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Learning mathematics with the use of simulation*

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Abstract

The purpose of this research work was to determine if the application of Phet Simulations improves the teaching and learning of equivalent fractions. It was of quantitative, experimental type, with a control group and an experimental group (test with the Phet simulator). The study population consisted of 40 eighth grade students of secondary education from the Educational Institution General Santander of Soacha (Cundinamarca province). Of the total of this study population, the experimental group (those who received the treatment) was made up of 20 students (11 men and 9 women); and the control group by 20 students (10 men and 10 women). In this case, the mean of the Experimental Group was statistically higher than the mean of the Control Group. That is to say, the academic performance of this group improved significantly when using the Phet simulator in the teaching of equivalent fractions.

Keywords: didactic strategy, equivalent fraction, simulation, information technologies.

Introduction

Internet is considered today as one of the most important phenomena of the beginning of the 21st century. Its development, together with the extraordinary progress in all communication and information techniques, can be compared to the birth of writing or printing.

The development of new information and communication technologies related to the Internet has opened new spaces in the educational field. The design of websites that integrate multiple multimedia applications is providing teachers, in general, new learning environments in which interactivity prevails; and the role of innovative teachers facilitate students to build their own knowledge.

However, it should be clear that although educational technology is an important element to improve teaching-learning processes, this improvement does not only depend on the use of educational software, but on its proper curricular integration, that is, of the educational environment designed by the teacher.

By using Phet simulations as an animated illustration, teachers find that it is easier to communicate effectively with their students. The Phet show dynamic processes, and these can be slow down, accelerated, or paused, depending on the concept shown; the invisible becomes visible; and multiple representations are linked. Finally, the **sims** are easily adjusted by the instructor during the debate. These features often make **sims** more effective for learning, and more practical to use static drawings or live demonstrations.

Phet has been designed to help students develop scientific research skills by exploring cause and effect relationships. Instructors can facilitate the consultation of the whole class by creating a scenario in the simulation, and asking students to predict the effect of manipulating variables. In these classrooms, students often spontaneously ask more; they also ask deep questions. It is common for them to ask for a series of "what if" questions, and direct the use of the sim card of the teachers.

Phet simulations allow assignments, as well as to use a guided research approach in which the students participate in the scientific-exploration as a direction that would normally require an instructor to be present, in order to facilitate the progress of the students.

How does this work? The simulation is designed to give signals to students to explore productively by using implicit (as opposed to explicit) guidance, with the choice of controls, visual representations, and the immediate feedback provided by visual changes. This approach allows the tasks to be less directed, and to use more open conceptual questions. (Muñoz, 2012: 1).

Now the simulators:

They are learning objects that through a software program try to model part of a replica of reality phenomena; their purpose is that the user builds knowledge from exploratory work, inference and discovery by learning (Peña and Alemán, 2013).

According to Fatela: "Digital simulators are interactive applications that simulate situations

of real physical experiments or that illustrate mathematical topics" (Fatela, 2012: 1). Simulators are programs that represent a dynamic model or environment, which through graphics or animations enable students to see what happens in the environment that is simulated; and which by interactively modifying the characteristics of the environment, allow the students to understand what happens in the environment that they are trying to know. Given the updating of technology, we should always be looking for new simulators that are more effective and interesting. (Ortega, 2001).

This in line with Bagur:

> Personally, I think that for these simulators to be fully successful, it is first necessary that teachers identify very well the elements of the subject to be taught, dealing with it by means of some examples, and then they use simulators as means of practice or evaluation. (Bagur, 2011: 2).

Mathematical simulators offer varieties of topics in this area of knowledge, contain a very didactic explanation, (which is) funny, entertaining, and above all, as clear as possible, with many examples of application to everyday life, so that the user gets the best out of this type of tools, which abound in the internet. (Duran, 2012).

According to Muñoz: "It is a page of great didactic value with very entertaining and interactive free simulations supported by research of the PhET project of the University of Colorado" (Muñoz, 2012: 1).

He adds that "Initially, the project focused on physics simulations and was named as the Physics Education Technology Project, or PhET. When they launched simulations of chemistry, biology, earth sciences, mathematics and other areas, they decided to keep the PhET name." (Muñoz, 2012: 1).

Given the importance of the use of simulators as a learning tool, several authors mention the following: Galicia (2005) in his thesis: "Virtual classrooms in the teaching-learning process at intermediate level, basic cycle, private sector of the urban area of the municipality de Jalapa" of the Faculty of Humanities of *Universidad de San Carlos de Guatemala*, highlights the progress of science and technology and the use of computers as necessary tools in all social areas.

His objective was to establish the importance of virtual classrooms in the teaching process. The sample was composed by a total of three hundred and seventeen subjects, corresponding to thirty percent (30%) of the student population; and fifty (50) teachers, corresponding to 30% of the educational centers of intermediate level, basic cycle, private sector of the urban area of the municipality of Jalapa (Jalapa province). There were used 2 questionnaires of 10 questions each as instruments. He concludes that students and teachers are aware that technology is useful to create a virtual classroom and improve methods, solve problems or needs in the teaching-learning process, and this way achieve a quality education. He recommends to professionalize teachers in order to acquire knowledge about the use and operation of virtual classrooms, and thus improve the methods and techniques used in the teaching-learning process. (Galicia, cited by Méndez, 2014).

He adds (Arbelaez, 2010) in his thesis: "Virtual worlds for health education simulation and learning in Open Simulator, at *Universidad de Caldas*, Manizales, Colombia," that the use of simulation and video game has been strongly transferred to industry, military practices and medicine, becoming a powerful training tool in recent years; in the area of medicine, simulators of equipment and devices for high-risk procedures and simulators have been developed to fortify educational processes in health; these instructions have been introduced to other areas, such as education.

Similarly, Pósito (2012) mentions that modern technological advances have achieved great impact on education, expanding educational scenarios, providing media and materials support to give interaction among persons. The objective was to offer technological and pedagogical solutions to the problem of the design of learning skills, in order to learn Natural Sciences in the new educational contexts.

García contributes (2012) in the thesis: "Promoting classroom learning strategies to raise the educational level of students in third primary (basic education) in the area of Mathematics of the Faculty of Humanities at University Rafael Landivar, Guatemala," reflecting on the inadequacies in the learning of mathematics by different factors, and highlighting the importance of using learning strategies to improve the academic level of students.

Materials and methods

The methodology used in this study was experimental-quantitative, with a control group and an experimental group (test with the Phet simulator). The study population consisted of 40 eighth grade students of secondary education from the General Santander Educational Institution of Soacha (Cundinamarca province). The innovation component is the technological one, as a means that projects a better learning in the students.

The project was carried out through a type of experimental piloting research, with a random assignment of a study group; in addition, it had to contain a control group, whenever possible. A quantitative design should only handle one variable at a time; otherwise, the statistical analysis can be very complex and open to questions.

One of the peculiarities of this methodology is that it allows us to assume the role of researchers and teachers; in this way, it will be possible to vary and make decisions in the prescribed experiments. The second characteristic is intervention, because we proposed to improve the learning of the elements of the quadratic function, through simulation practices of problem situations mediated by Phet, looking for students to make use of the diverse representations of this mathematical tool.

Population

This project focused on students of the afternoon shift; specifically, eighth grade students, whose ages ranged from 12 to 15 years. The sample was represented by 40 students.

Simple random sampling

Each of the elements of the sample was randomly selected, one by one. A raffle was held, with 20 ballots labelled as Experimental Group, and 20 labelled as Control Group; they were taken one by one, as much as indicated by the size of the sample; in this case, 40.

Hypothesis

The research hypothesis was designed as a causal relationship, and was stated as follows:

Alternate hypothesis (Ha): Using Phet simulations improves the grade point average for the subject "equivalent fractions" in eighth grade students.

Null hypothesis (Ho): Using Phet simulations does not improve the grade point average for the subject "equivalent fractions" in eighth grade students.

Statistical test: The value of significance of the test is $\alpha = 0.05$ (5%); if it is greater, the null hypothesis is accepted; if it is smaller, the null hypothesis is rejected. For a random (numerical) variable, it will be applied the Student's t test for difference of means in independent samples. This is a statistical test to evaluate if two groups differ significantly from their means. The SPSS v 23.0 software will be used.

Results

Interpretation of the results

Table 1. Results written test control group

Estudiante	Calificación
1	7
2	8
3	10
4	10
5	8
6	8
7	10
8	9
9	9
10	9
11	10
12	7
13	9
14	8
15	10
16	5
17	9
18	9
19	10
20	8

Table 2. Results virtual test experimental group

Estudiante	Calificación
1	9,1
2	9,1
3	10
4	10
5	10
6	9,1
7	10
8	10
9	10
10	10
11	10
12	9,1
13	10
14	10
15	10
16	10
17	8,3
18	10
19	9,1
20	10

Source: the author

Normality: It should be confirmed that the random variable in both groups is distributed normally. For this, the Kolmogorov-Smirnov test is used when the samples are large (> ~~of~~ 30 individuals); or the Chapiro Wilk test when the sample size is (< ~~of~~ 30 individuals). The criterion to evaluate if the (VA) is distributed normally is:

P-value = > α Accept Ho = Data comes from a normal distribution.

P-value < α Accept H1 = Data does NOT come from a normal distribution.

Equality of variance (Levene test). The equality of variance between the groups should be corroborated.

P-value = > α Accept Ho = Variance values are equal.

P-value < α Accept Ha = There is a significant difference between the variance values.

Calculate the p-value of the Student's t test, independent samples.

Criterion to determine normality:

P-value = > α Accept Ho = Data comes from a normal distribution.

P-value < α Accept Ha = Data does NOT come from a normal distribution.

Table 3. Normality tests

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistical	gl	Sig.	Statistical	gl	Sig.
Classification	Experimental	0,427	20	0	0,634	20	0
	Control	0,18	20	0,089	0,879	20	0,017

Source: the author

Table 4. Normality for (school) grades

Normal Ratings		
P-Value (EXP) = 0,00	<	α= 0.05
P-Valuer (CONTROL) = 0,89	<	α= 0.05
Conclusion: The variable "(school) grades" does NOT behave normally in any of the two groups.		

Source: the author

As the variable "(school) grades" did not behave *normally*, it was carried out an Anderson-Darling test:

> This is used to test whether a set of sample data comes from a population with a specific continuous probability distribution (usually, the normal distribution). The Anderson-Darling test is based on comparing the cumulative empirical probability distribution (data result) with the theoretical cumulative probability distribution (defined in H0) (López, 2011: 2).

The statistical value (A^2 = -81.96) is less than the critical value (A^2 Critical = 0.752); therefore, the null hypothesis is not rejected. For this reason, the observed data have a normal distribution nature.

Equality of variance

Levene test: P-value = > α Accept Ho = Variance values are equal.
P-value < α Accept Ha = There is a significant difference between the variance values.

Table 5. Student's t test, independent samples

		Levene's test of equality of variances		T-test for equality of means		
		F	Sig.	t	gl	Sig. (bilateral)
Qualification	Equal variances are assumed	13,586	0,001	3,515	38	0,001
	Equal variances are not assumed			3,515	24,346	0,002

Source: the author

Table 6. Equality of Variance

Equality of Variance			
P-Valor =	0,001	<	α= 0.05
Conclusion: Ha is accepted, There is a significant difference between variances.			

Source: the author

Table 7. T student's test (Statistical Decision)

T student test			
P-Value=	0,01	<	α= 0.05
Conclusion: There's a significant difference among the mean value of school grades for the experimental group and the mean value of school grades for the control group			

Source: the author

The criteria to decide are:

If the probability obtained from P-Value ≤ α, I reject Ho (Ha is accepted).

If the probability obtained from P-Value > α, I do not reject Ho (Ho is accepted).

Discussion

Contributing to improve the learning of fundamental concepts of mathematics, equivalent fractions in this case, through pedagogical innovation is a task of the teachers who teach this area of knowledge, in order to obtain the best results and motivate the students Therefore, it is important to know strategies and tools that accompany the learning of mathematics.

In the present investigation it was possible to identify that the Phet simulator applicable to the equivalent fractions and given the characteristics of its use online or download it to the computer, offers a free and interactive simulation.

The simulator applied in the present investigation is in the area of simulations of mathematics, simulators of fractions, of the website: https://phet.colorado.edu/es/simulation/fraction-matcher

The changes that are evident today cover virtually all human activities, from the political, economic, social and certainly education (all human activities: political, economic, social, and certainly, educational ones). This variable context intervenes in the way and style of life of the individuals that make up society, especially young people and adolescents.

One of the alternatives that exist today is the use of technology, which offers a range of tools for dissimilar activities of daily life. They facilitate a series of means that can be used for teaching work, and as a teaching-learning strategy for students.

The present study established the incidence of the use of the Phet simulator in the learning of the equivalent fractions of the eighth grade students of the Baccalaureate in mathematics of the General Education Institution Santander of the municipality of Soacha-Cundinamarca [for learning equivalent fractions, in eighth grade high-school students, enrolled in a mathematics subject at the Educational Institution General Santander of the municipality of Soacha (Cundinamarca province]. Arbeláez (2010) mentions that the use of simulation and video games has been transformed in recent years into a powerful training tool; Aguirre (2012) adds by explaining that simulation has become widespread in the last 20 years in the formation of the students of the world, due to the need that teachers have for using this didactic tool.

In this research, we worked specifically on the Phet simulator in Java language, applicable to equivalent fractions. From the results of this research, it can be asserted that the use of the Java simulator affects the learning of equivalent fractions; we can observe the significant difference between the statistical

data of the control group and the experimental group, as a result of the incidence of the use of simulators in the development of the didactic unit between both groups. The average score was 8.65 in the control group and the experimental group 9.19. (The average score was 8.65 in the control group, and 9.19 in the experimental group). In this case, the mean value for the latter is statistically greater than the mean value for the control group.

Arias (2009) emphasizes that simulation can be used as a resource for the formation of new concepts, such as for the acquisition of new knowledge, skills, strategies and behavior. Another study conducted by Méndez (2014) states: "The use of Java simulators improves the learning of the work-energy theorem between the pre-test and post-test of high school fourth-year students" (Méndez, 2014: 58).

Pérez highlights: "Simulators in education are a very useful learning tool; they help students and teachers to develop knowledge with a high degree of autonomy, understanding real situations." (Pérez, 2011: 5).

The Phet application as a virtual learning tool in the experimental group favored a new way of learning for eighth grade students of the I.E. General Santander of Soacha (Cundinamarca province).

Conclusions

The methodology supported in performing research works with the use of simulators encourages the evolution of the student's scientific affirmations towards a sketch more contiguous to scientific thought.

From the statistical analysis of the data by applying the Student's t test, it can be observed that there is evidence to reject the null hypothesis; therefore, the mean values are significantly different. In this case, the mean value of the experimental group is statistically greater than the mean value of the control group.

Implementing a virtual learning object (OVA, for its initials in Spanish) in the teaching of mathematics through Phet simulation showed a motivation on the part of the students, who according to the background, had not had the opportunity to interact with the technology within of a classroom in a more dynamic way in academic subjects other than technology and computer science; and when applying this concept to the mathematics classes, it was evidenced in the results obtained by the experimental group once the application phase of the OVA was finished.

It is important to mention the importance of the **talente** of the virtual object of learning, and the way in which it is elaborated, since if it is not interesting, it will not be impressive for students, who are increasingly visual in the educational field.

Information and communication technologies (ICT) favor a new form of teaching-learning, where virtual spaces are created that facilitate interactions between teachers and students, in order to improve and develop educational processes in any field.

The application of the Phet simulator allowed an active, participative and characteristic learning, increasing the level of student participation, the fulfillment of tasks and activities and interest in the subject of study, which was demonstrated.

The eighth grade students mostly hold opinions conducive to conducting research activities with the help of simulators.

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