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*Artículos científicos*

# Realidad aumentada como técnica didáctica en la enseñanza de temas de cálculo en la educación superior. Estudio de caso

## *Augmented Reality as a Didactic Technique in the Teaching of Calculus Topics in Higher Education. Case Study*

## *A realidade aumentada como técnica didática no ensino de disciplinas de cálculo no ensino superior. Estudo de caso*

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## Resumen

En este documento se presenta un estudio cuasiexperimental para medir el impacto de la realidad aumentada en el proceso de enseñanza-aprendizaje con alumnos del Tecnológico Nacional de México, campus Jerez, de la carrera de Contador Público. Se consideró un grupo de control y un grupo experimental. En el grupo experimental se utilizó una *app* de realidad aumentada como herramienta de apoyo, mientras que en el grupo de control se realizaron las clases de manera tradicional. En ambos casos la intervención se llevó a cabo exclusivamente en la asignatura de "Cálculo diferencial e integral". Se utilizó la prueba no paramétrica de Mann-Whitney-Wilcoxon para mostrar si había diferencia entre ambos grupos. Los resultados muestran que no hay diferencia si se utiliza realidad aumentada como herramienta de apoyo o se presentan las clases de forma tradicional. Sin embargo, los estudiantes que utilizaron la realidad aumentada consideraron que esta les ayudó a mantener la atención en el transcurso de la asignatura, así como a despertar o aumentar el interés por el contenido impartido.

**Palabras clave:** educación superior, enseñanza de las matemáticas, realidad aumentada.

## Abstract

In this document, a quasi-experimental study is presented which was designed to measure the impact of augmented reality on the teaching-learning process involving accounting majors from the Jerez Campus of the Mexican higher education institution Tecnológico Nacional de México. A control group and an experimental group were formed with students enrolled in the same Differential and Integral Calculus subject. An augmented reality app was used with the experimental group as a support teaching tool, while with the control group the lessons were carried out in a traditional fashion. The Mann-Whitney-Wilcoxon nonparametric test was used to show if there were any difference in academic performance between the groups. The results show that there is no difference whether augmented reality is used as a support teaching tool or classes are taught in a traditional fashion. However, the students who used augmented reality considered that it helped them to keep focused throughout the course, and that it likewise awakened or increased their interest on the subject.

**Keywords:** higher education, mathematics teaching, augmented reality.

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**Resumo**

Este documento apresenta um estudo quase experimental para medir o impacto da realidade aumentada no processo de ensino-aprendizagem com alunos do Instituto Tecnológico Nacional do México, campus Jerez, da carreira de Contador Público. Um grupo controle e um grupo experimental foram considerados. No grupo experimental, um aplicativo de realidade aumentada foi utilizado como ferramenta de apoio, enquanto no grupo controle as aulas foram ministradas de forma tradicional. Em ambos os casos a intervenção foi realizada exclusivamente na disciplina de "Cálculo diferencial e integral". O teste não paramétrico de Mann-Whitney-Wilcoxon foi usado para mostrar se havia diferença entre os dois grupos. Os resultados mostram que não há diferença se a realidade aumentada é utilizada como ferramenta de apoio ou as aulas são apresentadas de forma tradicional. No entanto, os alunos que utilizaram a realidade aumentada consideraram que ela os ajudava a manter a atenção ao longo do curso, bem como a despertar ou aumentar o interesse pelos conteúdos ministrados.

**Palavras-chave:** ensino superior, ensino de matemática, realidade aumentada.

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# Introduction

The human being currently lives in a changing and versatile state. The new forms of communication have revolutionized the way in which knowledge is created and disseminated, the way in which interpersonal relationships are given and the way education is given. This is largely due to the invention of the Internet. The last 100 years have contributed to the development of these social changes (from the Horra, 2017). Information and Communication Technologies (ICT) have influenced virtually all areas of knowledge: Health Sciences, Social Sciences, Fine Arts, Economics, Administration, Engineering, Education Sciences, for mentioning some.

In the field of education, as in many others, as technologies progress, the processes to interact also do so, hence, the human being is immersed in a constant change dynamics (Ballesteros and Bernal, 2016). The use of technology within classrooms at any educational level should be a support for the learning difficulties that the student has, without losing sight of that learning and knowledge to acquire should be the axis on which activities Educational spin, and not technology itself (blonde, habitar, Leiva, Moreno, Barroso and López, 2016).

For its part, Cupitra and Duke (2018) mention that the goal of ICT in education should be to generate and imagine new pedagogical strategies. Johnson, Smith, Willis, Levine and Haywood (2016, cited in maququil, seete and avilés, 2017) stand out from among the technologies that are currently being developed to augmented reality (RA), which is opening a space as an innovative resource in The educational terrain.

> The concept of RA refers to a technology based on the real world observation increased with additional information generated by computer (Buitrago, 2015). Berryman (2012, cited in Barba, Yasaca and Finger, 2015) adds that the RA is a third-dimensional image technology that imposes data originated by computers in geographic objects or places in the real world. This technology has three features. The first is that it combines the real and the virtual, the second peculiarity is that it is interactive and in real time and the third singularity is that it is recorded in 3D (Azuma, 1997). The concept was introduced for the first time by the American Tom Caudell in 1992, a researcher of the Boeing Aeronautical Company, after developing an experimental system that aimed at helping workers with the assembly of cables for their aircraft (Álvarez, Castle, Pizarro and Espinoza, 2017). This indicates that it is a term coined within the industry and not in the academic field.
>
> Some of the problems commonly present upper-level institutions are high rates of reprobation and desertion. Particularly, the low academic performance in the mathematics subjects is one of the problems that semiannually faces the Superior Technological Institute of Jerez (ITSJ), one of the campuses of the National Technology of Mexico (TECTM). Taking this situation into account, it was considered that the design and use of RA application (APP) would motivate the learning of some select mathematics issues, specifically in one of the subjects that presents higher reproving rates, calculation.

First, an app of RA was designed with the topic of functions. From the Horra (2017) mentions that there are different RA levels according to the type of interactivity:

- Zero level. QR codes.
- Level one. RA with markers.
- Level two. RA for geolocation.
- Level three. RA with Viewers (HDM, for its acronym in English).

The APP design stood at level two, since you do not need specific markers to work, and despite not using geolocation completely to establish an exact position, use capabilities that allow the mobile device to know its location and interact with objects 3D and the user. This is due, according to Amadeo (2017), to three key technologies: 1) Six degrees of freedom allow the phone to understand and track their position in relation to the world, using a process called simultaneous location and mapping (Slam, for its acronym in English); 2) Environmental understanding allows the telephone to detect the size and location of horizontal flat surfaces such as soil or a table, and 3) the light estimate allows the telephone to assess the current lighting conditions of the environment.

Second, a quasi-experimental design was carried out with a control group and another experimental. In the control group, the classes were taken traditionally and in the experimental group, activities were carried out using the RA App during the teaching of functions. At the end of the topic, a postst evaluation was applied in both groups to measure their academic performance.

At this point, it is not more likely to specify that the question that the research process was as follows: Does the use of the RA will improve the academic performance of the students in the topic of functions of the calculation subject?

For the design of the didactic tool, two main elements were considered. The first element was that the RA is a didactic tool posed by an active dynamic (Malaquyl et al., 2017). Likewise, Pedraza, Beloved, Lasso and Mungavar (2017) mention that the RA has a constructivist approach, since it includes the student within a physical and social context in the real world. The second aspect has to do with the fact that the tool was designed to deal with the topic of functions because it provides fundamentals for subsequent calculation topics, especially for limitations. The concept of limits is fundamental for many problems of engineering and physics, among other branches; In fact, the calculation is defined as the study of the limits (Purcell, Varberg y Rigdon, 2007).

As of the second half of the twentieth century, the increase of higher-level institutions in Latin America has been considerable. No doubt Higher Education plays an important role in the development of society. However, this increase brings its own difficulties, such as the low performance of students and high renovation rates. In the case of our country, Mexico, the flag indicators, school dropout and terminal efficiency are some of the main variables that explain poor academic performance levels (Edel, 2003).

Therefore, it is necessary to innovate existing educational practices, which will contribute to a certain extent to improving the academic performance of students. The use of ICT is a professional tool that every teacher should use. In that line, Cabero and Barroso (2016) mention that if a teacher wishes to enter into the use of ICT it requires seizing the knowledge of three areas: technology, content and pedagogical knowledge. Particularly, the RA is an emerging and innovative tool that improves the learning of the contents (from Cerro y Morales, 2017).

Tejedor and Muñoz (2007) mention that at the top level most of the school dropout occurred in the first years of career, especially in the first and second year. Without losing sight of this point, the present investigation was developed with first-year students. In addition, Ocampo, Martínez, from the sources and Zataraín (2010) indicate that at the higher education level, the higher reproving rates are presented in mathematics: for that reason the intervers will take place in the calculation subject.

There are several important references of research related to the use of ICT in higher education, particularly in the RA.

First, articles related to the systematic review of the use of the RA were analyzed. Skip and Arslan (2017), for example, filtered, as part of its systematic review, 23 items of a 102 search. The findings of this research show a better academic performance, increase in the commitment and satisfaction of students in environments educational favored with the use of the RA. Likewise, Lopes, Sartor, Pozzebon and Ferenhof (2019) conducted a systematic review to verify how the RA is being used in education. Among the results found is mentioned that the use of the RA in education in students increased motivation and academic performance. Lorenzo and Scagliarini (2018), for its part, carried out an investigation into the state of scientific production on the RA in education. They reviewed 347 articles published in the period 1990-2018 and found that between 2015 and 2017 there has been as many articles related to the RA in education (71%), that is, the RA, in the educational field, It is a subject that still has a lot to contribute, since it is a technology that is still booming.

Secondly, articles that develop RA experiences were analyzed in the teaching-learning process in higher education. As that of Barba et al. (2015), who carried out a global and specific assessment of the impact of the RA on the teaching-learning process in 63

students of Anatomy III at the Polytechnic High School of Chimborazo del Ecuador. From a quasi-experimental design with a control group and another experimental, its results show that the RA power more motivating, collaborative and interactive training scenarios and helps a more open and creative education. While Cabero, Fernández and Marín (2017) undertook a study with 148 students at the University of Seville, Spain, and found that there is a significant relationship between the motivation and use of notes with RA objects. On the other hand, round, Fonseca, Sánchez and Navarro (2017) describe an educational experience with 25 students of architecture using RA on mobile devices for learning urban design concepts. As in the previous case, from a quasi-experimental design with a control group and another experimental, they found that there was a significant improvement in the qualifications of the experimental group. In the end, the data obtained supported the hypothesis that RA technology is a valuable tool in the field of architecture.

In other areas of knowledge such as mathematics, physics and chemistry also found some experiences with the use of RA strategies. Buitrago (2015) conducted an investigation with 83 Industrial Engineering students from the Colombian School of Industrial Racing; He analyzed the association between the achievement of learning in mathematics, cognitive style and RA; He developed a quasi-experimental design with a control group and another experimental. The results show, in short, that it is significant to develop virtual learning environments. Also, the study of Álvarez et al. (2017), who developed a RA experience in the teaching-learning process of fluid mechanics, concludes that the RA allows better results regarding the acquisition of knowledge. Likewise, the parish work, Ramírez, González and Mendoza (2013) describes the development of a software application that uses RA for physics teaching with an experimental group (with the use of software) and a control group (Without the use of the software) and they verified that the first one has a profit on the second. Finally, the study conducted by Martínez, García and Escalona (2017) created objects from RA and were applied as means of teaching in the study of chemical compounds. The results showed that the RA contributed to increase interest in the subjects and expand the understanding of the contents.

While it is true that there is a variety of studies that report the use of the RA in education, the experiment conducted in this research, as a case of study, was directed to the use of this technology in the area of mathematics, particularly in the Theme of functions This

subject, by its nature of abstraction, is complex of teaching and difficult to understand / learn. Part of the importance of the study lies in the creation and implementation of RA App within the institution. The APP was generated based on the Study Study Program of the TechnMum.

# Materials and methods

## Design of the investigation

A quasi-experimental research was designed. Thus, considering that it is a case study, it was taken as a sample to the second semester of the ITSJ Career (CP) career of the semester January-June 2020, made up of 21 students. This was divided into two: a control group (10 students) and an experimental group (11 students). In both groups (control and experimental), the issue of functions of the subject of "differential and integral calculation" was taught. It is important to mention that prior to the experiment was asked for permission and consent to the students to carry out the experiment. In the classes of the experimental group, it was worked with a RA App for mobile devices that were previously designed and developed specifically for this purpose, because there was no application with the required features (this point is exposed more closely ). While in the control group the classes were taken traditionally. There were no a priori measurements, but yes a posteriori through a series of activities related to the issue of functions. The process was carried out as follows:

- A RA app focused on the topic of functions was designed and developed.
- An experimental ITSJ group (11 students) was chosen.
- An ITSJ control group (10 students) was chosen.
- The RA app was used in the experimental group as a support tool on the topic of functions.
- Classes were performed in the control group in the topic of functions.
- A posttest evaluation was applied to both groups to know the educational impact on each of them.
- A Likert survey of 11 items (Annex 1) was applied to the experimental group in order to collect student information regarding their knowledge of the RA, the availability of resources for its application, motivational criteria and criteria on the use of La Ra, taken from Martinez *et al*. (2017).

To compare if it existed or does not differentiate between the qualifications of the posttest assessment between both groups (control and experimental), the non-parametric test of Mann-Whitney-Wilcoxon, also known as Mann-Whitney test or as proof of the sum of the Wilcoxon ranges (Anderson, Sweeney and Williams, 2008). The test was used for the case of large samples ($n \geq 10$). In addition, this test does not require data to be normally distributed and the requirement is that the data measurement scale is ordinal. The test determines whether the two populations are identical or not.

## Creation gives the augmented reality app

For the development of the application, it was executed to be executed in Google's Android operating system for being an operating system with a free software license, as well as being the most used worldwide, with 74.45% of the total market, while IOS registers only 22.85%.

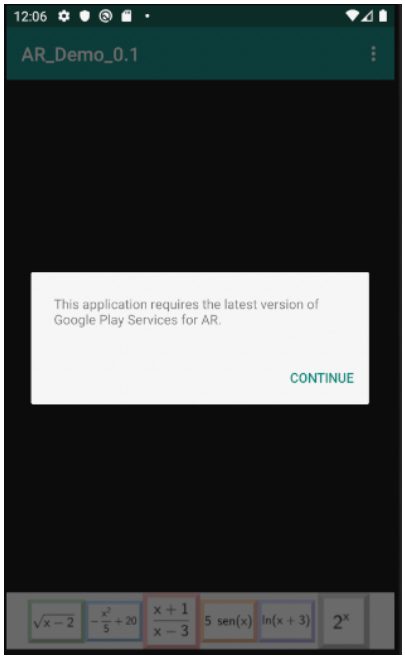
The classical software development methodology called Waterfall was used, in addition to scheduling natively through the Integrated Development Environment (IDE) supported by Google: Android Studio. The programming language used was Java.

With respect to the technology selected for the implementation of the RA, various options were analyzed: VUFORIA, ARKIT, ARCORE and AR.JS. However, it was ARCORE from Google the option chosen due to the compatibility it has with Android, with the Java programming language and for free use. In addition, this technology implements the superposition of 3D models (third dimension) with RA through the recognition of flat surfaces, which avoids the need for markers or other extra options to be able to use the RA. To perform the 3D models necessary to be displayed within the application, Blender was used, also for free software.

## Analysis and design

Once the requirements were analyzed, an initial design was performed on the main screen where they are shown, in the form of buttons, the six basic functions that can be worked (see Figure 1).

**Figura 1**. Pantalla inicial

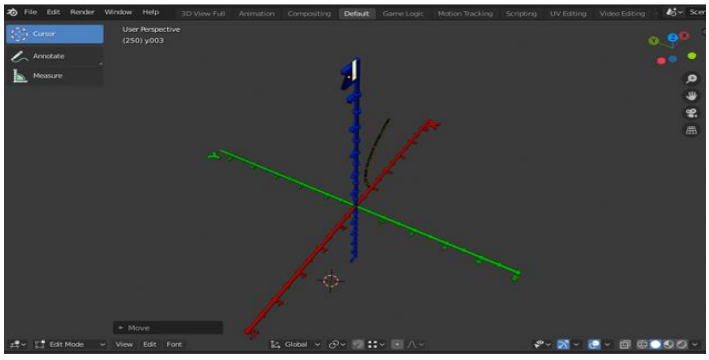



Fuente: Elaboración propia

## Models

For the development of the application, the 3D models were needed to be deployed by pressing the buttons. Said graphic models were performed through software called Blender. In Figure 2 the three-dimensional representation of the irrational function is shown $f(x) = \sqrt{x-2}$.

**Figura 2**. Modelo 3D de una función irracional



Fuente: Elaboración propia

In Figure 3 the three-dimensional representation of the polynomial function is shown $f(x) = -\frac{x^2}{5} + 20$.

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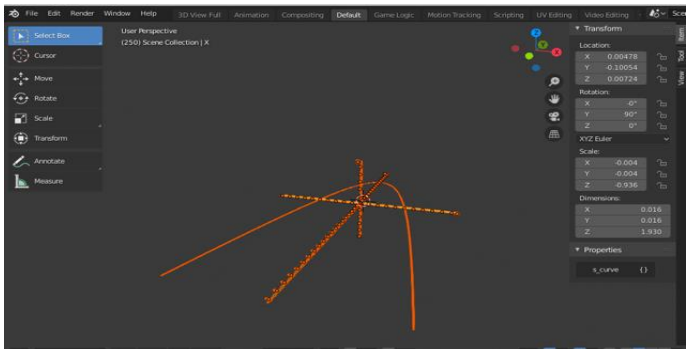
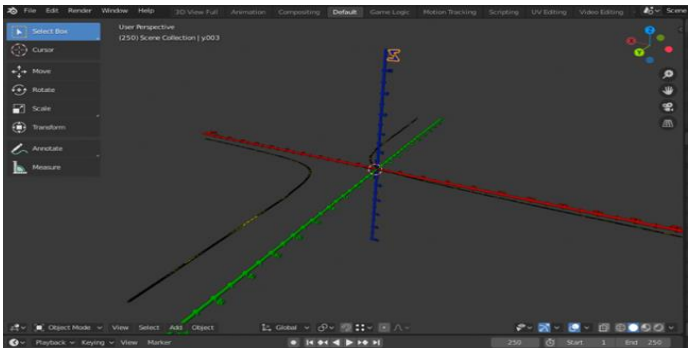
**Figura 3**. Modelo 3D de una función polinómica



Fuente: Elaboración propia

In Figure 4 the three-dimensional representation of the rational function is shown $f(x) = \frac{x+1}{x-3}$.

**Figura 4**. Modelo 3D de una función racional



Fuente: Elaboración propia

Figure 5 shows the three-dimensional representation of the trigonometric function $f(x) = 5sen(x)$.

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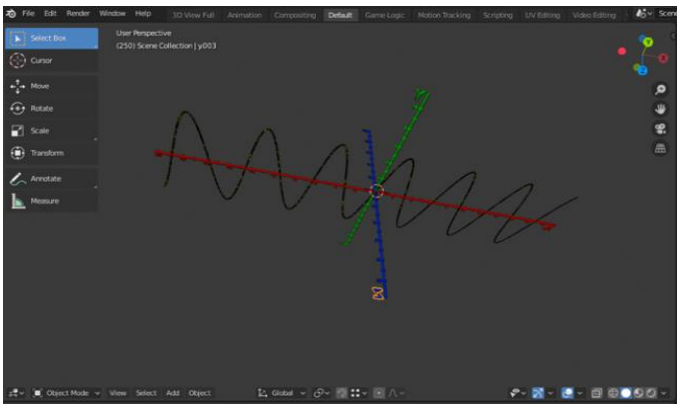
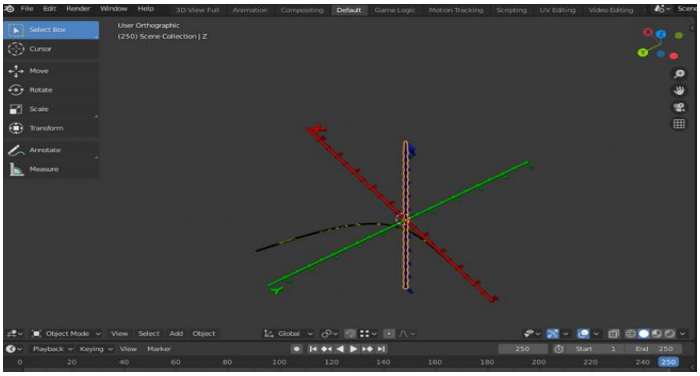
**Figura 5**. Modelo 3D de una función trigonométrica



Fuente: Elaboración propia

In Figure 6 the three-dimensional representation of the exponential function is shown $f(x) = 2^x$.

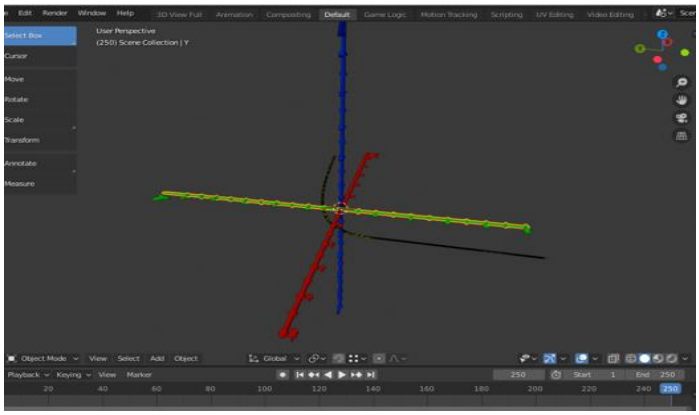
**Figura 6**. Modelo 3D de una función exponencial



Fuente: Elaboración propia

In Figure 7 the three-dimensional representation of the logarithmic function is shown $f(x) = ln(x + 3)$.

**Figura 7.** Modelo 3D de una función logarítmica



Fuente: Elaboración propia

## Android application

For the preparation of the application, the Google Development Guide for Arcore was used, following the process indicated in said tutorial, which is shown below:

*1)* Configure the development environment.

*2)* Open the example project.

*3)* Prepare the device or emulator for the execution and testing.

*4)* Execute the application

Whenever the correct execution of the example application was obtained, the relevant changes were made to adapt it to our project:

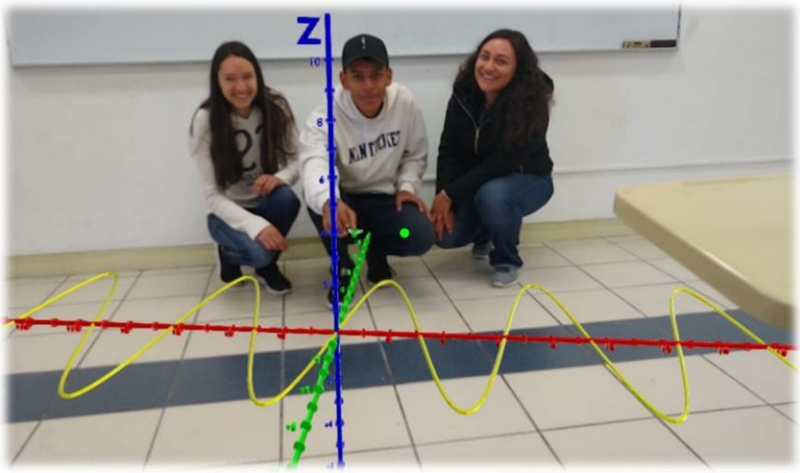
*1)* Adding 3D models of functions to be displayed.

*2)* Adapting the necessary code within the application.

*3)* Adding the code of the main menu to show the selected function.

An application for mobile devices with Android operating system was obtained that have an application programming interface (API) version 24 or later. The functionality of RA can be displayed on a flat surface, which will be automatically detected by the application, and once said that surface one of the functions that appear at the bottom of the main menu can be selected. A real application of the use of the APP is in Figure 8.

**Figura 8**. Ejemplo real de uso de la *app*




Fuente: Elaboración propia

## Study population

The population of this study was composed of the total of 21 students who attended the matter of "differential and integral calculus" during the semester January-June 2020 of the ITSJ of the CP race distributed as shown in Table 1.

**Tabla 1.** Distribución de alumnos que cursaron la materia de "Cálculo diferencial e integral" durante el semestre enero-junio de 2020 del ITSJ

| Grupo | Carrera | Hombres | Mujeres | Total |
|---|---|---|---|---|
| Experimental | CP | 4 | 7 | 11 |
| Control | CP | 3 | 7 | 10 |
| Total | | 7 | 14 | 21 |

Fuente: Elaboración propia

## Data collection

First, two sets of qualifications of each group (control and experimental) were collected after applying the Post with a total of 36 successes (see Table 2 and 3). Secondly, a survey taken from Martínez et al was applied. (2017) to obtain information from students in relation to the RA (see Annex 1). The reliability of the instrument was verified and an alpha of Cronbach of 0.733 was calculated.

**Tabla 2**. Aciertos del grupo experimental

| Núm. | Aciertos (36) |
|---|---|
| 1 | 34.0 |
| 2 | 28.5 |
| 3 | 34.0 |
| 4 | 23.0 |
| 5 | 24.0 |
| 6 | 36.0 |
| 7 | 28.0 |
| 8 | 34.0 |
| 9 | 17.0 |
| 10 | 19.5 |
| 11 | 25.5 |

Fuente: Elaboración propia

**Tabla 3**. Aciertos del grupo de control

| Núm. | Aciertos (36) |
|---|---|
| 1 | 31.0 |
| 2 | 15.5 |
| 3 | 24.5 |
| 4 | 19.5 |
| 5 | 20.0 |
| 6 | 25.0 |
| 7 | 25.5 |
| 8 | 29.5 |
| 9 | 36.0 |
| 10 | 27.0 |

Fuente: Elaboración propia

## Analysis of data

To compare whether or not it existed between the qualifications of the control group and the experimental group, the nonparametric test of Mann-Whitney-Wilcoxon was applied. The test determines whether the two populations are identical and, by extension, the hypotheses were the following:

- $H_0$: The two populations are identical.
- $H_1$: The two populations are not identical.

The test was used for the case of two large samples ($n \geq 10$). Since the samples sizes were $n_1 = 11$ y $n_2 = 10$, The approximation of the sample distribution of the sum of the T ranges, determined by:

- Average: $\mu_T = (1/2)(n_1)(n_1 + n_2 + 1)$.
- Standard deviation: $\sigma_T = \sqrt{(1/12)(n_1)(n_2)(n_1 + n_2 + 1)}$.
- Statistical Test Value: $Z = (T - \mu_T)/\sigma_T$ as $T$ is the sum of the ranks.
- A level of significance was considered $\alpha = 0.05$.

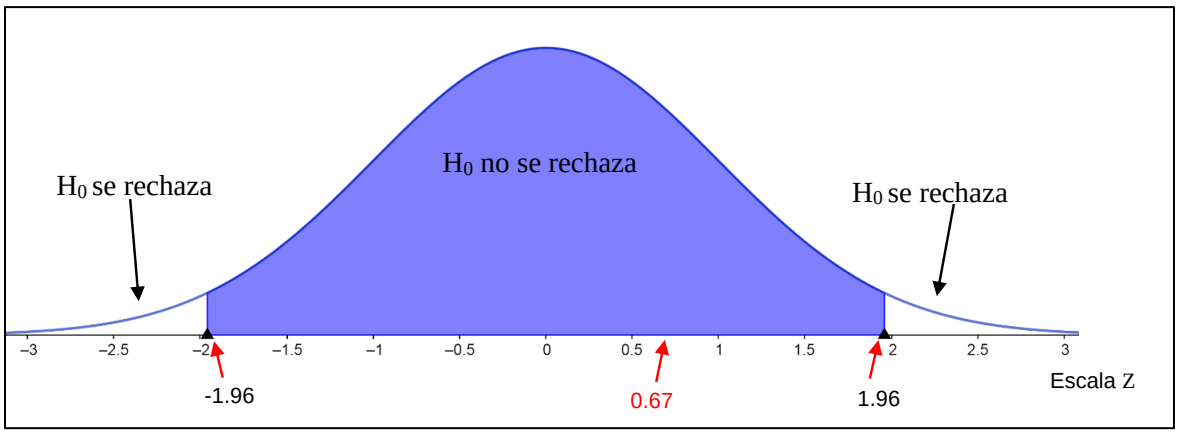
In addition to performing the calculations of the previous formulas manually, the SPSS version 22 software was used to verify them.

The results were:

- $\mu_T = 121$
- $\sigma_T = 14.201$
- $T = 130.5$
- $Z = 0.67$

In Figure 9 the previous amounts are represented; In addition, it is observed that Z value is in the area where H0 is not rejected, that is, as we do not have evidence to reject H0 we can conclude that the two populations are identical.

**Figura 9**. Distribución normal




Fuente: Elaboración propia

## Results

The analysis of the results of the research was carried out in two sections: the non-parametric test of Mann-Whitney-Wilcoxon and the results of Annex 1.

As observed in Figure 9, H0 is not rejected, that is, as we do not have evidence to reject H0 we can conclude that the two populations are identical. This means that in our case study, the use of the RA does not improve the academic performance of students in the topic of functions of the calculation subject. The qualifications obtained in the posttest of the control group and the experimental group are similar. On the other hand, let's see the results obtained in Annex 1, from which information of the students was collected in relation to their prior knowledge of the RA, the availability of resources for its application, motivational criteria and criteria on the use of the RA .

There are some data such as the following: 36.4% are men and 63.6% are women, an average age of 18.3 and a standard deviation of 0.47. As for the questions, 81.8% say that it knew the term RA, although 54.5% had not employed the RA; 81.8% mentions that the employment of the RA helped him maintain attention during the course; 72.7% consider that the RA is not so complex; 81.8% say that the interaction with the RA helped him in the interaction with the subject; 81.8% considered that the information provided by the RA aroused or increased interest in the subject, and 54.5% evaluated that the amount of activities were very few. Finally, 90.9% considered that as he worked with the RA, he felt safer than he could learn with this tool.

# Discussion

The RA is a tool that is being very used in different environments. Insert it into the teaching-learning process of the calculation, according to the results obtained, does not have a significant impact. However, in the questionnaire applied, most students considered that it felt safer when learning with this tool, which coincides with the quasi-experimental study carried out at 63 students at the Polytechnic High School of Chimborazo del Ecuador, whose results show that the RA strengthens more motivating, collaborative and interactive training scenarios (Barba et al., 2015).

On the other hand, round et al. (2017) carried out a similar experiment with 25 students using the RA on mobile devices and found that there was a significant improvement in the qualifications of the experimental group; Thus, in this particular case, they showed that RA technology is a valuable tool in the field of architecture. This study evidence that, indeed, the use of the RA improves the final ratings of students, however, the comparison of both studies is carried out with respect to the size of the sample, that is, they are small (similar) samples.

In this same order of ideas, Parroquín et al. (2013) describe the development of a software application that uses RA technology for the teaching of physics; Here it was also experienced a practice developed with RA in an experimental group, and in another control group the practice was developed in the usual way, without use of the software. In a part of their conclusions alludes to the realization of more learning tests. The comparison with this study is exhibited because the APP was created solely for use in the experiment in the Mathematics area.

It is a fact that, with the advancement of technology and with the use that this has had due to the pandemic by the COVID-19, the teaching practice will have to look for and build tools that are adaptable to various situations, tools that at all times They contribute to students in general, and in particular mathematics, appropriate knowledge from a new perspective, from their vision, which can no longer be separated from technology.

## Conclusions

RA applications are increasingly used in our environment: Medicine, advertising, engineering, tourism, museums, games, etc., and within the educational sector This technology is also present. This is largely due to the use of smartphones and tablets. In the experiment carried out asked as a question: Does the use of the RA allow to improve the academic performance of the students in the topic of functions of the calculation subject? The case study shows us that there is no difference if RA is used as a support tool or the classes are presented traditionally, that is, in terms of ratings there is no significant difference. However, the students who used the RA consider that this helped them maintain attention in the course of the subject; Likewise, he aroused or increased interest in the subject, and, in addition, a high percentage considered that as he worked with the RA, he felt safer than he could learn.

Taking into account the above, it can be considered that the RA has a high potential to be used in educational environments and that, in addition, the RA arouses interest among students. A disadvantage of this study is the size of the sample; It will be necessary for the following studies to increase the size of this and, on the other hand, create apps for different topics. While it is true that the RA will not be the perfect solution for the needs of education related applications, it is an option that can not be considered.

## Future lines of research

The use of technology that can complement traditional education and promote knowledge is a challenge for teachers, especially in the case. It will be a constant challenge for teachers the innovation of their teaching activities within classrooms. For the development of future research, the following actions are proposed: regarding the software, you can perfect some aspects of the RA app, there are opportunities to create a more dynamic, that is, that the student has the option to add their own function and That this is displayed in RA, since that created in this research was static and was only scheduled to be used with six different functions.

Considering that the RA allows visualizing the problem, it is proposed to replicate the study in other mathematics issues that are visual, such as the slope of the tangent, comprehensive defined transformations, linear transformations, system of linear equations and vector operations, to mention some . Finally, although it is true that there was no

significant difference in academic performance with or without the use of the RA, the experiment with larger samples can be repeated, in addition to incorporating non-specialized teachers in programming other subjects for the creation of objects with ra.

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**Annex 1. Survey of satisfaction**

We are doing an investigation into the use of an APP of augmented reality in higher education, we ask you to answer all the questions with the greatest sincerity. Your answers will be treated confidentially. Next to each statement, five options are presented, on a scale of one to five. Read each phrase carefully and then surround the number that best relates to what you do or think. You must choose only one.

- *1* = Totally in disagreement.
- *2* = Non-agreement.
- *3* = It's fine but…
- *4* = In agreement.
- *5* = Totally agree.

Thank you for your collaboration!

**Tabla 4**. Encuesta de Satisfacción

| | | | | | |
|---|---|---|---|---|---|
| Indica tu género | Hombre | | Mujer | | |
| Escribe tu edad actual (años) | | | | | |
| Indica la carrera que estudias | ISC | IM | IIA | LA | CP |
| Estudios de tu papá | Ninguno | Primaria | Secundaria | Bachillerato | Superior |
| Estudios de tu mamá | Ninguno | Primaria | Secundaria | Bachillerato | Superior |

| **Pregunta** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| *1)* Conozco el término *realidad aumentada.* | 1 | 2 | 3 | 4 | 5 |
| *2)* He empleado la realidad aumentada antes de este curso. | 1 | 2 | 3 | 4 | 5 |
| *3)* Cuento con los recursos necesarios para el uso de la realidad aumentada en el estudio independiente. | 1 | 2 | 3 | 4 | 5 |
| *4)* El empleo de la realidad aumentada en las clases me ayudó a mantener la atención en el transcurso de la asignatura. | 1 | 2 | 3 | 4 | 5 |

| | | | | | |
|---|---|---|---|---|---|
| *5)* La realidad aumentada es tan compleja que me fue difícil emplearla. | 1 | 2 | 3 | 4 | 5 |
| *6)* La interacción con la realidad aumentada me ayudó en la interacción con la asignatura. | 1 | 2 | 3 | 4 | 5 |
| *7)* La información que brinda la realidad aumentada me despertó o aumentó mi interés por la asignatura. | 1 | 2 | 3 | 4 | 5 |
| *8)* La cantidad de actividades en las que se empleó la realidad aumentada fueron muy pocas. | 1 | 2 | 3 | 4 | 5 |
| *9)* La variedad de temas presentados en realidad aumentada fue amplia. | 1 | 2 | 3 | 4 | 5 |
| *10)* En la medida que trabajé con la Realidad Aumentada me sentí más seguro de que podía aprender con esta herramienta. | 1 | 2 | 3 | 4 | 5 |
| *11)* Los modelos presentados en la realidad aumentada fueron muy pocos. | 1 | 2 | 3 | 4 | 5 |

Fuente: Tomada de Martínez et al. (2017).