

## Evaluating the Use of Wolfram Alpha for Linear Algebra Learning in Teleducation

Evaluación del uso de Wolfram Alpha en el Aprendizaje de Algebra Lineal en Teleducación

Gabriela Campuzano\*  
Esther Gonzabay\*



### Abstract

The use of ICTs in mathematics learning has the potential to improve academic performance in an interactive environment. Teleducation in COVID times demands the active use of technological tools, thus generating the need to determine which tools are suitable for the different branches of mathematics. This work evaluates the use of the Wolfram Alpha tool in the teaching of Linear Algebra in teleducation in COVID times. This tool was selected because of its ease of use, detailed answers and because it does not require software installation. The research was applied to second semester engineering students, dividing the students into a control group and an experimental group. Pre- and post-treatment test results were statistically analyzed to detect whether there was an increase in academic performance. Students using Wolfram Alpha completed a survey and interview to assess their perception of the tool. The experimental group performed better than the control group. The use of Wolfram Alpha was well accepted by the students suggesting its

---

\* Magister, Universidad Estatal Península de Santa Elena, Ecuador, [mcampuzano@upse.edu.ec](mailto:mcampuzano@upse.edu.ec), <https://orcid.org/0000-0003-1522-0228>

\* Magister, Universidad Estatal Península de Santa Elena, Ecuador, [egonzabay@upse.edu.ec](mailto:egonzabay@upse.edu.ec), <https://orcid.org/0000-0002-3897-3700>

future use in Linear Algebra courses for tele-education and even face-to-face education in post-pandemic times.

**Keywords:** Wolfram Alpha, Algebra Lineal, teleeducación, vectores, matrices

## Resumen

El uso de las TICs en el aprendizaje de matemáticas tiene el potencial de mejorar el rendimiento académico en un ambiente interactivo. La teleeducación en tiempos de COVID demanda el uso activo de herramientas tecnológicas, por lo que se genera la necesidad de determinar que herramientas son adecuadas para las distintas ramas de las matemáticas. Este trabajo evalúa el uso de la herramienta Wolfram Alpha en la enseñanza de Algebra Lineal en teleeducación en tiempos de COVID. Se seleccionó esta herramienta por su facilidad de uso, respuestas detalladas y porque no requiere instalación de software. La investigación se aplicó a estudiantes de segundo semestre de ingeniería, dividiendo al estudiantado en un grupo de control y uno experimental. Se analizaron estadísticamente los resultados de exámenes pre y post tratamiento para detectar si hubo un incremento en el rendimiento académico. Los estudiantes que usaron Wolfram Alpha respondieron una encuesta y entrevista para evaluar su percepción sobre la herramienta. El grupo experimental obtuvo un mejor rendimiento que el grupo de control. El uso de Wolfram Alpha tuvo buena aceptación entre los estudiantes sugiriendo su uso futuro en cursos de Algebra Lineal para teleeducación e incluso educación presencial en tiempos post pandemia

**Palabras clave:** Wolfram Alpha, Algebra Lineal, teleeducación, vectores, matrices

## Introduction

In the last decades, the number of people attending university has increased and digitalization has penetrated the educational field resulting in the introduction of distance or remote education methods through digital technologies. (Kalmar et al., 2022). Teleeducation is understood as distance training through the use of information and communication technologies (ICTs) offering an interactive and flexible environment without requiring the physical presence of students facilitating distance learning. (Benítez et al., 2021; Suescun Valero, 2021). Traditionally, teleeducation has offered advantages such as ease of mass education, diversity of content and ease of

access to information so that the student can read, listen and watch the content several times until it is fully understood. In addition, the student does not need to travel to the study center, saving time and economic resources. (Lares & Peña, 2021). Among the negatives, Benítez et al. (2021) The absence of physical contact, the fear of teachers and students before a new learning model and access to computers, tablets, smartphones and limited internet in some sectors of society.

Due to the development of the COVID-19 pandemic, the face-to-face classroom had to be replaced by virtuality in whole or in part, with teleducation being implemented around the world at all levels of education (El-Soussi, 2022; Fretheim et al., 2021; Rodríguez-Rivas, 2021; Yau et al., 2022). The lack of physical contact, which was seen as a disadvantage of teleducation, became the main advantage of this form of learning to avoid the escalation of SARS-CoV-2 cases. In some countries, education became entirely virtual, while other countries opted for a hybrid model where some students attend classrooms more than others. (Fretheim et al., 2021). In some countries, where access to technological resources and the Internet is limited, virtuality imposed new challenges to be overcome. (Fretheim et al., 2021). Education has been forced to innovate and opt for flexible learning modalities that allow it to be more resilient for both COVID and post-COVID times. (Lennox et al., 2021).

Education in times of COVID requires the development of interactive content that motivates the learner and mitigates the lack of physical contact to which students are accustomed and the adverse effects that the pandemic has had such as depression and anxiety (El-Soussi, 2022; Hoofman & Secord, 2021; Suberviola, 2021). Therefore, it is necessary to train teachers and study technological tools to determine which tools are appropriate for each subject. Many professionals are required to take mathematics during their university education, which requires the study of mathematics. (Costa & Rossignoli, 2017) This calls for a study of mathematics teaching in the current context. Hoofman y Secord (2021) collected evidence suggesting that students have the perception that mathematics is assimilated in a better way when there is interaction in a face-to-face environment with the teacher, which makes teaching mathematics online in COVID times a challenge.

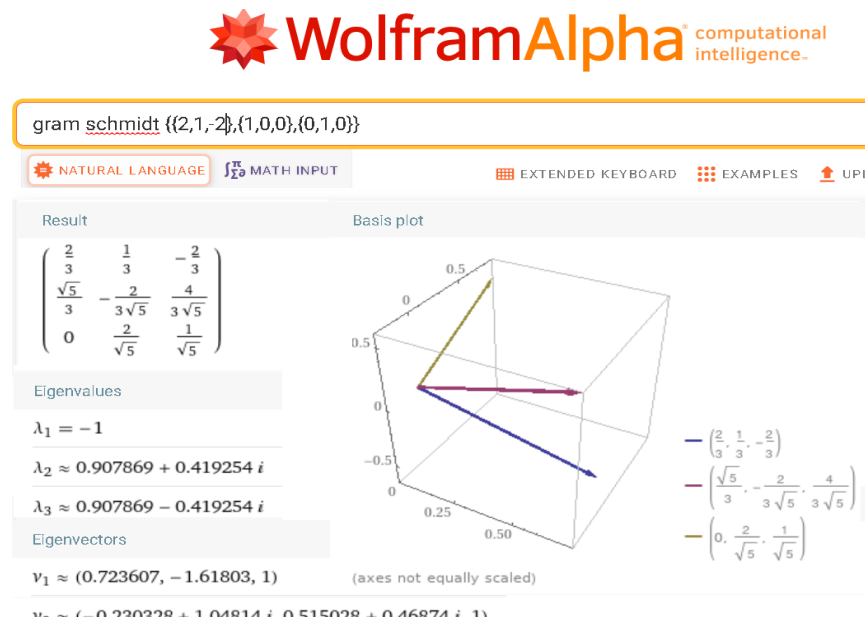
Del Pino y Lozano (2012) state that sometimes students present difficulties in learning mathematics attributable to the lack of understanding of the conceptual part and lack of development of skills to solve problems where an algorithm cannot be applied. The correct use of ICTs for teaching mathematics can increase usefulness, motivation, enjoyment and confidence and decrease anxiety about these subjects. Technology strengthens the mathematics learning process by presenting content numerically, graphically, and symbolically without the extra burden of spending time solving complex computational problems by hand, allowing students to deepen conceptualization and self-assessment. (Kilicman et al., 2010). However, when ICT is not used correctly, it can become a major obstacle to learning mathematics. (Del Pino & Lozano, 2012; Hu et al., 2018; Real Pérez, 2013). Hardman (2019) points out that the literature on the use of ICTs in mathematics is conflicting, with some studies concluding that ICTs improve student performance, while other studies show the opposite.

Despite the existence of various technological tools for learning the different branches of mathematics, in some sectors, there have traditionally been barriers to their implementation, such as the lack of computer laboratories, sometimes the software is paid and lack of teacher training. (Fernández & Muñoz, 2007; Marshall et al., 2012). During teleducation, the student has been forced to use a computer or a mobile device to attend classes, do homework and assignments. Thus, in teleducation, the barrier of not having access to a computer lab has been overcome by having personal computers, tablets and cell phones available to use the different technological tools selected by the teacher. The subject of linear algebra is present in the curriculum of many careers such as those related to economics and above all in the various branches of engineering (Costa & Rossignoli, 2017). Studies have shown that students find the learning of linear algebra difficult, which makes it pertinent to study its teaching. (Harel, 2017) This makes it pertinent to study its teaching during COVID and post COVID times. Educational research in mathematics initially focused mainly on the subject of calculus, while in the last thirty years the study of linear algebra has also gained momentum. (Aydin, 2009). Most of the software and applications for learning algebra have traditionally been studied for

the face-to-face modality, so it is necessary to carefully analyze the tools that are used in teleducation of this branch of mathematics. The problem arises because there is scarce literature on the tools used in tele-education in COVID times for teaching algebra, however, there is available literature on tools for face-to-face education that is very useful.

Matlab is the most widely employed paid software for teaching linear algebra and the main program included in Linear Algebra books as. Grossman (2008); Kolman y Hill (2006); Ortiz y Giraldo (2018). Other paid computer algebraic systems (CAS) used in linear algebra include Cabri, Maple (Klasa, 2010) and Mathematica, Linalg (Aydin, 2009) while in free software we have Scilab and Octave (Atencio, 2013). For this study it was decided to use the Wolfram Alpha tool as an alternative to traditional CAS, because it does not require the installation of software for its operation as the tools mentioned above, it is easy to use as it does not require programming knowledge and provides a detailed answer to the problems. Wolfram Alpha (Fig. 1) is a Mathematica-based answer finder that includes algebra processing, numerical computation, symbolic computation, visualizations and statistics. (Abramovich, 2021; Rosly et al., 2020). There are several ways to write the mathematical problem and it can be written in natural language and does not require writing programming code as in the case of computer algebraic systems. This tool was released in 2009 by Wolfram Research and can be used with Windows, Macintosh and Android systems through the url [www.wolframalpha.com](http://www.wolframalpha.com). (González Martel et al., 2018). The difference between the free and the paid version lies in the number of steps shown in the step-by-step solution. During the literature review, no studies on teaching linear algebra with Wolfram Alpha were found, however, studies of Wolfram Alpha for other branches of mathematics relevant to this study are analyzed.

**Figure 1** Wolfram Alpha snapshot of a linear algebra exercise (adapted for publication)



Dimiceli et al. (2010) successfully replaced the use of traditional CAS in teaching differential and integral calculus in their computer labs with Wolfram Alpha. However, they suggest a combined teaching of CAS and Wolfram Alpha for the subject of calculus of several variables. This study involved the analysis of the results of student surveys on the development of calculus laboratory practices. Říhová et al. (2020) Through survey analysis, we collected positive student responses to using Wolfram Alpha for financial mathematics. The use of this tool was not only for solving mathematical problems but also for financial concepts. In the Czech Republic, Necesal y Pospíšil (2012) they taught mathematics for two years with the help of Wolfram Alpha at the higher level. A proprietary system called TRIAL stored the problems and evaluations were given using Wolfram Alpha. Wolfram Alpha was studied for one-variable calculus courses through quizzes where student acceptance of this tool was evidenced by making classes more interactive and motivating the student to learn and prepare for assessments. (C Conceição & Fernandes, 2017; Palencia-González

& Llamas, 2019). Muñoz y Porras (2018) used the same methodology used in this study, the analysis of academic performance with a control group and an experimental group, for the teaching of differential calculus, integral calculus and differential equations with Wolfram Alpha, Derive and Geogebra. The statistical analysis of the pre and post evaluations showed a better academic performance of the experimental group. Campuzano y Crisanto (2021) In the experimental group, a similar methodology to this work was used to study the learning of analytical geometry using Wolfram Alpha, showing that the tool contributes to an improvement in academic performance and that students have a good acceptance of Wolfram Alpha.

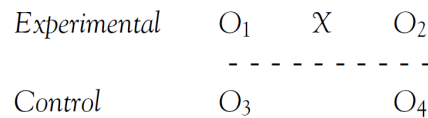
This work responds to the need to study tools for learning mathematics through tele-education as a consequence of the total or partial replacement of classroom attendance due to the spread of the COVID-19 virus. This study analyzes an online tool called Wolfram Alpha as a replacement for traditional computer algebraic systems that offers advantages such as ease of use and does not require the installation of software as it only requires an internet connection through a computer or mobile device. This research responds to the following objectives: a) To evaluate the effect of Wolfram Alpha on the academic performance of teleeducation students in the subject of engineering linear algebra b) To determine the student's perception of Wolfram Alpha for the learning of linear algebra through teleeducation.

## **Materials and methods**

The first component of the research corresponds to a quantitative methodology in a quasi-experiment employing control and experimental groups (Figure 2). Cohen et al. (2017) indicates that this type of research is widely used in education where participants cannot be randomly selected. This method has been employed by other studies evaluating Wolfram Alpha for mathematics learning. (Campuzano & Crisanto, 2021; Muñoz & Porras, 2018). To assess academic performance, pre- and post-treatment tests were administered to the control and experimental groups. Wolfram Alpha was employed for the topics of orthonormal (Gram-Schmidt) base construction and eigenvalues and eigenvectors. These topics

were selected based on experience in previous years, taking into account the topics in which the students had the greatest difficulty.

**Figure 2** Diagram of a quasi-experiment with pre- and post-evaluations.



Fuente. (Cohen et al., 2017)

The null hypotheses analyzed by this work are the following: a) In the means of the pre-treatment test scores, there is no significant difference between the control group and the experimental group b) In the means of the post-treatment test scores, there is no significant difference between the control group and the experimental group. The control group received classes without the use of Wolfram Alpha and the experimental group with the use of this tool in its free version. Both groups were taught by the principal investigator and took the exams without the use of this tool. The test scores were analyzed with Minitab statistical software. Descriptive statistics and the Student t-test for two independent samples were used once it was determined that the data had a normal distribution through the Ryan-Joiner test. The second component of the research corresponds to the analysis of student perception of the use of this tool. It was carried out through the analysis of surveys under the Likert scale conducted only to the experimental group. The results were analyzed under descriptive statistics using.

This study was carried out for a linear algebra course for engineering students at the Peninsula de Santa Elena State University of Ecuador (UPSE). This work is part of the research project "Use of ICTs in the teaching of mathematics at UPSE in COVID and post COVID times", which evaluates the use of these tools in subjects such as geometry, trigonometry, calculus of one variable, calculus of several variables, differential equations and linear algebra. A total of 80 students in the second semester of the electronics course were randomly divided into a control group and an experimental group. The semester where the research was carried out was the third semester taught online. At the beginning of the semester, the students were invited to participate in the study and the consent of the entire

student body was obtained. The content of the face-to-face classes was adapted for teleducation. Both groups received the same content through the use of the Moodle platform and Zoom sessions, the difference being that the experimental group used Wolfram Alpha for which they received training in the use of the tool. This tool was accessed through an internet browser on a computer, tablet or smartphone.

To analyze whether Wolfram Alpha contributes to improved academic performance when used for learning linear algebra, a pretest and a post-test were administered to both groups. The purpose of the pretest is to determine if both groups have similar knowledge of the subject so that the same starting point exists. The post-treatment test aims to evaluate if there is a difference in the academic performance of the group that had sessions with Wolfram Alpha with respect to the control group. The exams were elaborated based on evaluations made in past semesters in face-to-face and virtual modality, linear algebra books and solved exercises that were made available to the students in the form of a video were also used as a basis. The exams consisted of 10 multiple-choice questions and were peer-reviewed by professors from other engineering careers at the same university. The reliability of the instrument was determined using Minitab with a Cronbach's Alpha coefficient value of 0.84.

The perception of the use of Wolfram Alpha was evaluated with surveys conducted to the participants of the experimental group. It was conducted through Google Forms and the link to access it was placed in the virtual classroom. All members of the experimental group answered it. This instrument was developed based on the review of the literature and the objectives of the study (Dimiceli et al., 2010; Muñoz & Porras, 2018; Říhová et al., 2020) and the objectives of the study found in the introductory part of this document, using the Likert scale. As in the case of the exams, this instrument was reviewed by the university's peer professors.

## **Results**

The first result (Table 1) that is presented corresponds to the characterization of the study participants and the percentage of students who used a cell phone to access the course because they did

not have a computer at hand. In general in Ecuador, the percentage of women studying engineering is low, so the percentage of women is low. Given the closure of physical classrooms and the implementation of virtuality, many students who previously did not have permanent access to a computer were forced to acquire one or use an existing one, sharing it mainly with family members, so the percentage of students who access only via cell phone is low.

**Table 1** *Characteristics of the student body that participated in the study*

Group	Number	Percentage of women	Average age	Mainly cellular use
<b>Experimental</b>				
<b>Control</b>		28%		

The following are the results of the evaluation of academic performance that was performed using the pre- and post-tests in the control and experimental groups. Employing the Student t-test for two independent samples, the measures of the grades of both groups before the application of the treatment were compared to evaluate whether both groups have similar knowledge. The null hypothesis that was analyzed is the following:

H0: There is no significant difference between the control group and the experimental group in the means of the pre-treatment test scores ( $p > 0.05$ ).

**Table 2** *Results of the t-test for the pretreatment examination*

	Number	Media	Standard Deviation	t	P
<b>Control</b>		2.23	1.51		
<b>Experimental</b>		2.40	1.48	-0.52	0.602

Table 2 shows that p has a value of 0.602, which is higher than 0.05; therefore, the null hypothesis is accepted and it can be considered that both the control and experimental groups have similar

knowledge before receiving the algebra classes of the selected topics. The scores in the pre-treatment evaluation are not so low due to the fact that the students receive several concepts related to linear algebra during their pre-university training.

The Student's t-test for two independent samples to analyze the measures of the grades of both groups after the application of the treatment to evaluate whether the Wolfram Alpha tool produces an improvement in academic performance yielded the results shown in Table 3. This analysis corresponds to the following null hypothesis: H0: In the means of the post-treatment test scores, there is no significant difference between the control group and the experimental group ( $p > 0.05$ ).

**Table 3** Results of the t-test for the post-treatment examination

	<b>Number</b>	<b>Media</b>	<b>Standard Deviation</b>	<b>t</b>	<b>P</b>
<b>Control</b>		5.28	2.15	-3.30	0.001
<b>Experimental</b>		6.75	1.84		

The p-value is 0.001, less than 0.05, so the null hypothesis is rejected and the alternative hypothesis is accepted, i.e., there is a statistically significant difference between the means of the post-treatment evaluations, showing that the Wolfram Alpha tool is effective in learning linear algebra. This result is relevant because it means that this tool could replace computer algebraic systems only by requiring an internet connection and a minimum knowledge of writing commands.

Table 4 presents the main results of the surveys under descriptive statistics. The equivalence between the Likert scale and the numerical scale is as follows 0 = strongly disagree, 1 = partially disagree, 2 = neither agree nor disagree, 3 = partially agree, 4 = strongly agree.

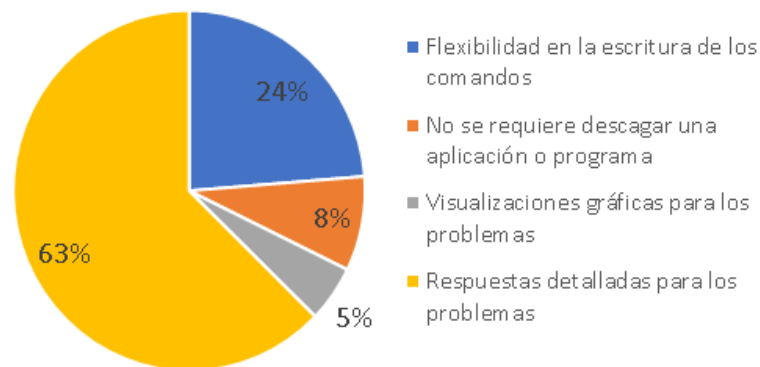
**Table 4** *Wolfram Alpha Tool Usage Survey Results*

Ask	Media	Standard Deviation
After using Wolfram Alpha, I find it useful for learning linear algebra.	3.9	0.389
Wolfram Alpha has helped me achieve long-term algebra learning	3.6	0.527
I think Wolfram Alpha makes algebra classes more interactive.	3.7	0.584
I liked using Wolfram Alpha for the different parts of this linear algebra course	3.7	0.54
I think Wolfram Alpha should continue to be used in virtual mathematics classes.	3.7	0.577
I think Wolfram Alpha should be deployed to face-to-face math classes.	3.7	0.515
Wolfram Alpha used through the cell phone allowed me to have the same experience as on the computer.		1.057

In general, a positive perception of users about the use of Wolfram Alpha can be evidenced, which is consistent with other studies of this tool for other branches of mathematics (Dimiceli et al., 2010; Muñoz & Porras, 2018; Říhová et al., 2020). Wolfram Alpha is considered a tool that adds interaction to the educational environment that should continue to be used in future linear algebra courses through tele-education or face-to-face with the use of computers or cell phones. Although the students responded positively on the long-term learning of algebra, for a more detailed evaluation of this aspect a study is needed to conduct new evaluations after a reasonable time. The lowest scoring question was regarding the use of Wolfram Alpha on the cell phone, possibly attributable in some cases to the fact that during the practices some students could not access through the default internet browser and

had to switch to another one because the Wolfram Alpha application for the cell phone is paid. Figure 3 shows the students' responses about the feature they liked the most about Wolfram Alpha. The features they liked the most are related to detailed answers to problems and flexibility in typing commands. These responses are related to the factor that these students have used Matlab in other subjects previously and that when comparing Wolfram Alpha to a CAS it is evident that no programming skills are required and that a single command line delivers detailed answers that would correspond to several lines of programming in a CAS

**Figure 3.** Features that Wolfram Alpha users liked the most



This study used the free version of Wolfram Alpha, however, the paid version offers advantages such as full visualization of the step-by-step resolution that has much potential to strengthen the learning process. Future studies can focus on this aspect and its influence on the student body.

## Discussion

The incorporation of technology in the learning of linear algebra has been mainly focused on the use of Matlab software, which is even included in the textbooks of this subject. Wolfram Alpha is an interesting alternative to this paid software since it only requires a computer, tablet or cell phone with internet connection and has an easy-to-use interface that does not require programming knowledge. The statistical analysis of the grades of the students in the control and experimental groups showed that the use of the Wolfram Alpha technological tool through the Internet allowed the students to improve their academic performance in a linear algebra course

carried out through tele-education in COVID times. Survey analysis shows a positive perception of the use of this tool and suggests that Wolfram Alpha be used in future Wolfram courses in tele-education or face-to-face mode. In post-COVID times, it is possible that students will use technological tools in a more active way for learning the different branches of mathematics in the classroom, so the use of this tool will continue and in areas where there are not enough computers for the entire student body, students will use mobile devices to access the tool.

## References

- Abramovich, S. (2021). Using Wolfram Alpha with Elementary Teacher Candidates: From More Than One Correct Answer to More Than One Correct Solution. *Mathematics*, 9(17). <https://doi.org/10.3390/math9172112>.
- Atencio, D. (2013). Use of free software in the teaching of linear algebra for engineers.
- Aydin, S. (2009). The factors effecting teaching linear algebra. *Procedia - Social and Behavioral Sciences*, 1(1), 1549-1553. <https://doi.org/https://doi.org/10.1016/j.sbspro.2009.01.272>
- Benítez, R. L., Vera, K. B. C., & Cárdenas, M. J. P. (2021). Analysis of the impact of the massive use of tele-education on the learning of first grade students: Impact of the massive use of tele-education on learning. *Didasc@ lia: didactics and education ISSN 2224-2643*, 12(5), 72-86.
- C Conceição, A., & Fernandes, S. (2017, 2017). Wolfram| Alpha: uma ferramenta de aprendizagem ativa em Cálculo I.
- Campuzano, M., & Crisanto, T. (2021). *Learning Analytic Geometry with the aid of Wolfram Alpha*. <https://osf.io/t7bph>
- Cohen, L., Manion, L., & Morrison, K. (2017). *Research methods in education*. routledge.
- Costa, V. A., & Rossignoli, R. (2017). Teaching linear algebra in an engineering faculty: Methodological and didactic aspects. *Engineering Education Journal*, 12.
- Del Pino, P., & Lozano, L. (2012). The didactics of linear algebra and its design: a vision with the use of technology. *CD de Monografías*.
- Dimiceli, V. E., Lang, A. S. I. D., & Locke, L. (2010). Teaching calculus with Wolfram|Alpha. *International Journal of*

- Mathematical Education in Science and Technology*, 41(8), 1061-1071. <https://doi.org/10.1080/0020739X.2010.493241>.
- El-Soussi, A. (2022). The shift from face-to-face to online teaching due to COVID-19: Its impact on higher education faculty's professional identity. *International Journal of Educational Research Open*, 3, 100139. <https://doi.org/https://doi.org/10.1016/j.ijedro.2022.100139>.
- Fernández, J., & Muñoz, J. (2007). ICT as an educational tool in mathematics. *Union. Revista Iberoamericana de Educación Matemática*, 9, 119-147.
- Fretheim, A., Helleve, A., Løyland, B., Sandbekken, I. H., Flatø, M., Telle, K., Watle, S. V., Schjøll, A., Helseth, S., Jamtvedt, G., & Hart, R. K. (2021). Relationship between teaching modality and COVID-19, well-being, and teaching satisfaction (campus & corona): A cohort study among students in higher education. *Public Health in Practice*, 2, 100187. <https://doi.org/https://doi.org/10.1016/j.puhip.2021.100187>.
- González Martel, C., Dávila-Cárdenes, N., & Gómez-Déniz, E. (2018). Wolfram| Alpha, a computational tool with multiple applications in university education.
- Grossman, S. I. (2008). *Linear algebra*. McGraw Hill Education.
- Hardman, J. (2019). Towards a pedagogical model of teaching with ICTs for mathematics attainment in primary school: A review of studies 2008-2018. *Heliyon*, 5(5), e01726.
- Harel, G. (2017). The learning and teaching of linear algebra: Observations and generalizations. *The Journal of Mathematical Behavior*, 46, 69-95. <https://doi.org/https://doi.org/10.1016/j.jmathb.2017.02.007>
- Hoofman, J., & Secord, E. (2021). The Effect of COVID-19 on Education. *Pediatric Clinics of North America*, 68(5), 1071-1079. <https://doi.org/https://doi.org/10.1016/j.pcl.2021.05.009>
- Hu, X., Gong, Y., Lai, C., & Leung, F. K. S. (2018). The relationship between ICT and student literacy in mathematics, reading, and science across 44 countries: A multilevel analysis. *Computers & Education*, 125, 1-13. <https://doi.org/https://doi.org/10.1016/j.compedu.2018.05.021>
- Kalmar, E., Aarts, T., Bosman, E., Ford, C., de Kluijver, L., Beets, J., Veldkamp, L., Timmers, P., Besseling, D., Koopman, J., Fan, C., Berrevoets, E., Trotsenburg, M., Maton, L., van

- Remundt, J., Sari, E., Omar, L.-W., Beinema, E., Winkel, R., & van der Sanden, M. (2022). The COVID-19 paradox of online collaborative education: when you cannot physically meet, you need more social interactions. *Heliyon*, 8(1), e08823.  
<https://doi.org/https://doi.org/10.1016/j.heliyon.2022.e08823>.
- Kilicman, A., Hassan, M. A., & Husain, S. K. S. (2010). Teaching and Learning using Mathematics Software "The New Challenge". *Procedia - Social and Behavioral Sciences*, 8, 613-619.  
<https://doi.org/https://doi.org/10.1016/j.sbspro.2010.12.085>.
- Klasa, J. (2010). A few pedagogical designs in linear algebra with Cabri and Maple. *Linear Algebra and its Applications*, 432(8), 2100-2111.  
<https://doi.org/https://doi.org/10.1016/j.laa.2009.08.039>
- Kolman, B., & Hill, D. R. (2006). *Linear algebra*. Pearson Education.
- Lares, K. Y. U., & Peña, J. M. A. (2021). Challenges and difficulties of primary education teachers in the face of tele-education adoption. *Revista Andina de Educación*, 4(1), 43-54.
- Lennox, J., Reuge, N., & Benavides, F. (2021). UNICEF's lessons learned from the education response to the COVID-19 crisis and reflections on the implications for education policy. *International Journal of Educational Development*, 85, 102429.  
<https://doi.org/https://doi.org/10.1016/j.ijedudev.2021.102429>
- Marshall, N., Buteau, C., Jarvis, D. H., & Lavicza, Z. (2012). Do mathematicians integrate computer algebra systems in university teaching? Comparing a literature review to an international survey study. *Computers & Education*, 58(1), 423-434.  
<https://doi.org/https://doi.org/10.1016/j.compedu.2011.08.020>
- Muñoz, M., & Porras, M. (2018, 2018). Wolfram Alpha, Geogebra and Derive as integrants of STEM education. UTMACH.
- Necosal, P., & Pospíšil, J. (2012, 2012). Experience with teaching mathematics for engineers with the aid of Wolfram Alpha.
- Ortiz, O. D. S., & Giraldo, H. (2018). *Linear algebra using MATLAB*. Universidad de Antioquia.

- Palencia-González, F. J., & Llamas, M. d. C. G. (2019). A course in Calculus with Wolfram Alpha. *Pi-InnovaMath*(3).
- Real Pérez, M. (2013). ICT in the teaching and learning process of mathematics. *Materiales para el desarrollo curricular de matemáticas de tercero de ESO por competencias*, 8.
- Říhová, V., Jílková, E., & Wossala, J. (2020). Wolfram Alpha in mathematics and economics. *International Days of Science*, 156.
- Rodríguez-Rivas, R. (2021). COVID-19 lockdown and tele-education tools at a neurology residency: A quasi-experimental study. *Journal of the Neurological Sciences*, 429, 119734.  
<https://doi.org/https://doi.org/10.1016/j.jns.2021.119734>
- Rosly, W., Abdullah, S. S. S. S., & Shukri, F. N. A. (2020). The uses of Wolfram Alpha in Mathematics. *Articles of Teaching and Learning in Higher Education*, 1, 96-103.
- Suberviola, I. (2021). From face-to-face to on-line methodology. Analysis of families' perception of tele-schooling in confinement. *Journal of Learning Styles*, 14(28), 121-135.
- Suescun Valero, I. (2021). Tele-education and quality control in universities: Work organization trends in times of Covid-19.
- Yau, A. H. Y., Yeung, M. W. L., & Lee, C. Y. P. (2022). A co-orientation analysis of teachers' and students' perceptions of online teaching and learning in Hong Kong higher education during the COVID-19 pandemic. *Studies in Educational Evaluation*, 72, 101128.  
<https://doi.org/https://doi.org/10.1016/j.stueduc.2022.101128>