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Enhancing Learning in Mathematics Through Technology: Impact on Critical and Metacognitive Thinking

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Abstract

A documentary review was conducted on the production and publication of research papers related to ICT, Learning, and Mathematics. The purpose of the bibliometric analysis in this document was to understand the main characteristics of publications registered in the Scopus database from 2018-2023 by Latin American institutions, identifying 46 publications. The data was organized into graphs and figures, categorizing information by Year of Publication, Country of Origin, Area of Knowledge, and Type of Publication. Following this, a qualitative analysis referenced various authors' positions on the topic. Key findings revealed that Ecuador, with 11 publications, was the Latin American country with the highest scientific production attributed to authors affiliated with its institutions. The Area of Knowledge contributing most to the study of the impact of information and communication technologies on learning in mathematics was Social Sciences, with 27 published documents. The most frequently used Publication Type was Journal Articles, comprising 52% of the total scientific production during the specified period.

Keywords: *ICT, Learning, Mathematics, Critical Thinking, Metacognitive Thinking*

INTRODUCTION

Logical mathematical learning is essential for individual and professional development. Traditional teaching methods ensured the retention of large amounts of mathematical information, but did not guarantee practical application of knowledge. Rote learning led to lower performance in mathematics compared to other subjects (Lozano, 2021). In a globalized world, the revolution brought by ICTs requires changes in teaching practices, models, strategies, and activities across all knowledge areas.

ICTs are used in education to strengthen and stimulate students' skills and different types of intelligence (Real-Pérez, 2013). This requires a new didactic-pedagogical model for a process that has remained unchanged for centuries. The reluctance of mathematics teachers to embrace change stems from their lack of training and use of ICTs and the potential for these tools to hinder learning if not used properly (Pérez, 2013). Improper use can lead to correct results in one context but inaccuracies in others, creating proto-learning and unreliable evidence. The balance between appropriate and inappropriate use depends on the teacher's proficiency and versatility (Grisales, 2018).

General Objective

To analyze, from a bibliometric and bibliographic perspective, the preparation and publication of research papers in high-impact journals indexed in the Scopus database on the variables ICT, Learning, and Mathematics during the period 2018-2023 by Latin American institutions.

METHODOLOGY

This article utilizes a mixed-methods approach, combining quantitative and qualitative research.

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On the quantitative side, a bibliometric analysis of the scientific production related to ICT, Learning, and Mathematics was conducted using data from Scopus. On the qualitative side, selected research works in the study area were analyzed from a bibliographic perspective, describing different authors' positions on the topic. The entire search was conducted through Scopus, establishing the parameters referenced in Figure 1.

Methodological Design

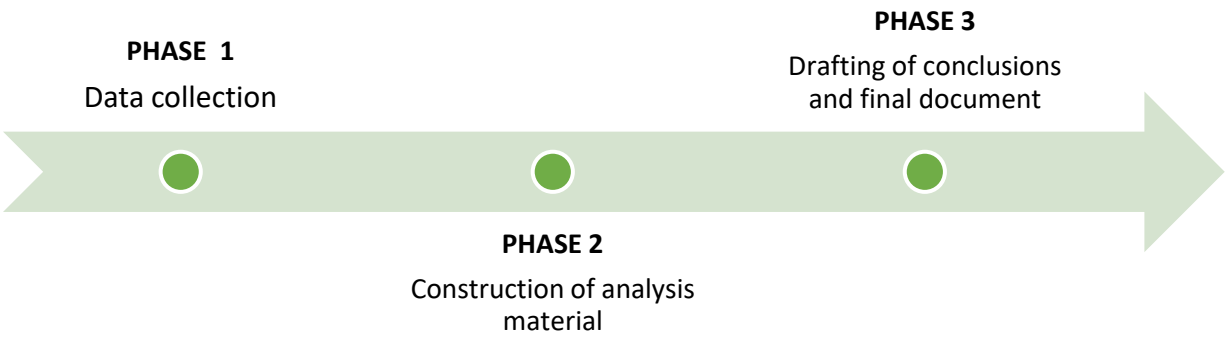

Figure 1. *Methodological design*

Source: Authors' own creation

Phase 1: Data collection

Data collection was carried out from the Search tool on the Scopus website, where 46 publications were obtained from the following filters:

TITLE-ABS-KEY (ict, AND learning, AND mathematics) AND PUBYEAR > 2017 AND PUBYEAR < 2024 AND (LIMIT-TO (AFFILCOUNTRY , "Mexico") OR LIMIT-TO (AFFILCOUNTRY , "Ecuador") OR LIMIT-TO (AFFILCOUNTRY , "Colombia") OR LIMIT-TO (AFFILCOUNTRY , "Brazil") OR LIMIT-TO (AFFILCOUNTRY , "Peru") OR LIMIT-TO (AFFILCOUNTRY , "Chile") OR LIMIT-TO (AFFILCOUNTRY , "Costa Rica") OR LIMIT-TO (AFFILCOUNTRY , "Uruguay") OR LIMIT-TO (AFFILCOUNTRY , "Honduras") OR LIMIT-TO (AFFILCOUNTRY , "Cuba") OR LIMIT-TO (AFFILCOUNTRY , "Argentina")

Published documents whose study variables are related to the study of the variables ICT, Learning and Mathematics

Limited to the period 2018-2023.

Limited to Latin American countries.

Without distinction of area of knowledge.

No distinction of type of publication.

Phase 2: Construction of Analytical Material

The information collected in Scopus during the previous phase is organized and then classified by graphs, figures and tables as follows:

Co-occurrence of words.

Country of origin of the publication.

Area of knowledge.

Type of publication.

Phase 3: Drafting of Conclusions and Outcome Document

In this phase, the results of the previous results are analysed, resulting in the determination of conclusions and, consequently, the obtaining of the final document.

RESULTS

Co-occurrence of Words

Figure 2 shows the co-occurrence of keywords found in the publications identified in the Scopus database.

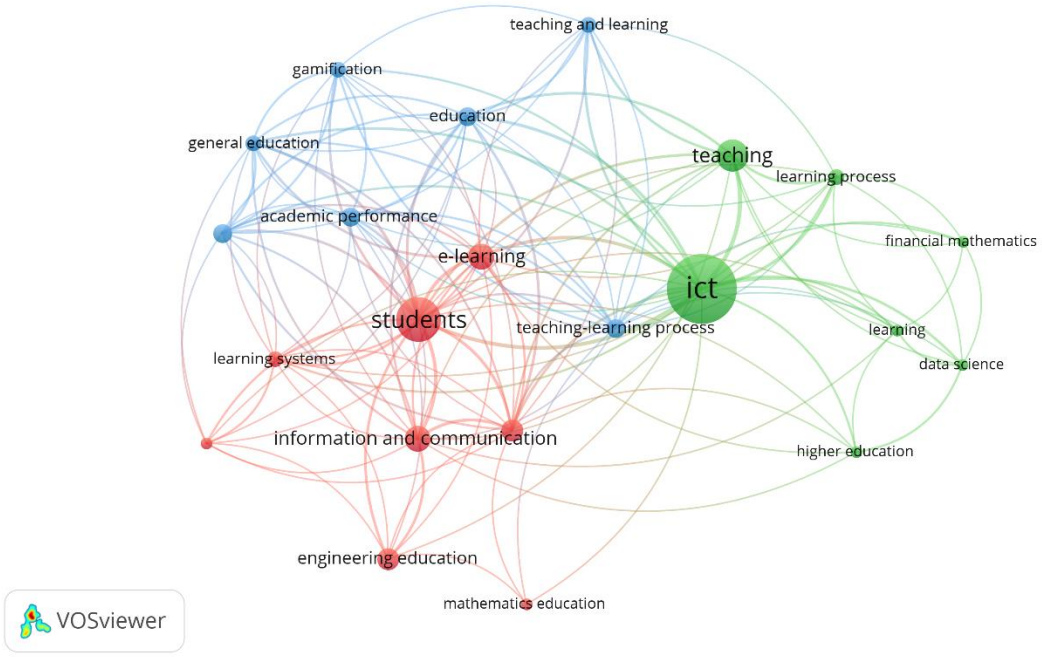

Figure 2. *Co-occurrence of words*

Source: Authors' own elaboration (2024); based on data exported from Scopus.

Figure 2 shows the co-occurrence of words where the terms ICT, students, and E-learning represent the largest number of publications analyzed. These three terms are central to the practice of teaching mathematics, influenced by the development of computing, the Internet boom, and advances in educational sciences. Following these terms are Teaching, Education, Teaching-Learning Process, and Gamification. This second group of words reflects didactic-pedagogical principles and human dimensions studied after significant advances by psychologists like Gardner, Piaget, Vygotsky, Bruner, Montessori, and Ausubel. A third set of words includes supra-pedagogical processes governing and regulating mathematics teaching, such as the learning system, engineering education, higher education, and information and communication.

Distribution Of Scientific Production by Year of Publication

Figure 3 shows how scientific production is distributed according to the year of publication.

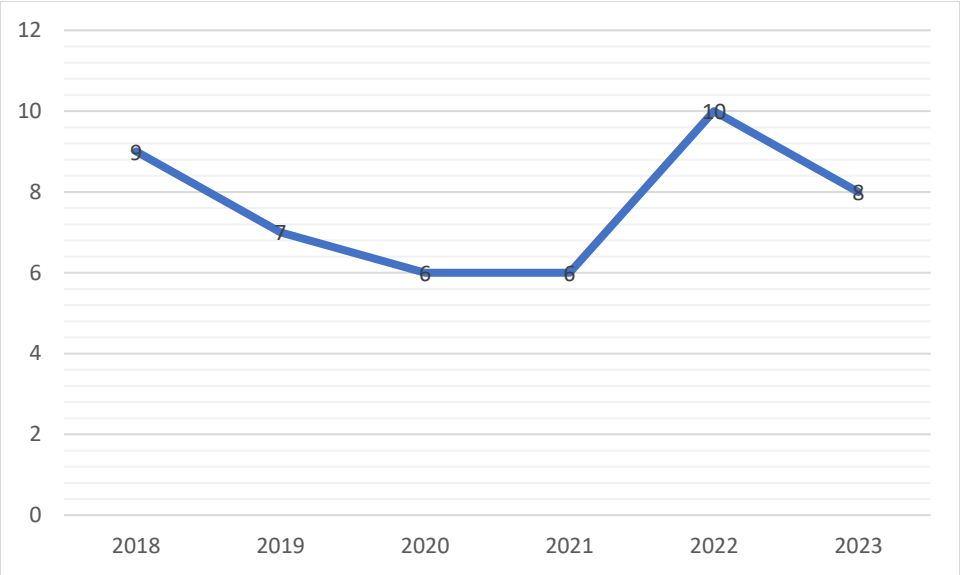

Figure 3. *Distribution of scientific production by year of publication.*

Source: Authors' own elaboration (2024); based on data exported from Scopus

Figure 3 shows the annual distribution of scientific production from 2018 to 2023 related to the use of technologies for teaching mathematics. In 2018, 9 scientific articles were published. There was a decrease to 7 publications in 2019. The trend remained stable with 6 publications in both 2020 and 2021. The downward trend since 2018 was interrupted in 2022, which saw the highest level of scientific production with 10 publications. However, the trend reversed again in 2023, with a drop to 8 publications.

In 2022, the most productive year, the standout work was "The flipped classroom in the meaningful learning of mathematics: case study eighth year of basic general education" by Morocho-Lara, D., Páez-Quinde, C., et al. (2022). This study aimed to analyze the contribution of the 'flipped classroom' model to meaningful mathematics learning using web 3.0 digital tools. The methodology was experimental-exploratory, using a structured questionnaire with 17 questions. The study concluded that the flipped classroom model significantly enhanced mathematics learning, benefiting 30 students in their daily educational activities. It also increased the use of digital documents, multimedia resources, and web 3.0 tools developed by the teacher, promoting optimal and flexible learning in a social environment.

Distribution Of Scientific Production by Country of Origin.

Figure 4 shows how the scientific production is distributed according to the nationality of the authors.

Figure 4. *Distribution of scientific production by country of origin.*

Source: Authors' own elaboration (2024); based on data provided by Scopus.

Figure 4 represents the distribution of scientific production by country of origin within the Latin American context. Ecuador ranks first in scientific productions on the use of ICTs in teaching mathematics, with 11 publications. Colombia follows with 8 publications, and Mexico with 7. Peru contributes 6 works, placing fourth. Brazil ranks fifth with 4 scientific papers, followed by Argentina with 2 articles. Costa Rica, Cuba, and Honduras each have 1 publication during the 2018-2023 period.

In Ecuador, the study "The management of ICT in the teaching of mathematics: a case study in Cuenca, Ecuador" (González, N., Sánchez, M., et al., 2018) aimed to determine the existence, management, and use of ICTs within the Mathematics teaching-learning process in Cuenca's Unified General Baccalaureate institutions through students' perceptions. The quantitative, prospective, cross-sectional, and observational study found that most teachers use ICT for preparing teaching materials, though only a small percentage use them as often as necessary. Search engines and word processors were the most used tools, while more relevant tools for learning mathematics, like Geogebra, were used less frequently.

In Colombia, the work "Integration of technology in a course for future mathematics teachers" (Castrillón-Yepes, A., Carmona-Mesa, J.A., Villa-Ochoa, J.A., 2020) aimed to integrate technologies into a mathematics course for future teachers. Two types of environments were created: one focused on interaction and communication technologies and the other on technologies for studying mathematics. The results showed that the first environment acted as an extension of the classroom, allowing teachers to recognize students' learning processes and needs, while the second environment enabled the creation of strategies to solve tasks.

Distribution Of Scientific Production by Area of Knowledge

Figure 5 shows the distribution of the elaboration of scientific publications based on the area of knowledge through which the different research methodologies are implemented.

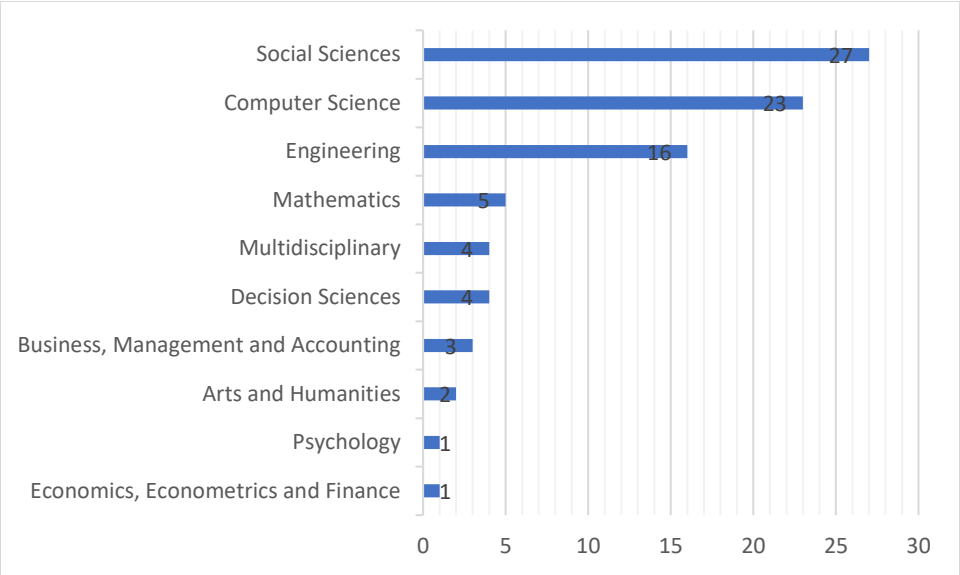

Figure 5. *Distribution of scientific production by area of knowledge.*

Source: Authors' own elaboration (2024); based on data provided by Scopus.

As shown in Figure 5, the distribution of scientific production by area of knowledge reveals that the Social Sciences lead with 27 publications. Computer Science follows with 23 scientific papers. Engineering holds the 3rd position with 5 scientific productions. Multidisciplinarity and Analytical and Decision Sciences are tied for 5th place with 4 publications each. Administrative, Business, and Accounting Sciences are in 6th place with 3 publications. Arts and Humanities occupy the 7th place with 2 scientific productions. Psychology and Economic, Econometric, and Financial Sciences are in the last place with 1 scientific production each.

Highlighted in this section is the study "Design, Construction, and Evaluation of a Web Application for the Teaching-Learning Process of Financial Mathematics" (Salas-Rueda, R., 2020), which analyzed the impact of the Web Application for the Simple Discount Teaching-Learning (WATLSD) process using data science and machine learning (linear regression). The results indicated that WATLSD positively influences motivation, active participation, and the development of mathematical skills. Data science established 3 predictive models for WATLSD's use in education, showing that technological advances like WATLSD create new virtual learning spaces.

Another notable work is "Digital Gamification in Students of Basic General Education," which analyzed educational gamification as an innovative alternative for learning multiplication and assessing logical-mathematical skills. A descriptive correlational study showed that students are more motivated when teachers use playful elements in the classroom.

Type of Publication

In the following graph, you will see the distribution of the bibliographic finding according to the type of publication made by each of the authors found in Scopus.

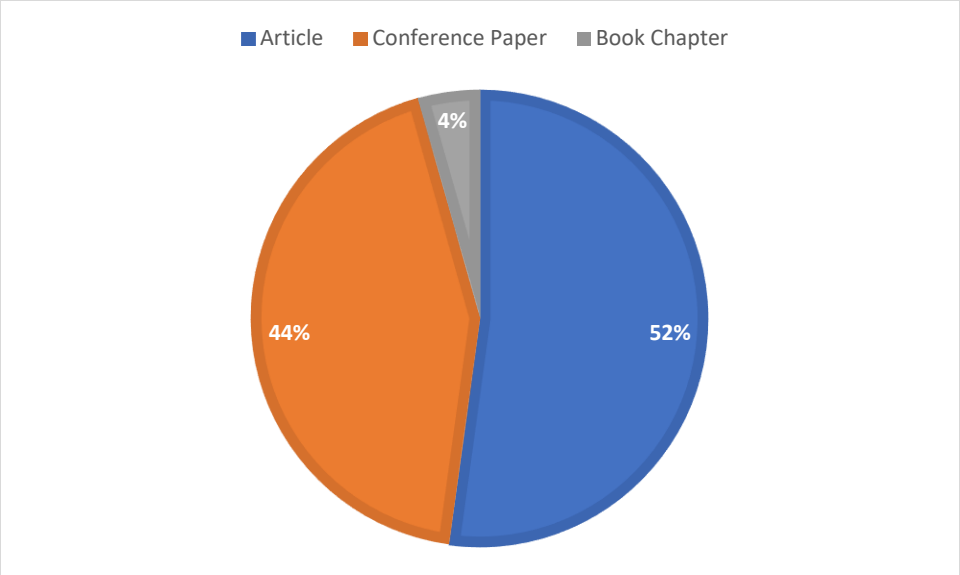

Figure 6. *Type of publication.*

Fountain: Authors' own elaboration (2024); based on data provided by Scopus.

Figure 6 illustrates the bibliographic findings according to the type of publication in the SCOPUS database. The largest number of scientific productions were journal articles, comprising 52% of the findings. Papers made up 44% of the analyzed publications, ranking second in scientific typologies. Finally, book chapters represented 4% of the results, making them the third most common type of research included in the database.

CONCLUSIONS

The bibliometric analysis conducted for this article confirms that between 2018 and 2023, Ecuador had the highest scientific production in Latin America regarding the use of technologies for learning mathematics. This research highlighted innovation and didactics as key areas that can enhance educational practices in mathematics, significantly impacting students' learning objectives.

Additionally, the area of knowledge with the greatest impact on the production of technologies for teaching mathematics was the Social Sciences. This field provides a socio-critical approach to teaching mathematics, aiming for transformation and adaptation to current educational system needs mediated by technology. The research highlighted various formats and activities that teachers can use to address classroom complexity, respecting different learning styles and manifestations of intelligence in students.

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