figure 10. UD2 method dimension with RA

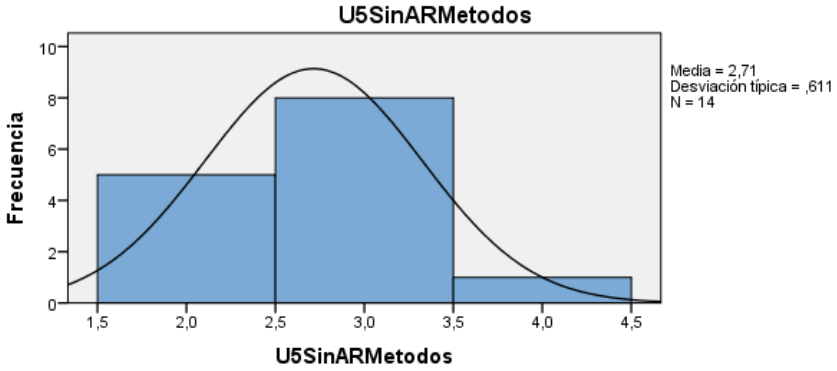

Figure 11. UD5 method dimension without AR

As for figures 10 and 11, it is observed that the number of students at the mastery level grows significantly when AR is used in the implementation of the didactic unit.

Unit 3 with AR and unit 4 without AR

Table 10
Method dimension analysis UD3 with RA and UD4 without RA

		U3 with AR methods	U4 without AR methods
N	Valid	13	13
Mean		3,54	3,31
Median		4,00	3,00
Standard deviation		,660	,630
Minimum		2	2
Maximum		4	4

Note: own elaboration

When analyzing the data obtained in UD3 with AR in Table 10, it is observed that the mean is 3.54, and that in UD4 without AR it is 3.31. This points to the fact that by using AR the average number of students shifts towards the maximum value, which implies a higher number of students between the mastery and learner levels in the dimension of understanding methods. On the other hand, the increase in the standard deviation shows a group of students in the lower levels; these still present difficulties. This is positive, as it allows us to identify more easily the cases in which students show deficiencies in comprehension; thus, they can be attended to in a particular way.

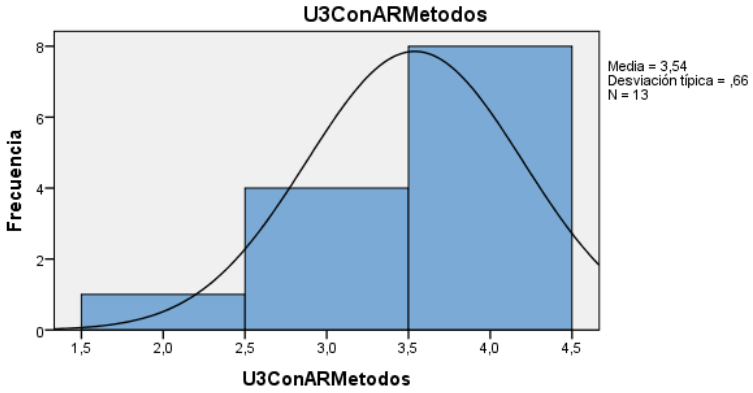

Figure 12. UD3 method dimension with AR

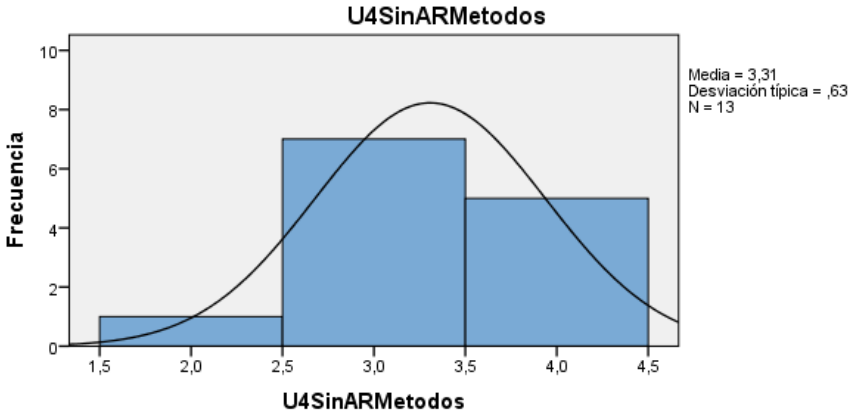

Figure 13. UD4 method dimension without RA

As for figures 12 and 13, it is observed that the number of students at the mastery level grows significantly when AR is used in the implementation of the didactic unit.

Purpose dimension analysis with AR and without AR

Unit 2 with AR and unit 5 without AR

Table 11
Purpose dimension analysis UD2 with AR and UD5 without AR

		U2 with AR purposes	U5 without AR purposes
N	Valid	14	14
Mean		2,93	2,71
Median		3,00	3,00
Standard deviation		1,072	,726
Minimum		1	1
Maximum		4	4

Note: own elaboration

When analyzing the data obtained in didactic unit 2 with AR in Table 11, it is observed that the mean is 2.93, and that in didactic unit 5 without AR it is 2.71. This indicates that by using AR the average number of students shifts towards the maximum value, which implies a higher number of students between the mastery and learner levels in the dimension of purpose understanding. On the other hand, the increase in the standard deviation shows a group of students in the lower levels; therefore, they still present difficulties. This is positive insofar as it allows us to identify more easily the cases in which students show deficiencies in comprehension; thus, they can be attended to in a particular way.

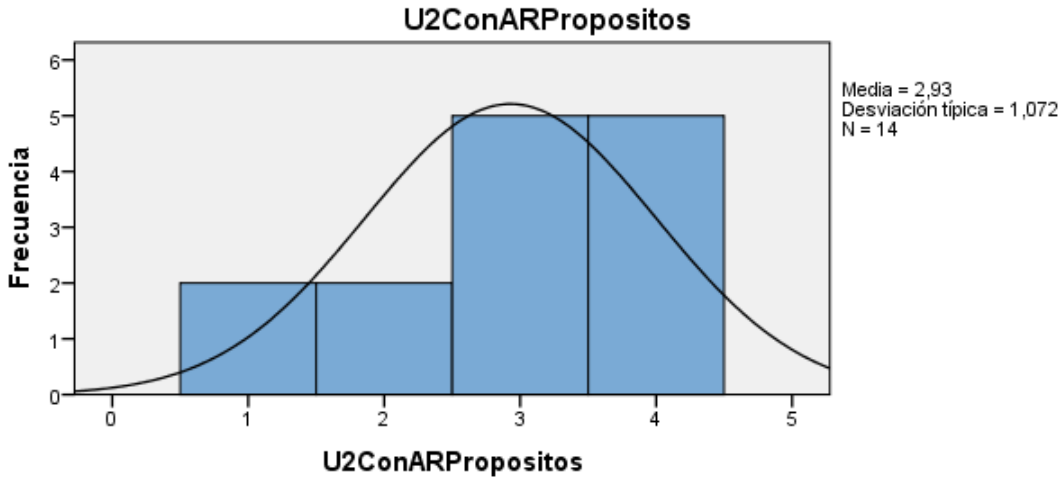

Figure 14. UD2 purpose dimension with RA

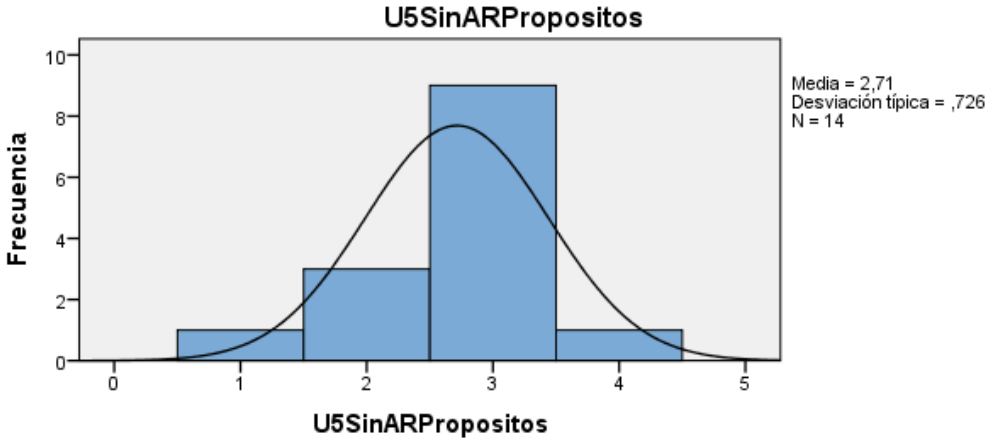

Figure 15. UD5 purpose dimension without RA

As for figures 14 and 15, it is observed that the number of students at the mastery level grows significantly when AR is used in the implementation of the didactic unit.

Unit 3 with AR and unit 4 without AR

Table 12
Purpose dimension analysis U32 with AR and UD4 without AR

	U3 with AR purposes	U4 without AR purposes
N Valid	13	13
Mean	3,62	3,15
Median	4,00	3,00
Standard deviation	,650	,899
Minimum	2	1
Maximum	4	4

Note: own elaboration

When analyzing the data in didactic unit 3 with AR in Table 12, it is observed that the mean is 3.62, and that in didactic unit 4 without AR it is 3.15. This indicates that by using AR the average number of students shifts towards the maximum value, which implies a higher number of students between the mastery and learner levels in the dimension of purpose comprehension. On the other hand, the decrease in the standard deviation shows a more homogeneous group of students approaching the higher levels. With respect to Figures 16 and 17, it is observed that the number of students at the mastery level grows significantly when AR is used in the implementation of the didactic unit.

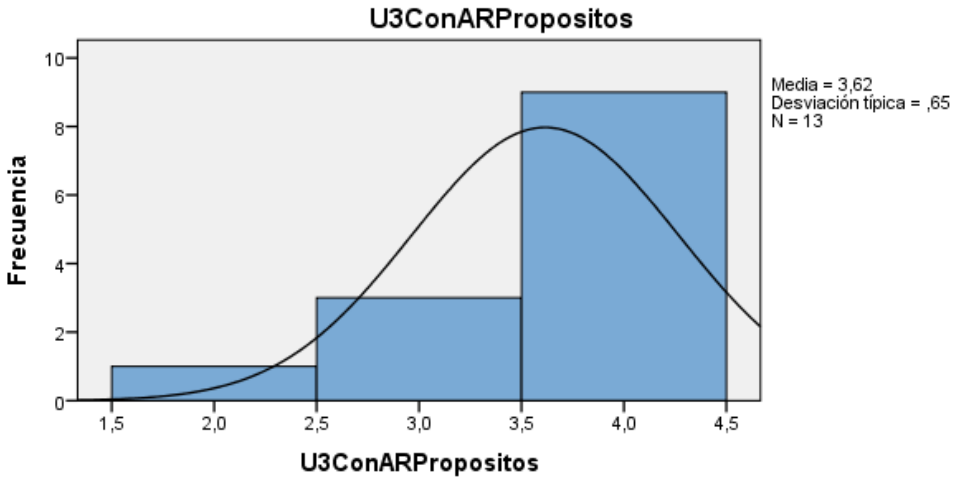

Figure 16. UD3 purpose dimension with RA

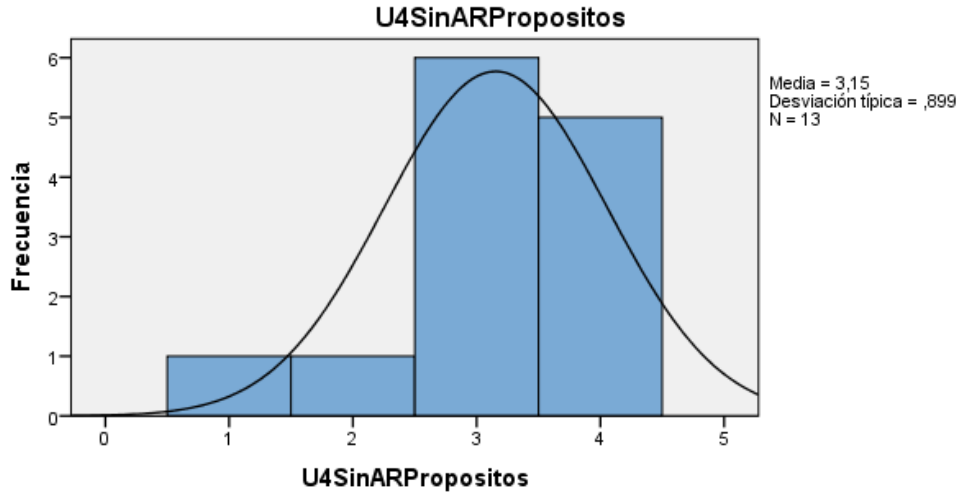

Figure 17. UD4 purpose dimension without AR

Dimensional analysis of AR and non-AR forms of communication

Unit 2 with AR and unit 5 without AR

Table 13
Communication dimension analysis UD2 with AR and UD5 without AR

		U2 with AR communication	U5 without AR communication
N	Valid	14	14
Mean		2,79	2,57
Median		3,00	3,00
Standard deviation		1,122	,938
Minimum		1	1
Maximum		4	4

Note: own elaboration

When analyzing the data in didactic unit 2 with AR in Table 13, it is observed that the average is 2.79, and that in didactic unit 5 without AR it is 2.57. This means that when using AR, the average number of students shifts towards the maximum value, which implies a higher number of students between the mastery and learner levels in the dimension of communication comprehension. On the other hand, the increase in the standard deviation shows a group of students in the lower levels; therefore, they still present difficulties. This is positive insofar as it makes it easier to identify the cases in which students show comprehension deficiencies, and these can be addressed in a particular way.

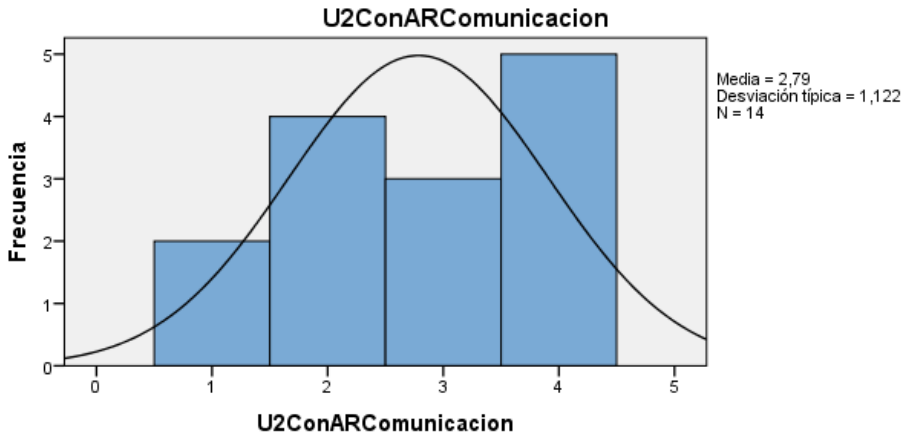

Figure 18. UD2 communication dimension with RA

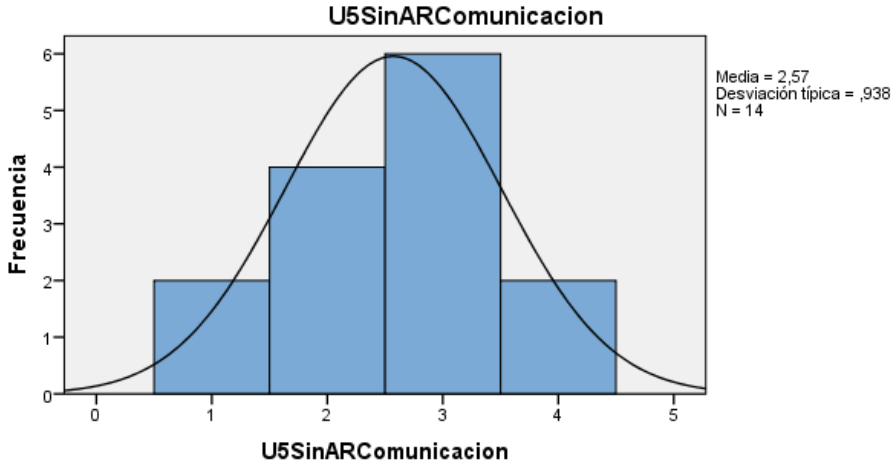

Figure 19. UD5 communication dimension without RA

As for figures 18 and 19, it is observed that the number of students at the mastery level grows significantly when AR is used in the implementation of the didactic unit.

Unit 3 with AR and unit 4 without AR

Table 14
Communication dimension analysis UD3 with AR and UD4 without AR

	U3 with AR communication	U4 without AR communication
N Valid	13	13
Mean	3,38	2,92
Median	3,00	3,00
Standard deviation	,650	,641
Minimum	2	2
Maximum	4	4

Note: own elaboration

When analyzing the data in didactic unit 3 with AR in Table 14, it is observed that the mean is 3.38, and that in didactic unit 4 without AR it is 2.92. This indicates that when using AR, the average number of students shifts towards the maximum value, which implies a higher number of students between the mastery and learner levels in the dimension of communication comprehension. On the other hand, the increase in the standard deviation shows a group of students in the lower levels; therefore, they still present difficulties. This is positive insofar as it allows us to identify more easily the cases in which students show comprehension deficiencies; thus, they can be addressed in a particular way.

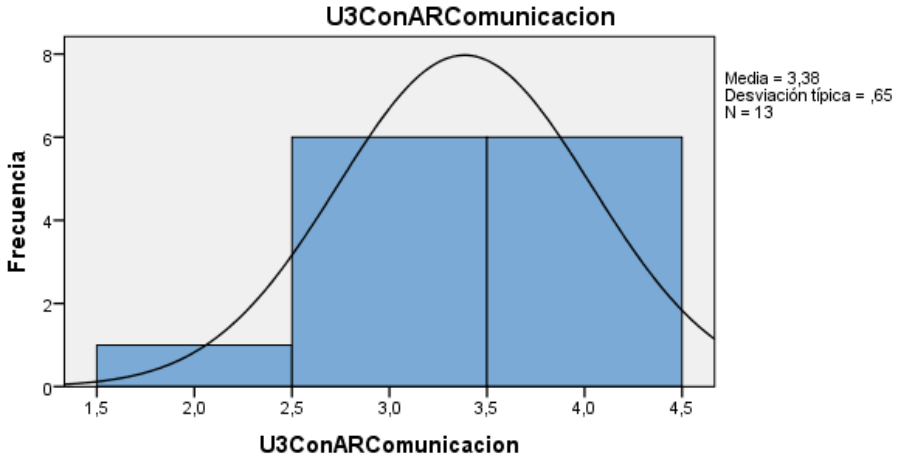

Figure 20. UD3 communication dimension with RA

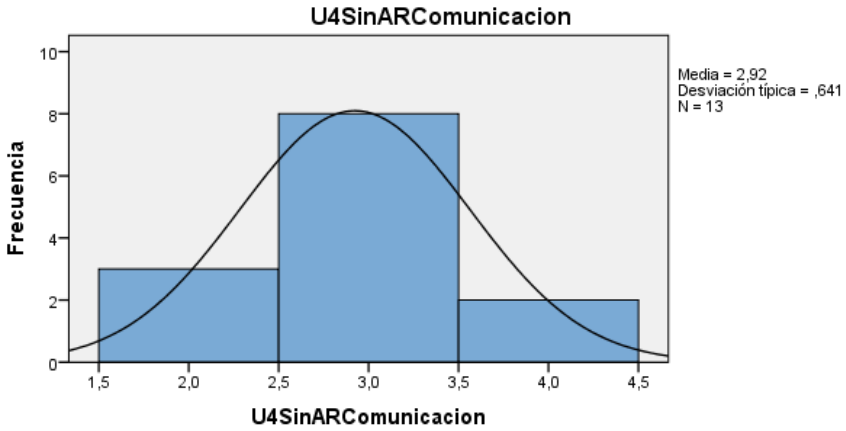

Figure 21. UD4 communication dimension without AR

As for Figures 20 and 21, it is observed that the number of students at the mastery level grows significantly when AR is used in the implementation of the didactic unit.

Discussion and conclusions

The following conclusions are established in relation to the objectives of this research and the results obtained. Taking into account the population under study, where the didactic units were implemented to determine whether AR mediation generated a differentiated effect in terms of learning and comprehension level in early childhood, it is concluded that the use of AR allowed obtaining "better results in an effective and significant way" (Buitrago-Pulido, 2015, p. 27), regarding comprehension in students who took the didactic unit with AR. The above was verified in the analysis of the differences in means between groups A and B, which a significant difference was observed; this implies that the group had a higher level of comprehension when working with AR.

Changes in the learning of preschool students at Colegio República de Colombia were identified according to what understanding means for the present study. In the words of Perkins (1999), as cited in Wiske (1999) "understanding is the ability to think and act flexibly, building on what one knows"; to put it another way, "understanding of a topic is the ability to perform flexibly with an emphasis on flexibility" (p. 11).

The results of the research are based on the theory of the conceptual framework of CPE and, specifically, on the conceptual model of understanding; this made it possible to discern, according to the students' performance, the changes in their understanding of the proposed work topics.

> Specifically, the methods dimension assessed students' ability to maintain a healthy skepticism about what they know or what they are told, as well as their use of reliable methods to construct knowledge and validate information. (Wiske, 1999, p. 232).

In the didactic units with AR, it was evident that students used different methods to validate and construct their knowledge. In the "purposes" dimension, it was evaluated, among other things, "the students' ability to use knowledge in multiple situations and the consequences of doing so" (Wiske, 1999, p. 235). In the didactic units with AR, a greater

interest and the ability to use knowledge in the development of the activities proposed was verified.

"The dimension of forms of communication evaluated the students' use of symbol systems (visual, verbal, mathematical, and bodily kinesthetic, for example) to express what they know" (Wiske, 1999). Likewise, in the didactic units with AR, different ways of communicating constructed knowledge were found.

If it is considered that, prior to the execution of the didactic units, none of the students had undergone a teaching-learning process with AR, the levels achieved in the dimensions of comprehension support changes in learning, which were sought with the present research:

The results show a determinant role of ICTs and, specifically, AR, in order to increase students' comprehension levels. It is also shown how the use of AR resources has a positive impact on the growth of comprehension levels for each of the dimensions considered in the conceptual framework of comprehension, especially in the dimension of forms of communication.

This situation is explained by considering the number of possibilities that ICTs offer to develop the criteria of this dimension and the ease of use of these by students thanks to their native digital competencies and the level of motivation they awaken in them. Therefore, when referring to educational practices, UNESCO supports the development of initiatives "aligned with the interests and characteristics of each student and the demands of the knowledge society" (UNESCO, Regional Bureau for Education in Latin America and the Caribbean, Orealc, 2013). The existence of invaluable and numerous resources offered by ICTs to support the educational processes is known, but these require the evaluation of the experts participating in the research, together with the support of the teacher-researcher. The latter knows the work methodologies at the preschool level to adapt the self-created applications to the contents, the characteristics of the students, and the context.

Cabero (2009) understood ICTs as tools to be developed in educational environments, where students construct their own knowledge through interaction with its elements. In this sense, the results of the present research show that AR, although an emerging technology, is suitable for use in educational environments; specifically, in early childhood education.

The results of the research show the positive impact that AR has on the learning of preschool students in the transition grade. However, what is most remarkable in this process is related to the way in which the different AR resources supported the comprehension processes and their determining and increasing role in this; especially, regarding the development of the dimension of the forms of communication.

The didactic units also worked without AR without minimizing the role played, considering the consistency of the pedagogical approach, the didactic strategies proposed, and the contents managed through the units. However, the same results were not achieved with and without AR, especially in the dimension of forms of communication, where AR allowed students to express their performances with resources that aroused greater interest and motivation. "ICTs offer a potential not only motivator but also structurer in student learning" (Perochena, 2009). On the other hand, through the performance in the didactic units with AR, students were given the opportunity to explore their abilities, live their passion, and visualize their potential.

The research shows the positive impact that AR has on the learning of transition students. In this sense, and referring to the conclusions provided in this study, it was considered interesting to propose criteria and guidelines to keep in mind when undertaking similar AR experiences. As a basis for this study, several lines of research can be considered for the future.

Starting with the theoretical framework and regarding the technological development of AR, in this research we worked on AR applications with markers. This could be a line of research in a study on AR applications that work without markers, through technologies such as ARKit and ARCore, where the space is recognized to make the superimposition of virtual elements in real space. This, in order to achieve a better integration of the elements, is what enhances interaction. The study of other types of commercial applications could also be deepened, in order to broaden the field of technical-pedagogical analysis of the applications; for this purpose, it is essential to evaluate the applications and their possible use in preschool.

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