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Impact of Teacher Training on the Use of ICT for Teaching Mathematical Operations in Primary Education: A Review Study

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Abstract

In some primary schools, mathematical operations are taught using traditional approaches, where teachers are unable to diversify their teaching resources due to their limited mastery of ICT. This research therefore analyzes the literature to determine how ICT can facilitate innovation in mathematics teaching. A literature review methodology was chosen, using a qualitative and descriptive approach. The results show how the incorporation of ICT can lead to a more extensive understanding of concepts, critical thinking, and autonomous learning. However, the use of ICT depends on the training that teachers receive. Therefore, it is concluded that training is the key to innovating teaching methods in mathematics in primary education, as it helps to bridge the cognitive digital divide, diversify methodologies, improve student learning, and optimize teaching processes.

Keywords: ICT, teacher training, mathematics education, basic operations, teaching innovation.

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Introduction

The teaching of mathematics in primary education presents difficulties that date back to the past, particularly the conceptual appropriation of basic operations. For many years, mathematics teaching in basic education has been centered on traditional methods, focused on memorization and repetition of procedures that do not enable correct conceptualization and meaningful understanding for students (Hussein, 2022). While this model may be useful, it can also limit the development of critical thinking and problem-solving skills.

Information and communication technologies (ICT) can be considered an essential element for achieving innovation in mathematics teaching, making use of more active strategies adapted to students' diverse learning styles (Das, 2019; Perienen, 2020; Rodríguez et al., 2023); However, how to integrate them correctly depends largely on the preparation and training of teachers. It should be emphasized that failure to provide proper training in the use of ICT leads to a cognitive digital divide, that is, a gap in the knowledge and skills needed to use these types of resources correctly in classroom practice (Chohan and Hu, 2020).

Training educators in the use of ICT has become established as a key factor in educational quality and the development of innovative methodologies that facilitate the understanding of mathematical operations, as reported by (Lovianova et al., 2021; Chapai, 2023), it is necessary to train educators, promoting the acquisition of digital skills that also enable them to integrate these skills pedagogically to optimize student learning. From this perspective, various studies have claimed that the presence of ICT in mathematics teaching promotes the visualization of concepts and autonomous learning and encourages student motivation (Maharjan et al., 2022).

Following this line of thought, the purpose of the research is to analyze how Information and Communication Technologies (ICT) affect the teaching of mathematical operations in primary education, highlighting the importance of teacher training as a key element for their effective integration into pedagogical processes. With a qualitative approach, descriptive scope, and a design based on a review of the literature, the study seeks to identify the main trends, approaches, and findings reported in recent global research that demonstrate the influence of teachers' digital competence on the teaching and learning of mathematics in the early stages of education.

Literature review

In this research, the literature review is structured around three axes that allow us to understand the training of educators in the implementation of new technologies, as well as to recognize the importance for teachers of acquiring digital and methodological skills that enable integration within the classroom. In this regard, previous studies are explored that demonstrate the relationship between teacher training and improvement in teaching-learning processes mediated by educational technology.

Similarly, learning the four basic operations is studied as an important aspect in the development of students' logical-mathematical thinking, highlighting how ICT can enhance this learning. Finally, the use of ICT in teaching practices and innovative methods and resources that are productive in mathematics learning in primary education is examined, which allows for an evaluation of the problem under study and provides theoretical support for the importance of teacher training in these technologies.

Teacher Training in the Use of ICT for Teaching Mathematics in Primary Education

In mathematics education, integrating ICT requires educators who have been trained in technology in order to take advantage of the possibilities offered by these tools. The integration of ICT in the classroom requires the articulation of technological, pedagogical, and curricular content knowledge, which is defined by the TPACK model: Technology, Pedagogy, and Content (Willermark, 2018; Ammade et al., 2020). Therefore, teacher training must address both technical mastery of digital tools and strategies for teaching mathematical operations in primary education.

Some research suggests that teacher training in ICT has a positive impact on their teaching practices and student outcomes. According to Elsayary (2023), ICT training programs must go beyond the instrumental use of technologies and develop teachers' digital skills for innovative teaching. In the case of mathematics, this means using educational software programs, developing interactive simulations, or using mobile applications that promote the development of mathematical logic and problem solving, promoting active methodologies such as problem-based learning (PBL) or technology-mediated collaborative learning.

However, the introduction of ICT in the classroom presents some obstacles, such as resistance to change among some educators and their lack of training. In this regard, (Mynaříková and Novotný, 2020; Ergado et al., 2021; Akram et al., 2022) indicate that although many teachers recognize the need to use ICT, This does not translate into a practice that actually includes them, as there are barriers such as a lack of knowledge of appropriate methodologies and the absence of technological infrastructure in educational institutions. For this reason, it is vitally important that teacher training programs not only include guidelines for learning about digital tools, but also encourage teachers to be open to any pedagogical innovation.

In primary education, the teaching of mathematical operational procedures mediated by ICT has introduced interactive platforms, video games, and applications with personalized learning. Dakhin (2021) and Saleem et al. (2021) defend gamification and digital learning environments from a didactic or pedagogical perspective, where the use of these tools can only be didactic and educational if teachers are trained to choose how to use them and to know how to select tools or adapt them to the needs and learning styles of their students.

Therefore, ongoing training for teachers in ICT is essential for successful integration into mathematics teaching. Gómez-García et al. (2020) argue that constant updating of teachers' skills should be on the

educational policy agenda, promoting training opportunities based on reflective practice and experimentation with digital resources. Support and the creation of learning communities among teachers can facilitate the adoption of new methodologies and ensure the sustainability of the incorporation of ICT in mathematics teaching in primary education.

The importance of learning basic mathematical operations at an early age

Learning elementary mathematical operations during childhood is essential for developing logical thinking skills and problem-solving abilities that children may encounter in their daily lives. As Supply et al. (2020) state, early numerical skills not only facilitate educational performance at higher levels, but are also a fundamental component associated with young children's ability to reason and make decisions. Addition, subtraction, multiplication, and division are fundamental to mathematical thinking and help students tackle more complex numerical operations with greater confidence as they progress through school.

Some studies have concluded that teaching mathematics from a very early age is associated with higher academic performance in the future (Rittle et al., 2019), showing that the level of mathematical competence during the early years of schooling is a very good predictor of success in areas such as science and technology in secondary and higher education. In addition, the authors mentioned above point out that the development of numerical skills from an early age is the basis for success in other areas of knowledge, highlighting the need for structured and meaningful teaching of basic mathematical operations.

The acquisition of these skills in early childhood is also related to the strengthening of working memory and abstract thinking, because, as Menon and Chang (2021) explain, learning mathematical operations promotes the development of cognitive structures on which more complex mathematical operations are based. In this way, teaching strategies such as the use of manipulative materials, educational games, and educational technology can promote meaningful learning and motivate students to favor learning arithmetic from early childhood.

Therefore, teaching basic operations in early childhood must be accompanied by appropriate methodologies that foster interest and the acquisition of a deep understanding of mathematical concepts. Vogt et al. (2018) and Hussein et al. (2021) stated that children learn better if they are presented with progressive difficulties and approach mathematics through play and investigation. In this regard, it should be considered that one of the requirements for teachers is to have training in mathematics teaching and in the use of technological resources that enhance and enable the learning that early childhood education students need to develop at this stage of cognition.

Benefits of using ICT in learning basic mathematical operations

ICT in teaching basic mathematical operations has proven to be an effective strategy for improving student learning and interest. According to Kobul (2022), students in the digital age learn differently and are more interested and curious about interactive and dynamic experiences than previous generations. With ICT, mathematics can be presented in an attractive and playful way with simulators, games, and multimedia materials that allow abstract concepts to be worked on in a simple way while helping to promote and acquire the skills considered basic in mathematics.

On the other hand, the use of ICT in mathematics teaching promotes more contextualized and meaningful learning. Swidan and Faggian (2021) define digital tools as instruments that facilitate the relationship between mathematics and a representation of the real world, allowing for an understanding of the usefulness of mathematics. For example, interactive programs and augmented reality environments make it possible to simulate specific contexts in which children have to use mathematical operations to solve real problems, promoting critical thinking and the resolution of specific problems.

Finally, the use of ICT in teaching and learning basic mathematical operations promotes the development of higher cognitive skills. As Trofimets (2021) points out, digital technologies not only help students learn mathematics, but also strengthen creativity, autonomy, and collaboration. The teaching materials now

available through ICT, such as digital whiteboards, mobile applications, and virtual classrooms, enable children to have a dynamic relationship with numbers, leading to more meaningful learning.

Materials and Methods

The approach of this study is qualitative, as it is based on obtaining knowledge that allows for understanding, interpreting, and analyzing scientific production in relation to teacher training in the use of Information and Communication Technologies in the teaching of mathematical operations in primary education. Considering the definition given by Elfenbein and Schwarze (2020), the qualitative approach allows for the exploration of complex phenomena in which the aim is to obtain the participants' interpretation of different situations without the need to quantify the data, which is fully in line with the objectives of the review in this study.

In terms of scope, the research is descriptive in nature, as its purpose is to identify, organize, and characterize the findings of previous studies, without intervening in them or establishing causal relationships. As Bulbulia et al. (2019) point out, descriptive studies allow us to specify the properties and profiles of individuals, groups, communities, processes, or phenomena under analysis, which is appropriate in the context of this review.

The integrated methodological design is a review study. This technique or strategy consists of collecting, exploring, and systematizing relevant information on published research to arrive at an overview of a given topic (Ocaña and Fuster, 2021). This design allows us to establish the state of the art and find gaps or trends in an area of research, as in the case of the study conducted, which seeks to explore how the issue of teacher training in the use of ICT for teaching mathematical operations at the primary education level has been addressed.

Techniques and instruments

Given that this research corresponds to a review study, the technique of documentary corpus analysis was used, which allows for the systematic examination of written sources relevant to the object of study. This technique is relevant in research where the objective is to interpret and synthesize information contained in scientific documents, ensuring rigor and analytical depth.

For the processing and organization of information, Microsoft Excel spreadsheets were used to record data such as the title of the study, authors, year of publication, country, methodological approach, main results, and contributions related to teacher training, the use of ICT, and the teaching of mathematical operations in primary education. This strategy allowed the findings to be categorized and compared in a structured manner.

The selection of bibliographic sources was based on a systematic search for information in academic databases of recognized impact and reliability, such as Scopus and Web of Science, among others. To this end, a search equation was defined, combining Boolean operators and key concepts associated with the subject of the study. The equation used was:

teacher training OR teacher education AND ICT OR "Information and Communication Technologies" AND mathematics AND primary education

Inclusion criteria were established to ensure the relevance and quality of the studies analyzed:

- Publications between 2019 and 2023,
- Studies in English or Spanish,
- Peer-reviewed research,
- Explicit focus on primary basic education,
- Studies addressing teacher training in the use of ICT applied to the teaching of mathematical operations.

In turn, exclusion criteria were applied to delimit the documentary corpus:

• Studies that were not available in full access,

• Research focused exclusively on educational levels other than primary,

• Works that addressed ICT from an administrative or technical perspective, without any link to mathematics teaching.

The verification and filtering process was carried out in three stages: reading the titles and abstracts, reviewing the full texts, and analyzing them based on the categories defined in the documentation matrix. This methodology made it possible to validate the analysis and consistency of the text and the objectives of the research itself.

Results

The results presented below in this study are aligned with the proposed objectives and phases that defined the methodological design. In this sense, the analysis was carried out in three stages, in which the impact of teacher training in ICT on the teaching of mathematical operations can be addressed in a contextualized manner. First, there is a stage of retrieving and systematizing bibliographic sources. Second, there is a qualitative analysis of the information surrounding the approaches, findings, and trends present in the scientific literature. Finally, guidelines and recommendations are formulated based on the analysis, which can serve to guide future teacher training actions and integrate ICT into the teaching and learning of mathematics.

- **First phase results: Retrieval of bibliographic sources**

The first phase of the research focused on the systematic retrieval of bibliographic sources. To this end, a controlled search for information was carried out in high-impact scientific databases such as Scopus and Web of Science, using a retrieval equation adapted to the characteristics of each platform and focusing on keywords such as teacher training, ICT, mathematics education, and primary education. This initial search yielded a considerable number of studies, which were then screened by reading the titles, abstracts, and full text to establish their thematic and methodological relevance.

The selection process yielded 52 documents that were most relevant and consistent with the study's objectives. The documents cover empirical research, systematic reviews, and case studies from different geographical contexts and types of methodological approaches, which provided an adequate and sufficient documentary basis to ensure further analysis. The information from the selected studies was systematized through analysis matrices that enabled the organization of the data and laid the foundations for the development of the following phases of the study.

- **Second phase results: Analysis of the research literature**

Based on a systematic review of the academic literature, it was established that, in relation to teacher training in the use of ICT for teaching mathematical operations in primary education, most studies have focused on three specific lines of research. First, the impact of teacher training in the use of ICT is addressed, exploring how various training programs have influenced teachers' ability to integrate ICT into mathematics classes, as well as the common challenges they face, such as lack of ongoing training, resistance to change, and a shortage of adequate technological resources.

Secondly, the use of ICT in mathematical operations has been analyzed, recognizing the existence of digital tools such as educational software, mobile applications, and learning platforms that facilitate learning in primary education. Researchers who have conducted studies in these areas also highlight the advantages of equipping teaching with tools that facilitate the learning process for students, based on processes such as improving understanding of mathematical operations, the visualization offered by ICT, feedback, and personalized learning, among other aspects. Finally, the impact of ICT integration on mathematics learning has been analyzed, highlighting how these technologies contribute to improving students' academic

performance and learning skills related to aptitude, such as problem solving, logical thinking, and mathematical reasoning.

- **Impact of teacher training on the use of ICT**

Based on the research analyzed, it appears that different professional development programs for teachers have had an impact on their ability to integrate ICT into mathematics teaching. The literature review has shown that training in the use of digital tools promotes educators' willingness to use ICT in their teaching. In this regard, Zengin (2023) indicates that teacher development programs with a practical component (use of educational software or apps) enable teachers to acquire technological skills for teaching mathematics. In addition, Narayanan and Komalavalli (2022) emphasize that training focused on the development of techno-pedagogical skills facilitates the integration of ICT not only when conveying concepts, but also during classroom management and the personalization of learning.

On the other hand, the researchers' findings have also indicated that, despite intensive teacher training, the process of training teachers still presents significant difficulties related to their continuing education. As Mlambo et al. (2020) state, the lack of time for training and the existence of few ICT refresher courses are common factors in many contexts. The results show that resistance to change is another limiting factor when it comes to the effective use of ICT in classrooms. Many teachers feel insecure when using new technologies, which can lead to resistance to change in their educational practice. The literature consulted reveals that these challenges are particularly acute in rural areas or in institutions with few technological resources.

The studies analyzed show that continuing education is important for the effective integration of ICT in mathematics teaching. Training programs that are not constantly updated become obsolete because ICT, by its very nature, is volatile and rapidly changing. The results of the review show that teachers who participate in continuing education are more likely to use ICT in their practice. The information analyzed highlights programs that include technological update modules, such as the use of emerging educational platforms, which increase confidence and digital skills to effectively integrate these technologies into the classroom (Delita et al., 2022).

Researchers agree that, despite the existence of training programs, the lack of adequate technological resources continues to be a very important consideration for many teachers. The results of the literature review highlight that there is a prevailing digital infrastructure gap due to the scarcity of digital devices and technological resources. Wu et al. (2022) point out that many programs that would provide ICT training for teachers would not allow for integrated improvement of digital skills due to the limited availability of technological resources, which causes a gap between the theory learned in training and classroom practice. The results of the literature analyzed suggest that in order to overcome these barriers, it is essential to implement strategies that ensure the availability of resources and technological infrastructure to support teacher training (Zaporozhchenko et al., 2022).

A review of academic literature suggests that one of the most effective ways to address these challenges is through collaboration between educational institutions, public administration, and communities to ensure access to technological resources. Studies suggest that institutional support and the design of collaborative networks among teachers would support the use of ICT. In addition, the design of learning communities and peer training help to overcome resistance to change (Chen et al., 2022). Following the proposals of the studies analyzed, the design of training content is being rethought so that the technical use of the tool is not the only content, but rather the formation of pedagogical skills is promoted, as these allow teachers to develop the skills to be able to propose and implement ICT in the learning of mathematical operations.

Use of ICT in Teaching Mathematical Operations

According to the studies reviewed, the use of educational software, mobile applications, or learning platforms has proven to be useful, and their implementation can be used to teach mathematical operations in primary education. According to research, tools such as GeoGebra, Khan Academy, and mobile applications such as Mathway have been used for this purpose. Studies indicate that this software allows

students to see abstract concepts while being taught interactively. Hence, they facilitate the teaching of mathematical operations such as multiplication and division, among others (Uwineza et al., 2023). Likewise, studies agree that the use of digital platforms allows teachers to personalize the learning experience as the content activity is adjusted to each student. Research such as that by Гуревич et al. (2020) has highlighted that platforms such as Google Classroom and Edmodo allow learning activities to be organized and students to be monitored in real time to see how much they have improved.

The studies analyzed indicate that ICT significantly promotes students' learning of mathematical operations, as it enables learning through an interactive teaching methodology with visual models of processes that allow students to learn about abstract concepts addressed at a given time. The studies reviewed find evidence that it is possible to represent mathematical operations dynamically through digital tools. In addition, students who use interactive educational programs tend to be better prepared than those who use traditional resources (Liburd and Jen, 2021). The studies also point out that feedback from the use of digital educational applications is among the advantages of ICT; instant feedback not only allows errors to be corrected at the same time, but also allows students to be autonomous and self-taught in their learning (Fanshawe et al., 2020).

Research shows that, while feedback is immediate, ICT enables more specific learning tailored to each student. According to the analysis of the studies, tools such as ClassDojo and Edmodo allow teachers to provide detailed feedback tailored to each student's activity, adapting tasks for the rest of the group based on the task performed. Researchers have confirmed that students can progress at their own pace, which allows for a better understanding of mathematical operations (Annisa et al., 2022). Based on the data found, it can be concluded that students with difficulties in certain subjects have the opportunity to be autonomous in their learning, without the pressure of attending a traditional class, and thus be able to overcome cognitive difficulties without feeling stigmatized (Hocine and Sehaba, 2023).

The literature review also indicates that the integration of ICT in the teaching of mathematical operations has a positive effect on student academic performance. In the literature reviewed, positive correlations have been found between the use of digital applications and improved academic results in mathematics. Ran et al. (2021) emphasize that students who have participated in classes in which educational software and interactive platforms have been introduced have significantly improved their grades in mathematics. The evidence found shows that these digital tools not only improve understanding of operations, but also increase student motivation, directly impacting their academic performance.

According to the literature review, ICT also contributes to the development of basic cognitive skills. Studies agree that digital tools stimulate logical thinking, problem solving, and creativity. Research by Olsson and Granberg (2022) highlights that the use of platforms such as Scratch and Tinkercad promotes innovative problem solving, allowing students to develop critical thinking skills while applying mathematical operations. Studies show that these platforms offer a fun and challenging environment that motivates learners to approach mathematical problems in different ways, thereby reinforcing cognitive skills and the ability to solve complex mathematical problems.

Integration of ICT in mathematics learning

The studies reviewed indicate that the introduction of ICT in mathematics teaching has had a positive effect on academic performance. According to the results of the literature, various studies affirm that the use of digital tools in the classroom contributes to an improvement in students' performance on mathematics tests, especially in complex operations or mathematical reasoning problems. The results of the literature review suggest that students who used interactive platforms improved their knowledge and performance more than those who only worked with traditional methods (Luo, 2023). Based on the studies analyzed, it can be concluded that the introduction of ICTs promotes personalized learning, since students work at their own pace (Saif et al., 2022). Along these lines, Hahn et al. (2021) emphasize that the use of ICT, such as online tutoring programs or educational games, provides instant feedback that allows students to overcome their mistakes and improve their results in real time.

The findings of the studies suggest that ICT not only improves academic performance, but is also important for the development of fundamental cognitive skills (problem solving, logical thinking, and mathematical reasoning). According to the results of the review, the use of digital tools in the classroom promotes the acquisition of cognitive skills through interactive teaching activities that encourage both problem solving and critical thinking. Applications such as Khan Academy and GeoGebra promote the development of students' ability to tackle structured mathematical problems, thereby improving their problem-solving skills (Juandi et al., 2021).

Furthermore, studies suggest that the use of ICT fosters students' ability to think logically and sequentially, which is essential for understanding abstract mathematical concepts such as fractions and algebraic expressions (Sanabría-Pérez, & Villamizar-Mendoza, 2020). According to findings in the literature, tools such as Scratch and Tinkercad have enabled students to develop programming and logical thinking skills, which reinforces mathematical reasoning in practical, everyday situations (Gökçe and Yenmez, 2022).

The findings also highlight that ICT promotes more dynamic teaching, in which students actively interact with content, improving their ability to analyze, experiment, and make decisions based on quantitative and logical information. According to the studies reviewed, the use of digital resources in the classroom strengthens mathematical reasoning by offering students the opportunity to tackle a variety of complex mathematical problems that require the development of diverse and creative strategies (Lubis, 2023).

Third stage results: Guidelines and recommendations for improving the integration of ICT in the teaching of mathematical operations

The findings resulting from the review of the academic literature allow us to formulate proposals that can guide the better integration of ICT in the teaching of different mathematical operations in primary education, emphasizing teacher training as a key element for the effective and sustainable pedagogical implementation of educational technology

Firstly, the importance of promoting teacher training from a technical and pedagogical perspective is highlighted. The studies analyzed show that training programs must integrate practical knowledge of computer software, specific methodologies in the field of mathematics, and the most appropriate teaching methods. The integration of the TPACK model is a reference point for guiding teacher training, as it allows technological and curricular knowledge to be combined with active learning methodologies. In addition, it has been found that training experiences that combine pedagogical reflection, cooperative work, and the creation of communities of practice promote a more appropriate appropriation of ICT for educators.

Secondly, the choice and correct use of digital resources are crucial in improving the teaching and learning process of mathematical operations, as research highlights the advantages provided by platforms such as GeoGebra, Khan Academy, Mathway, and others that allow abstract mathematical concepts to be represented interactively, which means that students' understanding and symbolic manipulation can be improved. Similarly, the use of mobile applications or gamified environments has proven to be effective in capturing students' interest and personalizing learning experiences, adapting them to each student's style, pace, and level.

From a methodological point of view, it is important to note that ICT integration should be carried out using student-centered methodologies. In this regard, one proposed methodology is problem-based learning; another very similar approach is technology-mediated cooperative learning; and the last could be the flipped classroom, given that these methodologies facilitate problem-solving, logical thinking, and even the transition to autonomous learning. Technology, used intentionally, allows for dynamic learning contexts, where students receive immediate feedback, solve contextualized mathematical challenges, and develop higher cognitive skills.

However, academic literature also points to the persistence of structural, organizational, and attitudinal barriers to the integration of ICT in primary school classrooms, including poor technological infrastructure, especially in rural areas, insufficient institutionalization of pedagogical support, and resistance to change among some teachers. This confirms what the studies analyzed suggest regarding the implementation of

institutional policies that allow access to devices, connectivity, digital resources, and educational innovation, with the support of institutional leaders. In turn, the studies emphasize that it is not enough to train teachers in the technical use of tools; it is necessary to develop favorable attitudes toward change and continuous improvement.

Ultimately, for ICT integration to be effective in the teaching practices of educators when guiding mathematics instruction, ongoing monitoring and evaluation are necessary. Schools must consider strategies for evaluating the effectiveness of technologies and formulate improvement plans. This also encourages educators to develop teaching strategies tailored to the particular needs of their students. In general terms, adequate training of teachers in the use of educational technologies and a favorable institutional context are conditions that give rise to the transformative integration of ICT in the appropriation of mathematical operations in primary education.

Discussion

The findings obtained from the literature review highlight that teacher training in the use of ICT in teaching mathematical operations has been an area of research in recent decades, resulting in three lines of research: teacher training, the didactic use of ICT, and learning mediated by these technologies.

With regard to teacher training, various studies agree that the professional development of educators is a key variable in achieving the effective integration of ICT in teaching and learning (Ajani and Govender, 2023). For a training program to be effective, it must combine technical learning with the practice of pedagogical and didactic skills, as this enables teachers not only to work with the tools, but also to do so in a more meaningful way (Akram et al., 2022). However, structural and attitudinal barriers are also evident, such as the lack of time devoted to continuing education, the poor technological infrastructure that sometimes exists in rural contexts, and resistance to change on the part of some teachers, especially those with more seniority in their work (Martínez-Soto and Prendes-Espinosa, 2022).

One of the main reflections that emerges from the findings points out how, in many cases, teacher training and classroom practice are disconnected. Murithi and Yoo (2021) emphasize that teachers may acquire knowledge about technology, but if they do not have the necessary resources in the classroom, it is difficult to implement educational innovations. Consequently, teacher training must be accompanied by educational policies that ensure structural conditions such as internet connectivity, equipment provision, and ongoing technical and pedagogical support (Cabero-Almenara, 2021).

On the other hand, the results also highlight that ICT promotes the development of higher cognitive skills such as logical reasoning, problem solving, and critical thinking (Rodríguez-Jiménez et al. 2023), as it allows students to progress at their own pace or even receive almost instant feedback or explore different ways to solve the same problem, in addition to facilitating the construction of meaningful and personalized learning. This concept takes on special significance in primary education, where motivation and playful interaction with knowledge are essential for the development of mathematical skills (Kakavas and Ugolini, 2019).

Finally, it is worth mentioning the importance of adopting a systemic approach to incorporating ICT in the classroom, as this involves not only teachers but also schools, families, and educational policy. As Farias-Gaytán et al. (2023) state, technology-mediated educational transformation is only possible if favorable conditions exist. In this sense, the successful experiences reported in the literature are often accompanied by communities of practice, pedagogical leadership, and a school culture that values innovation. Therefore, one of the most important challenges is the design of models of continuing education that go beyond instrumental logic and promote critical reflection on one's own practices.

Conclusions

The results of this research lead to the conclusion that effective integration of ICT into the teaching of mathematical operations in primary education is significantly influenced by the lack of teacher training in

digital skills and pedagogy. Although the educational potential of ICT is widely recognized, there may be a significant gap between what is learned in training and its practical application in the classroom.

One of the main challenges identified is the lack of continuing education programs that comprehensively address both technical mastery of digital tools and their pedagogical application. In many contexts, especially rural ones, this shortcoming is exacerbated by limited technological infrastructure and resistance to change on the part of some educators, who do not find sufficient institutional support to transform their practices.

Given this reality, it is necessary to establish teacher training programs that are aligned with integrative models such as TPACK (Technological Pedagogical Content Knowledge), which enable educators to develop the ability to select, adapt, and implement digital tools with pedagogical meaning. This model is presented as a relevant conceptual basis for guiding teacher training, as it articulates disciplinary knowledge, didactic knowledge, and technological knowledge, which are fundamental pillars for meaningful teaching of basic mathematical operations.

Similarly, the evidence gathered highlights the need to view teacher training as a continuous and ongoing process that not only updates knowledge in line with technological innovations, but also strengthens a positive attitude towards pedagogical change and the readjustment of educational practice. The rapid pace of new technologies and digital resources requires that teachers have opportunities for continuous updating and activities involving experimentation, critical reflection, and collaborative work among peers.

Finally, teacher training that promotes the transformative integration of ICT in mathematics learning must be addressed by governments, educational institutions, and school communities as a shared commitment, through specific educational policies for access to adequate technological infrastructure, as well as the design of training paths that contribute to developing the professional skills of teachers, understanding their central role in designing meaningful, motivating learning experiences that are tailored to the interests of their students.

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