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Uso del servicio en la nube GeoGebra durante el proceso enseñanza-aprendizaje sobre las matemáticas

Use of the GeoGebra cloud service during the teaching-learning process on mathematics

Uso do serviço da nuvem GeoGebra durante o processo de ensino-aprendizagem em matemática

Ricardo Adán Salas Rueda
Universidad La Salle, México
ricardo.salas@ulsa.mx

Resumen

Las universidades tienen la oportunidad de modificar las estrategias didácticas y los métodos educativos a través de las Tecnologías de Información y Comunicación (TIC). En particular, el servicio en la nube está transformando la interacción entre los participantes del proceso de enseñanza-aprendizaje en el siglo XXI debido a que el acceso, el almacenamiento y la distribución de la información se realizan desde cualquier lugar. Además, los estudiantes no necesitan instalar ningún programa en las computadoras y los dispositivos móviles para utilizar el servicio en la nube. El propósito de esta investigación cuantitativa es analizar el impacto del servicio en la nube GeoGebra en la Unidad didáctica Desigualdades lineales. La muestra está compuesta por 78 estudiantes que cursaron la asignatura Matemáticas intermedias para los negocios durante los ciclos escolares 2017, 2016 y 2015. El grupo experimental (31 alumnos) realizó cuatro prácticas de laboratorio sobre los temas de Desigualdad lineal, Sistema de desigualdades lineales, Función objetivo y Aplicaciones de las desigualdades por medio del servicio en la nube GeoGebra. Los resultados obtenidos permiten afirmar que GeoGebra es una aplicación útil y fácil para graficar las funciones, identificar las regiones y coordenadas en la gráfica, reconocer la región solución y asimilar

el conocimiento sobre los temas del álgebra. Incluso, los estudiantes están satisfechos de utilizar esta herramienta tecnológica en la Unidad didáctica Desigualdades lineales. Asimismo, el método ANOVA con los niveles de significancia 0.05 y 0.03 confirma que el servicio en la nube GeoGebra mejora el rendimiento académico de los estudiantes. En conclusión, GeoGebra representa una herramienta innovadora, creativa y útil para el área de las matemáticas.

Palabras clave: educación, enseñanza superior, GeoGebra, servicio en la nube, tecnología educativa, TIC.

Abstract

Universities have the opportunity to modify the didactic strategies and educational methods through Information and Communication Technologies (ICT). In particular, the cloud service is transforming the interaction between the participants in the teaching-learning process during the 21st Century because the access, storage and distribution of information take place from any place. Also, students do not need to install any program on the computers and mobile devices to use the service in the cloud. The purpose of this quantitative research is to analyze the impact of the GeoGebra cloud service in the didactic unit Linear inequalities. The sample is composed of 78 students who took the Intermediate Mathematics for business course during the 2017, 2016 and 2015 school cycles. The experimental group (31 students) carried out four laboratory practices on the topics of Linear inequality, Linear inequality system, Objective function and Applications of Inequalities through the GeoGebra cloud service. The obtained results allow affirming that GeoGebra is a useful and easy application to graph the functions, identify the regions and coordinates in the graph, recognize the solution region and assimilate the knowledge on the subjects of algebra. Even students are satisfied to use this technological tool in the Didactic Unit Linear Inequalities. Likewise, the ANOVA method with significance levels 0.05 and 0.03 confirms that the GeoGebra cloud service improves students' academic performance. In conclusion, GeoGebra represents an innovative, creative and useful tool for the area of mathematics.

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Keywords: education, higher teaching, GeoGebra, cloud service, educational technology, ICT.

Resumo

As universidades têm a oportunidade de modificar estratégias didácticas e métodos educacionais através das Tecnologias de Informação e Comunicação (TIC). Em particular, o serviço na nuvem está transformando a interação entre os participantes do processo de ensino-aprendizagem no século XXI, porque o acesso, armazenamento e distribuição de informações são feitos de qualquer lugar. Além disso, os alunos não precisam instalar nenhum programa em computadores e dispositivos móveis para usar o serviço na nuvem. O objetivo desta pesquisa quantitativa é analisar o impacto do serviço da nuvem GeoGebra na unidade didáctica Linear Inequalities. A amostra é composta por 78 alunos que tomaram o assunto Matemática Intermediária para Negócios durante os ciclos escolares de 2017, 2016 e 2015. O grupo experimental (31 alunos) realizou quatro práticas laboratoriais sobre os temas de Desigualdade Linear, Sistema de Desigualdades Lineares, Função objetiva e Aplicações de desigualdades através do serviço da nuvem GeoGebra. Os resultados obtidos permitem afirmar que a GeoGebra é uma aplicação útil e fácil de graficar as funções, identificar as regiões e coordenadas no gráfico, reconhecer a região da solução e assimilar o conhecimento sobre os temas da álgebra. Mesmo, os alunos estão satisfeitos em usar essa ferramenta tecnológica nas desigualdades lineares da Unidade didática. Do mesmo modo, o método ANOVA com os níveis de significância 0,05 e 0,03 confirma que o serviço de nuvem GeoGebra melhora o desempenho acadêmico dos alunos. Em conclusão, a GeoGebra representa uma ferramenta inovadora, criativa e útil para a área de matemática.

Palavras-chave: educação, ensino superior, GeoGebra, serviço em nuvem, tecnologia educacional, TIC.

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Introduction

Currently, educational institutions are supporting the creation and use of active methodologies in teaching to encourage participation and collaboration in the classroom (García, Urionabarrenetxea and Bañales, 2017, Kumar and Sharma, 2017). In fact, the use of digital tools in the field of education is growing because new generations are accustomed to using devices and programs (Stosic, 2015).

According to Abascal and López (2017, p.64), it is essential "to continue to cultivate a taste for learning to learn through the incorporation of new technological tools according to the new generations of students and the current context of information and social transformation. "

During the planning and organization of school activities it is necessary to consider the level of technological knowledge that students possess to achieve the optimal development of their competences (Castellanos, Sánchez and Calderero, 2017).

Information and Communication Technologies (ICT) are used in the field of education to motivate student learning and overcome problems related to the diversity of profiles and differences between generations (Abascal and López, 2017; Salas, 2016).

Even these digital tools allow the achievement of school goals, the identification of content and the establishment of conditions for learning (Badia, Chumpitaz, Vargas and Suárez, 2016). Other benefits of ICT in teaching are the increase of autonomy and the development of students' abilities (Abakumova, Bakaeva y Kolesina, 2016).

During the 21st century new ICTs are appearing for the teaching-learning process. In particular, the cloud service represents a technological alternative for the educational field by allowing access to applications from anywhere and without the need to install the software.

Therefore, this quantitative research proposes the incorporation of the GeoGebra cloud service during the teaching-learning process on linear inequalities. The research questions about the use of this emerging technology in the educational field are:

- What is the utility of the GeoGebra cloud service in the Linear Inequalities didactic unit?
- What is the ease of the GeoGebra cloud service in the Linear Inequalities didactic unit?
- What is the satisfaction of the GeoGebra cloud service in the Linear Inequalities didactic unit?
- What is the impact of the GeoGebra cloud service in the Linear Inequalities didactic unit?

Service in the cloud

Innovation through technology improves the efficiency of the teaching-learning process (Arsic and Milovanovic, 2016, Chiu and Li, 2015, Mahenge and Sanga, 2016, Novkovic and Stanojevic, 2017, Salas, 2017). In particular, the cloud service or Cloud Computing is an emerging technology that solves problems related to infrastructure, software and storage (Mathew, 2012).

It should be mentioned that the cloud service refers to the set of hardware, software, networks and storage over the Internet (Paul and Dangwal, 2015). In the field of education, this technological tool allows access, storage and distribution of resources at any time and place (Baris, 2015, Hew and Kadir, 2016, Lim, Gronlund and Andersson, 2015).

In fact, educational institutions are beginning to use cloud service to reduce costs (Changchit, 2015, Gutiérrez, Daradoumis and Jorba, 2015, Kumar, Kommareddy and Rani, 2013, Sharma and Kumar, 2017).

The advantages of the cloud service are the availability of information, creation of backups and dissemination of content (Mathew, 2012). In addition, students can access a wide variety of programs and resources for the purpose of personalizing the teaching-learning process (Wang, 2017).

Other benefits of software in the cloud are the elimination of the installation of applications, simplification of maintenance and access through the web browser (Mathew, 2012, Paul and Dangwal, 2015).

Currently, students are entering the cloud through mobile devices (Bebell, Clarkson and Burraston, 2014, Chang, Chen, Yu, Chu and Chien, 2017, Zhang, 2017).

It is worth mentioning that students obtain a better academic performance during the realization of activities through the cloud service (Despotovic, Simic, Labus, Milic and Jovanic, 2013, Li, 2016, Liu, Lan and Ho, 2014; Manca , Waters and Sandi, 2016; Segrelles, Martinez, Castilla y Molto, 2017).

For example, GeoGebra allows the construction of virtual environments for the teaching-learning process on mathematics (Zengin, 2017). Likewise, this tool is ideal for the educational field because it facilitates the understanding of the functions by means of the elaboration of the graphs (Takaci, Stankov and Milanovic, 2015).

Finally, the GeoGebra cloud service is free and improves the academic performance of students (Zengin y Tatar, 2017).

Method

This quantitative research was conducted at the La Salle University Campus in Mexico City. The sample consists of 78 students from the Business School who studied the subject Mathematics for business during the school years 2017, 2016 and 2015. In fact, the participants of this study take the Degrees in Administration, Accounting, Commerce, Marketing and Computers (ver Tabla 1).

Tabla 1. Grupos experimental y control.

No.	Grupo	Ciclo escolar	Semestre	Uso de GeoGebra	Alumnos
1	Experimental	2017	Enero-Junio	Si	31
2	Control 1	2016	Enero-Junio	No	28
3	Control 2	2015	Agosto-Diciembre	No	19

Fuente: elaboración propia.

The objectives of this study are:

- Analyze the utility, ease and satisfaction of the GeoGebra cloud service during the didactic unit Lineal Inequalities
- To evaluate the academic performance of the experimental and control groups during the examination of linear inequalities by means of the ANOVA method

The procedure begins with the design of the laboratory practices on the didactic unit Lineal inequalities through the use of the GeoGebra cloud service (ver Tabla 2).

Tabla 2. Actividades de enseñanza-aprendizaje.

No.	Práctica de laboratorio	Periodo	Objetivo didáctico	Ejemplo de ejercicio
1	Desigualdad lineal	Semana 1	Comprender el uso de la desigualdad lineal por medio de GeoGebra.	$6x + 2y \geq 60$
2	Sistema de desigualdades lineales	Semana 2	Comprender el uso de los sistemas de las desigualdades lineales por medio de GeoGebra.	$x + y \geq 60$ $2x + y \geq 90$
3	Función objetivo	Semana 3	Comprender el uso de las desigualdades lineales para maximizar o minimizar la función objetivo por medio de GeoGebra.	$x + y \geq 200$ $2x + y \leq 300$ Función objetivo: $2x + y$
4	Aplicaciones de las desigualdades	Semana 4	Comprender el uso de las desigualdades lineales en el contexto productivo por medio de GeoGebra.	Producción de piezas

Fuente: elaboración propia.

It is worth mentioning that the experimental group performed these laboratory practices through the GeoGebra cloud service during the 2017 school year. In addition, students access this application for free through Google Drive without installing any software.

At the end of the didactic unit Linear Inequalities, the Measurement Instrument 1 was applied to the students of the 2017, 2016 and 2015 school cycles (ver Tabla 3).

Tabla 3. Examen sobre las desigualdades lineales.

No.	Pregunta	Tema	Puntos
1	Graficar y encontrar la región solución para la siguiente desigualdad lineal: $12x + 4y \geq 60$	Desigualdad lineal	10
2	Graficar y encontrar la región solución para la siguiente desigualdad lineal $x + y \leq 60$ $2x + y \geq 80$	Sistema de desigualdades lineales	15
3	Graficar y encontrar la región solución. Además, maximizar la función objetivo. $x + y \leq 200$ $2x + y \leq 280$ Función objetivo: $5x + y$	Función objetivo	25
4	Determinada empresa desea minimizar los costos para los dos tipos de artículos que se producen (Tipo I y II). Máquina 1: Tipo I (4 minutos) y Tipo II (4 minutos) Máquina 2: Tipo I (2 minutos) y Tipo II (1 minuto) Por otro lado, el tiempo disponible de la Máquina 1 es de hasta 200 minutos y la Máquina 2 es de hasta 80 minutos. El costo de producir el Tipo I es de $4.00 y el Tipo II es de $2.00.	Aplicación de las desigualdades lineales	25
5	Cierta persona necesita cumplir con las recomendaciones del médico para mejorar su salud. El doctor recomendó consumir al menos 12 mg de Vitamina C y 16 mg de Vitamina D. Vitamina C: Producto 1 (1 mg) y Producto 2 (1 mg) Vitamina D: Producto 1 (2 mg) y Producto 2 (1 mg) El costo de cada pastilla para el Producto 1 es de $2.00 y para el Producto 2 es $4.00. Encontrar el número de pastillas que se deben consumir de cada Producto para minimizar el costo.	Aplicación de las desigualdades lineales	25

Fuente: elaboración propia.

The hypotheses used in this investigation are:

- Null hypothesis: The GeoGebra cloud service does not improve academic performance on linear inequalities.
- Alternative hypothesis: The GeoGebra cloud service improves academic performance on linear inequalities.

The ANOVA method with the levels of significance 0.05 and 0.03 evaluates the academic performance of the experimental and control groups by means of the scores obtained from the Measurement Instrument 1.

In February 2017, the experimental group answered the questions of the Measurement Instrument 2 about the student's profile (gender and degree) and the use of the GeoGebra software in the Linear Inequalities didactic unit. In fact, the utility, ease and satisfaction of this application in the cloud are evaluated through the categories Totally, Much, Regular, Little and Nothing (ver Tabla 4).

Tabla 4. Instrumento de Medición 2.

No.	Variable	Dimensión
1	Perfil de los estudiantes	Género
		Licenciatura
2	Utilidad del GeoGebra	Utilidad para graficar las desigualdades
		Utilidad para identificar las regiones en la gráfica
		Utilidad para identificar las coordenadas en la gráfica
		Utilidad para reconocer la región solución
		Utilidad para asimilar el conocimiento
3	Satisfacción del GeoGebra	Satisfacción para graficar las desigualdades
		Satisfacción para identificar las regiones en la gráfica
		Satisfacción para identificar las coordenadas en la gráfica
		Satisfacción para reconocer la región solución
		Satisfacción para asimilar el conocimiento
4	Facilidad de GeoGebra	Facilidad para graficar las desigualdades
		Facilidad para identificar las regiones en la gráfica
		Facilidad para identificar las coordenadas en la gráfica
		Facilidad para reconocer la región solución
		Facilidad para asimilar el conocimiento

Fuente: elaboración propia.

Finally, this study uses the spreadsheet to analyze the data collected about the students who took the subject Intermediate Mathematics for Business in the 2017, 2016 and 2015 school cycles.

Results

Academic performance

This research uses the ANOVA method with the levels of significance 0.05 and 0.03 to analyze the academic performance of the experimental and control groups of the 2016 school year through the Measurement Instrument 1.

The alternative hypothesis is accepted because the F value (6.0075) is higher than the critical values of 0.05 (4.0098) and 0.03 (4.9540). Therefore, the GeoGebra cloud service improves academic performance in the Linear Inequalities didactic unit (ver Tabla 5).

Tabla 5. Método ANOVA para los ciclos escolares 2017 y 2016.

Origen de las variaciones	Suma de cuadrados	Grados de libertad	Promedio de los cuadrados	F	Valor crítico 0.05	Valor crítico 0.03
Entre grupos	11.4873272	1	11.4873272	6.0075	4.0098	4.9540
Dentro de los grupos	108.992673	57	1.91215215			

Fuente: elaboración propia.

In the same way, the ANOVA method is used to evaluate the academic performance of the experimental group and control of the 2015 school year through the Measurement Instrument 1.

Table 6 shows that the alternative hypothesis is accepted again because the value F (5.3629) is higher than the critical values with the levels of significance 0.05 (4.0426) and 0.03 (5.0020).

Tabla 6. Método ANOVA para los ciclos escolares 2017 y 2015.

Origen de las variaciones	Suma de cuadrados	Grados de libertad	Promedio de los cuadrados	F	Valor crítico 0.05	Valor crítico 0.03
Entre grupos	10.1859182	1	10.1859182	5.3629	4.0426	5.0020
Dentro de los grupos	91.1662818	48	1.89929754			

Fuente: elaboración propia.

Table 7 shows that the experimental group has a higher grade point average than the control groups of the 2016 and 2015 school cycles during the examination of linear inequalities..

Tabla 7. Promedio de calificaciones del examen.

No.	Grupos	Ciclo escolar	Promedio	Varianza
1	Experimental	2017	9.41935484	1.36227957
2	Control 1	2016	8.53571429	2.52312169
3	Control 2	2015	8.48947368	2.79432749

Fuente: elaboración propia.

Utility of GeoGebra

This research analyzes the utility of the GeoGebra cloud service in the Linear Inequalities didactic unit. Table 8 shows that 54,839% of students consider that GeoGebra software is totally useful for graphing inequalities. Even, 35.484% is in the category Many.

Tabla 8. Utilidad del GeoGebra para graficar las desigualdades.

	Totalmente	Mucho	Regular	Poco	Nada
Administración	19.355%	9.677%	0.000%	0.000%	0.000%
Comercio	12.903%	9.677%	3.226%	0.000%	0.000%
Contaduría	9.677%	6.452%	0.000%	0.000%	0.000%
Mercadotecnia	9.677%	9.677%	3.226%	0.000%	0.000%
Informática	3.226%	0.000%	3.226%	0.000%	0.000%
Total	54.839%	35.484%	9.677%	0.000%	0.000%

Fuente: elaboración propia.

It is worth mentioning that 64.516% of the students think that this application is totally useful for the identification of the regions in the graph. In fact, Table 9 indicates that 87,097% is distributed in the categories Totally (64,516%) and Much (22,581%).

Tabla 9. Utilidad del GeoGebra para identificar las regiones en la gráfica.

	Totalmente	Mucho	Regular	Poco	Nada
Administración	19.355%	6.452%	3.226%	0.000%	0.000%
Comercio	19.355%	3.226%	3.226%	0.000%	0.000%
Contaduría	9.677%	3.226%	3.226%	0.000%	0.000%
Mercadotecnia	12.903%	6.452%	3.226%	0.000%	0.000%
Informática	3.226%	3.226%	0.000%	0.000%	0.000%
Total	64.516%	22.581%	12.903%	0.000%	0.000%

Fuente: elaboración propia.

Most of the university students who studied the subject of intermediate mathematics for business (54.839%) mention that the GeoGebra software is totally useful during the identification of the coordinates in the graph. However, 19.355% is located in the Regular category (see Table 10).

Tabla 10. Utilidad del GeoGebra para identificar las coordenadas en la gráfica.

	Totalmente	Mucho	Regular	Poco	Nada
Administración	16.129%	3.226%	6.452%	3.226%	0.000%
Comercio	16.129%	6.452%	3.226%	0.000%	0.000%
Contaduría	9.677%	6.452%	0.000%	0.000%	0.000%
Mercadotecnia	9.677%	6.452%	6.452%	0.000%	0.000%
Informática	3.226%	0.000%	3.226%	0.000%	0.000%
Total	54.839%	22.581%	19.355%	3.226%	0.000%

Fuente: elaboración propia.

According to the participants, the GeoGebra's usefulness to recognize the solution region has the highest preference in the category Totally (51.613%). It is worth mentioning that no student is in the categories Poco y Nada (ver Tabla 11).

Tabla 11. Utilidad del GeoGebra para reconocer la región solución.

	Totalmente	Mucho	Regular	Poco	Nada
Administración	16.129%	6.452%	6.452%	0.000%	0.000%
Comercio	16.129%	6.452%	3.226%	0.000%	0.000%
Contaduría	9.677%	3.226%	3.226%	0.000%	0.000%
Mercadotecnia	6.452%	12.903%	3.226%	0.000%	0.000%
Informática	3.226%	3.226%	0.000%	0.000%	0.000%
Total	51.613%	32.258%	16.129%	0.000%	0.000%

Fuente: elaboración propia.

The utility of this service in the cloud to assimilate the knowledge about the didactic unit Linear inequalities presents that 41.935% is located in the category Totally. On the other hand, the Regular category has 22.581% of the respondents (ver Tabla 12).

Tabla 12. Utilidad del GeoGebra para asimilar el conocimiento.

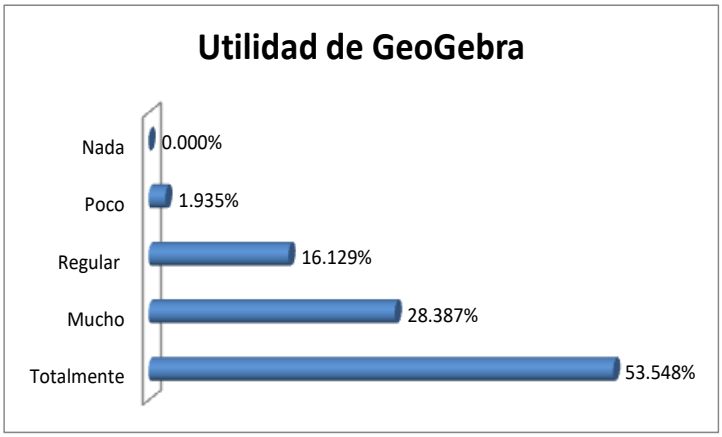
	Totalmente	Mucho	Regular	Poco	Nada
Administración	16.129%	3.226%	6.452%	3.226%	0.000%
Comercio	12.903%	6.452%	6.452%	0.000%	0.000%
Contaduría	6.452%	6.452%	3.226%	0.000%	0.000%
Mercadotecnia	3.226%	12.903%	3.226%	3.226%	0.000%
Informática	3.226%	0.000%	3.226%	0.000%	0.000%
Total	41.935%	29.032%	22.581%	6.452%	0.000%

Fuente: elaboración propia.

All dimensions of the GeoGebra Utility variable have a value greater than 40% in the Totally category.

In general, this variable presents the highest preference of students in the category Totally (ver Figura 1).

Figura 1. Utilidad de GeoGebra.



Fuente: elaboración propia.

Table 13 shows the correlation coefficient on the Utility of GeoGebra in the didactic unit Linear Inequalities. It is worth mentioning that the most significant relationship is located between the dimensions Identifying the regions in the graph and Recognizing the solution region with the 0.87304197.

Tabla 13. Coeficiente de correlación sobre la Utilidad.

	Graficar las desigualdades	Identificar las regiones en la gráfica	Identificar las coordenadas en la gráfica	Reconocer la región solución	Asimilar el conocimiento
Graficar las desigualdades	1				
Identificar las regiones en la gráfica	0.73426635	1			
Identificar las coordenadas en la gráfica	0.76302703	0.78367527	1		
Reconocer la región solución	0.59065947	0.87304197	0.82307401	1	
Asimilar el conocimiento	0.7732253	0.66683919	0.74486698	0.60883892	1

Fuente: elaboración propia.

GeoGebra satisfaction

Another aspect analyzed in this research is the Satisfaction of the GeoGebra cloud service during the teaching-learning process on linear inequalities.

According to university students, 45,161% are fully satisfied with using GeoGebra software to graph inequalities. Even, 41.935% of the respondents are in the category Much (ver Tabla 14).

Tabla 14. Satisfacción del GeoGebra para graficar las desigualdades.

	Totalmente	Mucho	Regular	Poco	Nada
Administración	22.581%	3.226%	3.226%	0.000%	0.000%
Comercio	9.677%	16.129%	0.000%	0.000%	0.000%
Contaduría	6.452%	6.452%	3.226%	0.000%	0.000%
Mercadotecnia	3.226%	12.903%	3.226%	3.226%	0.000%
Informática	3.226%	3.226%	0.000%	0.000%	0.000%
Total	45.161%	41.935%	9.677%	3.226%	0.000%

Fuente: elaboración propia.

Similarly, 45.161% of the students are totally satisfied with the use of this service in the cloud to identify the regions in the graph. Table 15 shows that 32,258% is in the category Many.

Tabla 15. Satisfacción del GeoGebra para identificar las regiones en la gráfica.

	Totalmente	Mucho	Regular	Poco	Nada
Administración	16.129%	3.226%	9.677%	0.000%	0.000%
Comercio	9.677%	12.903%	3.226%	0.000%	0.000%
Contaduría	12.903%	0.000%	3.226%	0.000%	0.000%
Mercadotecnia	3.226%	12.903%	6.452%	0.000%	0.000%
Informática	3.226%	3.226%	0.000%	0.000%	0.000%
Total	45.161%	32.258%	22.581%	0.000%	0.000%

Fuente: elaboración propia.

The GeoGebra software satisfaction variable shows that 77,419% of respondents are distributed in the categories Totally (38,710%) and Much (38,710%) for the identification of the coordinates in the graph (ver Tabla 16).

Tabla 16. Satisfacción del GeoGebra para identificar las coordenadas en la gráfica.

	Totalmente	Mucho	Regular	Poco	Nada
Administración	12.903%	9.677%	6.452%	0.000%	0.000%
Comercio	9.677%	12.903%	3.226%	0.000%	0.000%
Contaduría	9.677%	3.226%	3.226%	0.000%	0.000%
Mercadotecnia	3.226%	12.903%	3.226%	3.226%	0.000%
Informática	3.226%	0.000%	3.226%	0.000%	0.000%
Total	38.710%	38.710%	19.355%	3.226%	0.000%

Fuente: elaboración propia.

The majority of the respondents (38.710%) is totally satisfied about the incorporation of this service in the cloud to recognize the solution region during the didactic unit Linear Inequalities. However, 25.806% is located in the Regular category (ver Tabla 17).

Tabla 17. Satisfacción del GeoGebra para reconocer la región solución.

	Totalmente	Mucho	Regular	Poco	Nada
Administración	12.903%	6.452%	9.677%	0.000%	0.000%
Comercio	9.677%	12.903%	3.226%	0.000%	0.000%
Contaduría	9.677%	3.226%	3.226%	0.000%	0.000%
Mercadotecnia	3.226%	12.903%	6.452%	0.000%	0.000%
Informática	3.226%	0.000%	3.226%	0.000%	0.000%
Total	38.710%	35.484%	25.806%	0.000%	0.000%

Fuente: elaboración propia.

It should be mentioned that 38.710% of students are totally satisfied with the GeoGebra cloud service to assimilate knowledge about linear inequalities (see Table 18). In fact, 70.968% are in the categories Totally (38.710%) and Much (32.258%).

Tabla 18. Satisfacción del GeoGebra para asimilar el conocimiento.

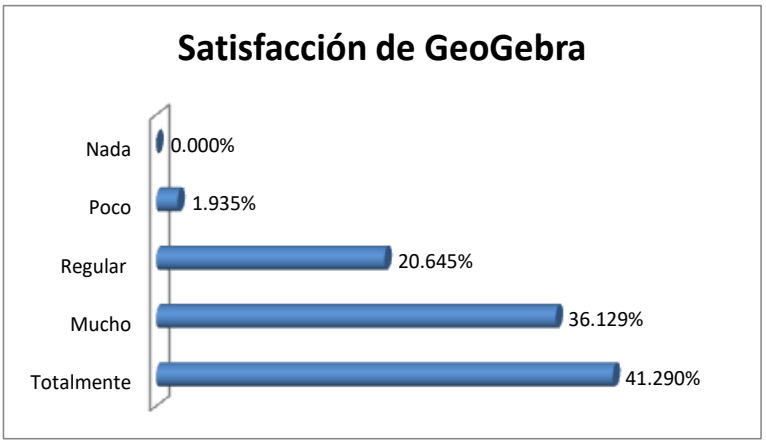
	Totalmente	Mucho	Regular	Poco	Nada
Administración	12.903%	6.452%	9.677%	0.000%	0.000%
Comercio	9.677%	9.677%	6.452%	0.000%	0.000%
Contaduría	9.677%	3.226%	3.226%	0.000%	0.000%
Mercadotecnia	3.226%	9.677%	6.452%	3.226%	0.000%
Informática	3.226%	3.226%	0.000%	0.000%	0.000%
Total	38.710%	32.258%	25.806%	3.226%	0.000%

Fuente: elaboración propia.

It should be mentioned that no student is in the Nothing category for the GeoGebra Satisfaction variable.

Also, Figure 2 shows that this variable has the highest preference in the Totally category.

Figura 2. Satisfacción de GeoGebra.



Fuente: elaboración propia.

Table 19 presents the correlation coefficient on the Satisfaction of the GeoGebra application. It is worth mentioning that the most significant relationship is located in the dimensions Identifying the regions in the graph and Recognizing the solution region with the 0.93034954.

Tabla 19. Coeficiente de correlación sobre la Satisfacción.

	Graficar las desigualdades	Identificar las regiones en la gráfica	Identificar las coordenadas en la gráfica	Reconocer la región solución	Asimilar el conocimiento
Graficar las desigualdades	1				
Identificar las regiones en la gráfica	0.68626268	1			
Identificar las coordenadas en la gráfica	0.69627812	0.69015411	1		
Reconocer la región solución	0.67830837	0.93034954	0.80568507	1	
Asimilar el conocimiento	0.73599457	0.90794286	0.78344717	0.91541304	1

Fuente: elaboración propia.

GeoGebra facility

Finally, this study analyzes the ease of GeoGebra during the didactic unit Linear Inequalities. Table 20 shows that 51.613% of the students think that it is totally easy to use the GeoGebra cloud service to graph inequalities. Even, 32.258% is located in the category Much.

Tabla 20. Facilidad del GeoGebra para graficar las desigualdades.

	Totalmente	Mucho	Regular	Poco	Nada
Administración	16.129%	9.677%	3.226%	0.000%	0.000%
Comercio	12.903%	9.677%	3.226%	0.000%	0.000%
Contaduría	9.677%	3.226%	3.226%	0.000%	0.000%
Mercadotecnia	9.677%	6.452%	6.452%	0.000%	0.000%
Informática	3.226%	3.226%	0.000%	0.000%	0.000%
Total	51.613%	32.258%	16.129%	0.000%	0.000%

Fuente: elaboración propia.

In the same way, the GeoGebra facility variable to identify the regions in the graph has 51,613% in the Total category and 32,258% in the Large category (ver Tabla 21).

Tabla 21. Facilidad del GeoGebra para identificar las regiones en la gráfica.

	Totalmente	Mucho	Regular	Poco	Nada
Administración	16.129%	9.677%	3.226%	0.000%	0.000%
Comercio	12.903%	9.677%	3.226%	0.000%	0.000%
Contaduría	9.677%	3.226%	3.226%	0.000%	0.000%
Mercadotecnia	9.677%	6.452%	6.452%	0.000%	0.000%
Informática	3.226%	3.226%	0.000%	0.000%	0.000%
Total	51.613%	32.258%	16.129%	0.000%	0.000%

Fuente: elaboración propia.

It is worth mentioning that 45,161% of university students consider that it is very easy to use this application to identify the coordinates in the graph. In addition, 38.710% is located in the category Many (ver Tabla 22).

Tabla 22. Facilidad del GeoGebra para identificar las coordenadas en la gráfica.

	Totalmente	Mucho	Regular	Poco	Nada
Administración	12.903%	9.677%	3.226%	3.226%	0.000%
Comercio	12.903%	9.677%	3.226%	0.000%	0.000%
Contaduría	9.677%	6.452%	0.000%	0.000%	0.000%
Mercadotecnia	6.452%	9.677%	3.226%	3.226%	0.000%
Informática	3.226%	3.226%	0.000%	0.000%	0.000%
Total	45.161%	38.710%	9.677%	6.452%	0.000%

Fuente: elaboración propia.

According to 48.387% of the respondents, the use of the GeoGebra application is totally easy to recognize the solution region. Even 29.032% is located in the category Many (ver Tabla 23).

Tabla 23. Facilidad del GeoGebra para reconocer la región solución.

	Totalmente	Mucho	Regular	Poco	Nada
Administración	12.903%	9.677%	3.226%	3.226%	0.000%
Comercio	12.903%	6.452%	6.452%	0.000%	0.000%
Contaduría	9.677%	3.226%	3.226%	0.000%	0.000%
Mercadotecnia	9.677%	6.452%	6.452%	0.000%	0.000%
Informática	3.226%	3.226%	0.000%	0.000%	0.000%
Total	48.387%	29.032%	19.355%	3.226%	0.000%

Fuente: elaboración propia.

With respect to the GeoGebra facility to assimilate knowledge, 45.161% of the participants are in the Total category and 38.710% in the Many category. However, 9,677% of students are in the Regular category (ver Tabla 24).

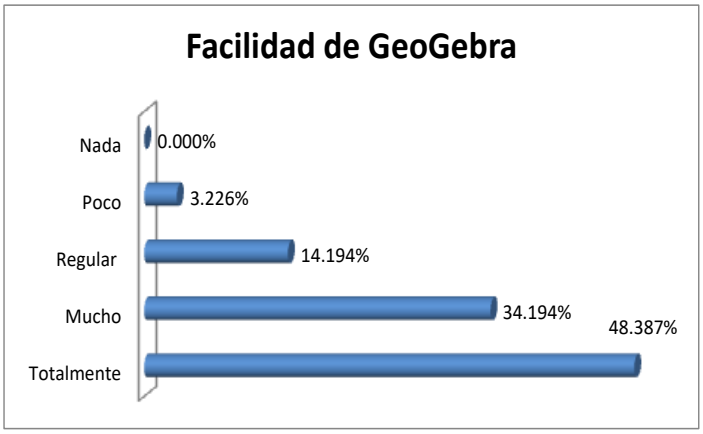
Tabla 24. Facilidad del GeoGebra para asimilar el conocimiento.

	Totalmente	Mucho	Regular	Poco	Nada
Administración	12.903%	9.677%	3.226%	3.226%	0.000%
Comercio	12.903%	9.677%	3.226%	0.000%	0.000%
Contaduría	9.677%	6.452%	0.000%	0.000%	0.000%
Mercadotecnia	6.452%	9.677%	3.226%	3.226%	0.000%
Informática	3.226%	3.226%	0.000%	0.000%	0.000%
Total	45.161%	38.710%	9.677%	6.452%	0.000%

Fuente: elaboración propia.

All aspects of the GeoGebra facility indicate that none of the participants is in the Nothing category. Also, this variable has the highest preference in the category Totally (ver Figura 3).

Figura 3. Facilidad de GeoGebra.



Fuente: elaboración propia.

Table 25 shows the Correlation Coefficient on the GeoGebra Facility in the Linear Inequalities didactic unit.

It is worth mentioning that the most significant relationship is in the dimensions Identifying the regions in the graph and Recognizing the solution region with the 0.925349186.

Tabla 25. Coeficiente de correlación sobre la Facilidad.

	Graficar las desigualdades	Identificar las regiones en la gráfica	Identificar las coordenadas en la gráfica	Reconocer la región solución	Asimilar el conocimiento
Graficar las desigualdades	1				
Identificar las regiones en la gráfica	0.883018868	1			
Identificar las coordenadas en la gráfica	0.725447968	0.775423273	1		
Reconocer la región solución	0.725447968	0.925349186	0.786501377	1	
Asimilar el conocimiento	0.625497359	0.775423273	0.701101928	0.786501377	1

Fuente: elaboración propia.

Discussion

This quantitative research confirms the ideas of various authors (Abakumova, Bakaeva and Kolesina, 2016; Zengin and Tatar, 2017) on the benefits of ICT in the educational field. For example, the GeoGebra cloud service improves the academic performance of the students who attended the didactic unit Linear inequalities in the subject Mathematics for business.

Undergraduate students in Administration, Accounting, Commerce, Marketing and IT present an active role during the teaching-learning process when accessing the GeoGebra application at any time and place to solve the exercises on linear inequalities.

Even university students have the ease of accessing this service in the cloud through desktop computers and various mobile devices such as cell phones, tablets and laptops.

It is worth mentioning that GeoGebra is an innovative technological alternative for the educational field because the user does not have to worry about the installation, updating and maintenance of the programs.

Another benefit of the GeoGebra cloud service is related to personalized learning, that is, students control simulations about linear inequalities.

This quantitative study shares the ideas of the authors (Arsic and Milovanovic, 2016, Chiu and Li, 2015, Mahenge and Sanga, 2016, Novkovic and Stanojevic, 2017) on the use of technology to improve the efficiency of the teaching-learning process . In particular, the experimental group obtained a higher average in the exam (9.41935484) than the control groups corresponding to the 2016 school cycles (8.53571429) and 2015 (8.48947368). Even the ANOVA method with the levels of significance 0.05 and 0.03 allow us to affirm that the GeoGebra cloud service improves academic performance on the issues of linear inequalities.

Likewise, the students of the Business School think that the GeoGebra cloud service is useful in the area of mathematics to graph the inequalities, identify the regions and coordinates in the graph, recognize the solution region and assimilate the knowledge related to the algebra.

In fact, 53,548% of university students consider that this service in the cloud is totally useful during the teaching-learning process.

It is worth noting that this research shares the ideas of Zengin (2017) on the use of GeoGebra to build virtual educational experiences in the field of mathematics. The majority of students (41.290%) indicate that they are totally satisfied to use this web application during the realization of teaching and learning activities on linear Inequality, the System of linear inequalities, the objective Function and the Applications of inequalities.

In the same way, undergraduate students in Administration, Accounting, Commerce, Marketing and IT (48.387%) emphasize that it is totally easy to manage the GeoGebra cloud service during the educational process. Therefore, this study coincides with the ideas raised by Takaci, Stankov and Milanovic (2015) related to the fact that this software facilitates the understanding of mathematical functions through the elaboration of graphs.

Finally, GeoGebra represents a technological tool suitable for the teaching-learning process on linear inequalities. As mentioned by several authors (Li, 2016, Manca, Waters and Sandi, 2016, Segrelles, Martinez, Castilla y Molto, 2017), the cloud service improves the academic performance of students in the field of mathematics.

Conclusion

At present, information and communication technology is changing the planning, organization and implementation of school activities. For example, GeoGebra represents a novel application for the educational context related to mathematics. In fact, this service in the cloud facilitates the assimilation of the contents on linear inequalities.

The cloud service allows educational institutions to reduce operating and investment expenses related to the incorporation of technology in the classroom. In particular, the students of the subject Mathematics for business entered the GeoGebra application for free through Google Drive.

It is worth mentioning that the students of the bachelor's degrees in Administration, Accounting, Commerce, Marketing and Information Technology used the GeoGebra application from any place and time. Even, access to this service in the cloud is done through the web browser, which allows the university students to forget about the maintenance, implementation and configuration of the programs.

Another advantage of the cloud service for the educational field is related to the ease of access through various electronic media such as desktops, laptops and mobile devices. Also, students do not have to worry about operating system updates and file installation for security.

In fact, the students of the Mathematics Intermediate course for business consider that GeoGebra is an easy to use tool and useful to make graphs about inequalities, identify coordinates and recognize the solution region.

The results of the ANOVA method allow to affirm that the incorporation of this service in the cloud improves the academic performance of the students during the didactic unit Linear Inequalities.

It is worth mentioning that the dimensions Identify the regions in the graph and Recognize the solution region present the most significant relationship on the correlation coefficient for the variables Utility (0.87304197), Satisfaction (0.93034954) and Facility (0.925349186).

This research recommends the use of GeoGebra in other subjects of the Faculty of business as basic Mathematics for business in order to facilitate the assimilation and application of knowledge through graphics.

Finally, universities together with teachers must modify their teaching strategies through technology with the purpose of creating new educational experiences. In particular, the use of the service in the cloud during the teaching-learning process allows to eliminate the processes on the installation, the updating and the maintenance of the programs, to enter the applications from any place and to consult the information at any time.

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