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Teaching and Learning Mathematics in Primary Education: The Role of ICT-A Systematic Review of the Literature

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Abstract: Nowadays, ICT play a fundamental role in education, as they are essential in all areas of knowledge at any educational stage. Specifically, in the area of mathematics, within the Primary Education stage, they are also very valid resources. This is demonstrated by the latest scientific studies. In recent times, the scientific literature has provided evidence of all this through different research studies. The aim of this paper is to analyze all those publications that deal with the teaching–learning processes of mathematics through ICT in primary education. The aim is to show the current state of the scientific literature and what elements and aspects to highlight are common to the documents analyzed. By means of the systematic literature review method, we analyzed 11 articles indexed in Scopus and the Web of Science, with the result that the use of ICT in this area is still scarce, as the volume of publications in this respect is very low. This could also indicate a prevalence of traditional methodologies associated with the teaching of mathematics that could hinder students' acquisition of mathematical competence. However, those studies that show the use of ICT demonstrate that its use leads to an improvement in performance, motivation, and problem solving.

Keywords: mathematics; ICT; primary education; teaching–learning

MSC: 97D10

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1. Introduction

It goes without saying that technology plays an important role in everyone's daily life today. This, of course, includes every aspect of society and of individuals.

As the last few decades have shown, the education sector is not left out of all these changes. Moreover, it has great interest in everything concerning technology, as all elements and participants in the teaching and learning processes (hereafter referred to as e-learning) benefit from the advantages that technology and all its derivatives bring daily.

Of course, within the educational area, there are many subjects or subareas where the role of technology in general and ICT has a notable influence. In this way, a first division can be made between subjects, which can be proven by the research or innovations that have been carried out in recent years on the role of ICT in e-learning—for example, in Spanish language teaching [1,2], in the area of science [3], in the area of sports [4], in the area of arts education [5], or in the area of mathematics education [6,7].

It is in the latter area that this paper will focus on, specifically at the primary education stage. This stage is fundamental for students in everything related to the different subjects they are taught. However, mathematics is necessary at this age because students must learn that in their daily life, any element or situation can be susceptible to be mathematized.

The T-L processes of mathematics are essential in today's knowledge society, where there is an imperative need for students to master broad skills from basic to advanced topics

in all educational contexts. Mathematics is a discipline that has been gaining prominence in various areas, particularly scientific and technological development.

However, even though training in this field, as we have been saying, is a process that begins at very early stages, reaching optimum levels of quality and handling of basic concepts is proving to be very difficult. This is due in most cases to the lack of motivation on the part of students or to the difficulties encountered by teachers in designing practical and effective guidance [8].

Moreover, the constant technological innovation cannot be understood today without the presence of mathematics and its different methods. Therefore, ICT and mathematics education are two elements that must always go hand in hand, and the primary education stage is ideal as students are in their early childhood.

They should be taught to respond to the different challenges that society exposes them to on a daily basis and to the large amount of data around them, which they must know how to interpret appropriately [9].

To achieve this, the following elements need to be clear [10]:

1. How the mathematics E-A process should be oriented at the educational stage.
2. What specific ICT (and other) resources are to be used.
3. Coherence between the reality and the objectives to be achieved.

The aim of this paper is to analyse ICT as an effective resource to facilitate the learning process of mathematics in Primary Education, due to the peculiar characteristics of this subject in teaching. Through the study of the published scientific literature, the aim is to locate the focus of attention, to know the most relevant aspects and the most innovative methods in this field.

In accordance with the theoretical contributions collected, this study sets out to analyze research that deals with the use of ICT for learning mathematics in primary education. The research questions derived from the main objective and which guide the research are as follows:

RQ1: How many studies have been published since 2010 on learning mathematics through ICT resources in primary education?

RQ2: Which institutions have developed this research on the use of ICT for learning mathematics in primary education?

RQ3: In what fields of knowledge are the studies on this subject framed?

RQ4: What type of resources and strategies have been used with ICT for learning mathematics in primary school education? What conclusions have been reached based on the results?

2. Materials and Methods

2.1. Design and Protocol

The systematic review methodology was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [11,12]. The research process was carried out in two distinct stages: a first planning stage and a second action stage [13,14].

The PRISMA statement unifies the quality criteria for systematic reviews by updating them within a process, which provides an opportunity to discuss how to reorganize the design and reformulate the existing checklist items, to increase clarity and discuss strategies to facilitate endorsement and implementation by the journals where these studies are indexed.

In a first part called planning, the research objectives and questions were defined, the inclusion and exclusion criteria were decided, based on the objectives, the most appropriate descriptors that appear in Eric's thesaurus were selected and, finally, the databases in which the search for articles was carried out were chosen.

In the action stage, a survey was carried out of the documents indexed in the databases analyzed, refining the results to extract the most interesting information that met the inclusion criteria of the research. Finally, the results were presented in tables and graphs.

The protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols with the number 2022110083 and DOI: 10.37766/inplasy2022.11.0083.

2.2. Eligibility Criteria

The inclusion and exclusion criteria can be found in Table 1 according to the PICO approach [15].

Table 1. Inclusion and exclusion criteria.

	Inclusion Criteria	Exclusion Criteria
Population	Primary school students between 6 and 12 years of age	Students coming from educational stages other than primary education, such as kindergarten, secondary education, or higher education
Intervention	Interventions for teaching mathematics in which ICT has been used to accompany an innovative methodology	Interventions where ICT has not been used for mathematics teaching
Comparator	Not applicable	Not applicable
Outcome	Results that provide new innovative ways of teaching mathematics, which can be extrapolated to any primary education classroom, serving as an applicable example of good practices	Results that cannot be used to implement in primary education classrooms to improve the way mathematics is taught

2.3. Information Sources and Search

Publications from two databases (Scopus and Web of Science) were analysed in September 2022. The Web of Science database search was not restricted to any area, as it was subsequently established which article belongs to which area to see which areas are the most prolific. Keywords were in the title, abstract or keywords: (ICT) AND (Mathematics) AND ("Primary Education").

Two authors (CRJ and MRNP) conducted separate searches, discarded duplicate papers, reviewed the titles and abstracts of articles to select those that met the inclusion criteria and analysed their full content. A third author (JCdlCC) performed Cohen's Kappa [16], which measured inter-rater agreement, obtaining a good value (Kappa = 0.70), and also verified that the article selection process had faithfully followed the inclusion and exclusion criteria.

2.4. Data Extraction

An ad hoc Microsoft Excel sheet (Microsoft Corporation, Redmond, WA, USA) was used to check the inclusion requirements, following the premises of the Cochrane Consumers and Communication Group's data extraction template [17]. The authors (JCdlCC and MNCS) performed this task separately, resolving in a discussion the results obtained by each of them and recording the excluded articles and the reasons for exclusion.

2.5. Data Items

The articles selected for analysis dealt with the teaching of mathematics at the Primary Education stage using ICT. The following data items were recorded in this process: (i) type of study design and sample number (n); and (ii) characteristics of the experimental approach to the problem, methodologies and research settings.

2.6. Summary Measures, Synthesis of Results, and Publication Bias

In this study, a meta-analysis was performed for every three or more studies that obtained the same results, although this can be done every two [18].

2.7. Study Identification and Selection

After performing the search formula with the descriptors in the databases, 67 documents were obtained (Web of Science = 48; Scopus = 19). These were exported to a reference management programme (EndNote X9, Cla-rivate Analytics, Philadelphia, PA, USA). Du-

plicate papers (3 references) were then manually subtruncated. Of the remaining 64 papers, their titles and abstracts were analysed to select those that met the inclusion criteria and discard those that met the exclusion criteria (Table 1). Following this process, 30 papers were eliminated. The remaining 37 were carefully read and the 11 articles suitable for the analysis of this study were finally selected (Figure 1).

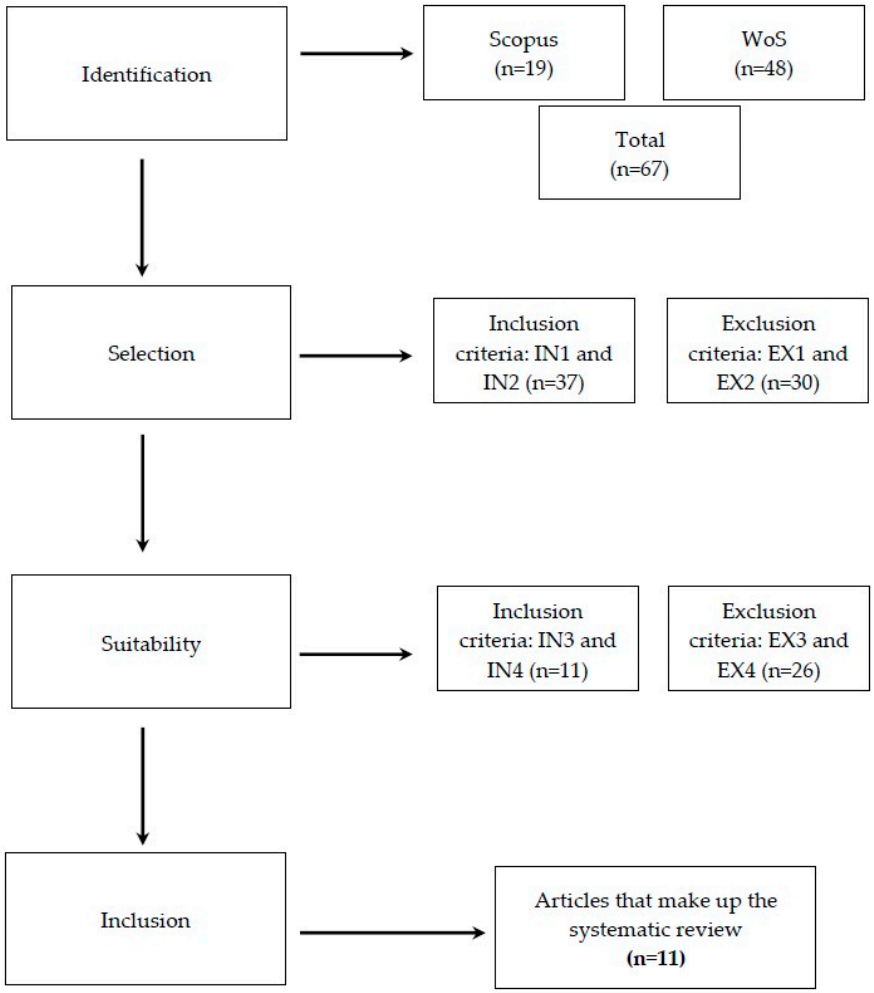

Figure 1. Flow chart. Source: own elaboration based on [12].

3. Results

RQ1: How many studies have been published since 2010 on mathematics learning through ICT resources in primary education?

Since 2010, 67 papers related to the topic in question have been published: 19 in Scopus and 48 in WOS (Figure 2).

Of the 19 documents indexed in the Scopus database, 11 are articles, 4 session papers, 2 books, and 2 book chapters. Of these 11 papers, 3 are from 2010, 2 from 2011, 1 from 2013, 4 from 2014, 1 from 2015, 2 from 2016, 3 from 2018, and 1 each from 2019, 2021, and 2022. After refining the documents to submit them to the inclusion and exclusion criteria and obtaining 11 articles, the highest number of publications were made in 2014, with 36.36% of the total (4 articles), decreasing in subsequent years until reaching 1 article in 2022.

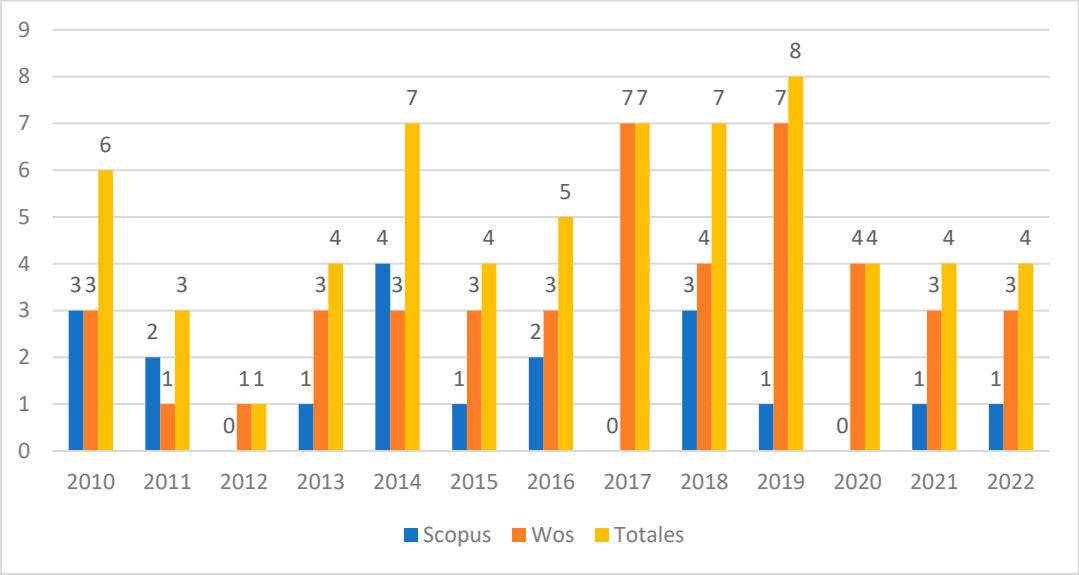

Figure 2. Articles published in the last 10 years in Scopus and WOS on learning mathematics through ICT resources in primary education. Source: own production.

In the WOS database, 48 documents are indexed, of which 26 are articles, 22 are meetings, and 2 are review articles. By submitting the documents to the exclusion and inclusion criteria and obtaining 26 articles, it was found that in the years 2017 and 2019 is when the highest percentage was published, i.e., 26.92% of the total (7 articles) for each year, decreasing in subsequent years to reach 3 articles in the year 2022.

A total of 11 articles met the objectives and inclusion criteria of this research in the two databases, Scopus and WOS. Prior to 2010, there is no publication that responds to the topic in question, in either database.

RQ2: Which institutions have developed this research on the use of ICT for learning mathematics in primary education?

There is a wide variety of institutions, 34 in total, and countries (13) that have published articles on the use of ICT for learning mathematics in primary education (Table 2).

It can be highlighted that the University of Granada is the institution with the most affiliations (5), followed by the University of Salamanca (2), belonging to Spain, and the University of Quindío (2), which is in Colombia. Figure 3 shows the percentage of countries to which the affiliated institutions belong, with Spain standing out (45%).

RQ3: In what fields of knowledge are the studies on this subject framed?

The five articles indexed in Scopus are in two different research areas: mathematics (two articles) and social sciences (three articles).

The six articles found in WOS are divided into five thematic areas, as shown in Table 3.

In WOS, the field of knowledge of education and educational research is the one with the most articles, with 83.33% of the total five (Figure 4). In Scopus, the predominant subject area is social sciences, with 60% (three articles).

RQ4: What type of resources and strategies have been used with ICT for learning mathematics in primary education? What conclusions have been reached based on the results?

Table 4 shows the type of resources and strategies used with ICT for learning mathematics in primary education, as well as the conclusions drawn from the results.

Table 2. Institutions with which the authors of the articles listed are affiliated.

Institutions	Affiliations Number	Country	Percentage
University of Murcia	1	Spain	45%
University Rey Juan Carlos	1		
University of Salamanca	2		
University of Vigo	1		
University of País Vasco	1		
University of Granada	5		
University Camilo José Cela	1		
University Pablo de Olavide	1		
University of Sevilla	1		
University Carlos III de Madrid	1		
International university of La Rioja	1		
University Jaume I	1		
University of Valencia	1		
University of Crete	1	Greece	12.5%
University of the Aegean	1		
National and Kapodistrian University of Athens	2		
University of Thessaly	1		
Central Educational Consultancy Centre Nederland	1	Netherlands	7.5%
University of Amsterdam	1		
CTR Educ. Consultoría cent. Nederland	1		
University College of Dublín	1	Ireland	7.5%
Technological University of Dublín	1		
University of Dublín	1		
Süleyman Demirel Üniversitesi	1	Turkey	5%
University Suleyman Demirel	1		
University of Quindío	2	Colombia	5%
Northern Arizona University	1	United States	2.5%
University of Queensland	1	Australia	2.5%
University Mykolas Romeris	1	Lithuania	2.5%
National Polytechnic Institute Mexico	1	Mexico	2.5%
University of South Bohemia Ceske Budejovice	1	Czech Republic	2.5%
University of South Africa	1	South Africa	2.5%
Higher Polytechnic Institute Porto Amboin	1	Angola	2.5%

Source: own production.

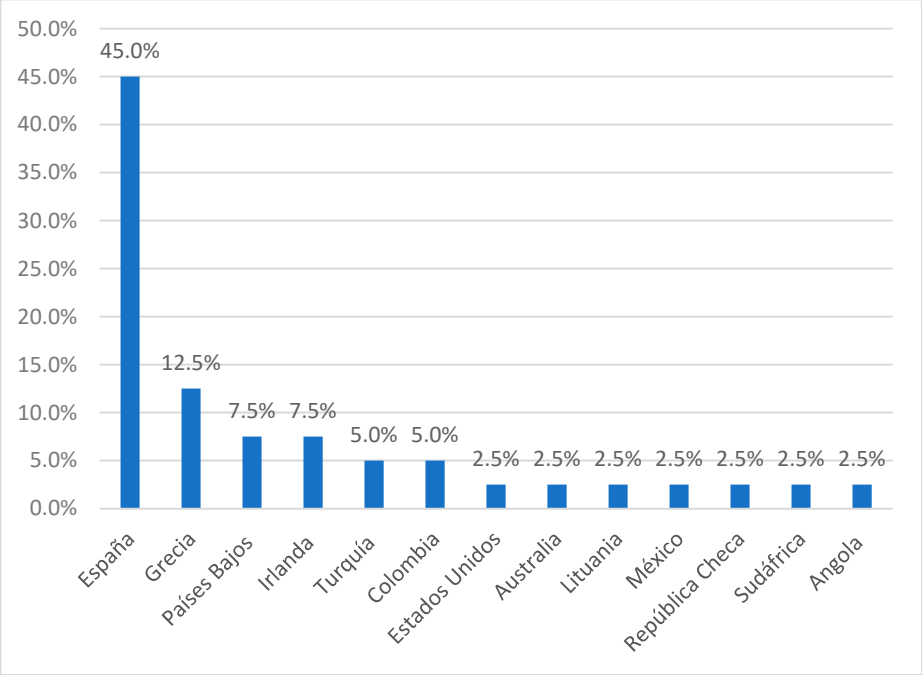

Figure 3. Percentage graph of the countries to which the affiliating institutions belong. Source: own production.

Table 3. Thematic areas of articles indexed in WOS.

Thematic Area	Articles	Percentage
Education and educational research	5	83.33%
Computer science	3	50.00%
Mathematics	3	50.00%
Engineering	2	33.33%
Robotics	1	16.66%

Note: The total percentage is more than 100% as some articles belong to several thematic areas. Source: own production.

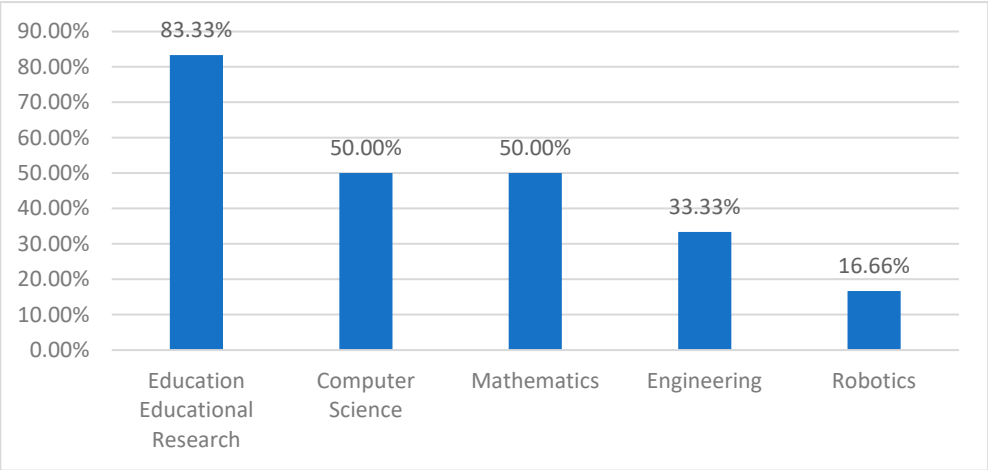

Figure 4. Articles published in the last 10 years in WOS on learning mathematics through ICT resources in primary education. Source: own production.

Table 4. Articles on the use of ICT for learning mathematics in primary school education.

Reference	Resources	Results/Conclusions
Contreras et al. (2019) [19]	Use of resources that show a sense of randomness and the use of probability	These virtual tools deepen the meanings of concepts, show the relevance of procedures and properties, and help to overcome difficulties mainly related to probabilistic biases
Gutiérrez-Zuluaga et al. (2020) [20]	Educational software	Visualization plays a very important role in students' problem-solving styles
Bacelo et al. (2020) [21]	They carried out math activities using a multitouch table with two different methodologies: turn-taking and consensus	The results show that both methodologies help students to acquire meaningful learning
Lara et al. (2020) [22]	Smile and learn, a smart platform with more than 4500 educational activities for children from 3 to 12 years old	It is concluded that it is necessary to continue the development of this type of materials, focusing on the integration of different fields, emphasizing games and the value of teacher training to improve their use in schools
Faustino et al. (2020) [23]	Free digitized textbooks for Spanish and mathematics subjects	It is necessary for the Directorate General of Educational Materials to assess the provision of recommended links for the achievement of learning in the subject of mathematics
Abiatal and Howard (2021) [24]	Focus on children with hearing impairment. Effects of assistive technology (AT) in primary education for the deaf in Namibia	Positive effect on children's performance in multiplication and division
Zaranis (2018) [25]	The level of geometric competence of first grade students and kindergarten students is compared. ICT is used as a targeted learning method specifically for geometry concepts	It is an interactive process that has a positive effect on learning
Zilinskiene and Demirbilek (2015) [26]	Use of GeoGebra in primary mathematics education in Lithuania: an exploratory study from the teachers' perspective	The software allows users to explore multiple mathematical concepts and representations
Etxeberría et al. (2014) [27]	The Ikasys program for integrating computers into mathematics learning.	The program has had a beneficial impact on overall performance in mathematics, as in all three grades, the scores obtained by students in the experimental group are higher than the scores obtained by students in the control group
Kuiper and de Pater Sneep (2014) [28]	A study of the opinions of students in grades 5 and 6 regarding two mathematics exercise and practice software packages	Most of the students preferred to work in their workbook as they found the structure of the software rigid
Campbell, C. (2013) [29]	Teaching Teachers for the Future (TTF) project. Digital technologies to teach mathematical content and develop students' mathematical understanding and improve skills using ICT	The packages present positive aspects, helping students to conceptualize how technology can be used to enhance classroom teaching

Source: own production.

4. Discussion

In this study, we set out to analyze research that deals with the use of ICT for learning mathematics in primary education, both quantitatively (number of studies published since 2010) and in terms of identification (institutions that have developed research on this focus, areas of knowledge, and the types of resources and strategies used), bearing in mind that the teaching of mathematical skills in the early years of education is essential for the acquisition of mathematical tools and progress of their long-term development [30].

We were only able to find 11 studies in the last 12 years that use ICT tools in primary mathematics teaching. Compared to other mathematical learning methodologies, both

traditional and innovative, ICT tools in mathematics learning at school level still represent a scarcely examined field of knowledge [31]. The scarcity of studies on the use of ICT in mathematics learning in primary education may reflect a deficit in relation to the use of traditional methodologies. Therefore, methodological change in mathematics teaching from the traditional model to the innovative ICT model is in process, but it is still slow and does not reach all classrooms to achieve mathematical competence in all pupils.

Despite this scarcity, the studies analyzed show that the use of ICT tools in mathematics teaching improves both academic performance [25,27] and problem solving in everyday mathematical life, improves procedures [19], improves problem solving [20], increases meaningful learning [21], and improves performance in basic mathematical processes [24] and abstract conceptualization [29].

Although confronting mathematics learning situations in primary education between different countries is very challenging because each society starts from very different situations, both outside of and inside the classroom, the contributions from Spanish institutions represent 45% of all the studies selected in the first screening, comprising a total of 13 institutions. This broad representation indicates the effort being made in Spain to include ICT in all educational fields and in STEM areas [32].

We found that ICT-enhanced learning in mathematics in primary education covers a wide range of areas, including education and educational research, computer science mathematics, social sciences, engineering, and robotics (WOS). This learning is not limited to strictly educational areas, but ICT-enhanced learning is also being used in applied areas (engineering, robotics) and even in social sciences. The variety of subjects can lead to the elimination of learning barriers in mathematics with the use of ICT [33].

Innovative methodologies incorporating ICT tools often use more varied teaching strategies and techniques than traditional ones, including instrument manipulation and graphing [21], which can undoubtedly be linked across disciplines and in the children's context [31], constituting an important driver for improving students' mathematical performance. Other ICT tools used include software applied to mathematics teaching, but also digitized books, tools to assist children with hearing difficulties, touchscreens, and resources for training in random procedures. It is striking that apps, gamification, mobile learning, or other e-learning tools have not been used within this focus of study and that they have already been used in different fields of study [34].

Some of the studies indicate the difficulties faced when implementing ICT, such as the need to develop specific software [22] and the integration of other tools such as traditional games, not only ICT tools [22], but also the need to train teachers in ICT and the difficulty of handling cumbersome software [28].

The selected studies also present some disadvantages compared to traditional methods of teaching mathematics, although some of them identify the future. Faustino et al., [23] indicate the need to involve educational policies to have links capable of making progress in the achievement of learning in the subject of mathematics.

It is difficult to compare the research results of traditional methodologies with those using ICT tools, as the research procedures and objectives used are different. However, the evidence provided in this review confirms the need to include technological and innovative strategies in the classroom to improve problem solving and mathematical competence.

When analyzing the studies, it was verified that eight of them confirm that technology helped to improve teaching in primary education classrooms, through increased performance, by means of the possibility of exploring multiple mathematical concepts and representations and carrying out interactive work. It has also been shown that ICT can improve the understanding of concrete operations such as multiplication or division, help to develop meaningful learning, enable the visualization of abstract concepts, help to assimilate the subject, show the relevance of procedures, and help to overcome difficulties.

The three remaining articles analyzed add to the findings of this research by showing the need to take advantage of the benefits of ICT and develop this type of resources through the integration of different areas, using games and valuing teacher training. It should also

be ensured that the structures of the software used are not too rigid, and that the General Directorate of Educational Materials provides appropriate links for the correct learning of mathematics.

The main limitations of this work were found in the search for empirical evidence of innovative ICT methods because this is a relatively recent field of research, and it has been difficult to find quantitative studies. The theoretical basis of each of the studies analyzed, the methods described, the students studied, and the materials and methodological proposals have been very varied and therefore very complex, so another limitation was synthesizing the information. Despite the limitations, the usefulness of the findings can be significant at the educational and professional teaching level, as this study synthesizes some interesting intervention methods for future research in the area. Moreover, the ICT tools studied could be both a starting point and a reference for the design of new teaching–learning strategies for mathematics at school level.

Future research should focus on analyzing the cognitive processes involved in mathematical learning by conducting empirical studies. Furthermore, it is essential to consider the training of future teachers not only in the use of ICT tools but also in the whole process from design to implementation, including the understanding and mastery of all the resources needed to implement an ICT tool, so that they can learn about new alternatives for teaching mathematics and the resources available to put them into practice. As proposed by [31], we believe that teacher training programs for preschool and primary education teachers should be designed to provide work sequences and resources that can be applied in the classroom, including the use of ICT tools.

5. Conclusions

In conclusion, the most important scientific contribution of this work is that it provides different practical frameworks on the use of ICT tools in primary school classrooms on which to base future work, both empirical and experimental, and could provide a research synthesis on which to support new educational challenges. This review can broaden the practical basis in the classroom for using ICT tools in non-traditional mathematics learning, bringing significant benefits in terms of motivation and improved academic results.

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Conflicts of Interest: The authors declare no conflict of interest.

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