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The Use of ICT in the Teaching of Primary Education Mathematics: The Impact on Learning Outcomes and on the Career Development of the Teachers

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Abstract

This paper, which focuses on a review of contemporary scientific literature, examines the impact of incorporating Information and Communication Technology (ICT) into the teaching of Mathematics in Primary education. The research data reveal that the use of ICT overturns the 'traditional' pedagogical code, favouring open and inquiry based approaches to learning. ICT strengthens cognitive development through the visualizing of mathematical concepts, promotes student autonomy and teamwork and contributes to a significant improvement in their learning outcomes. At the same time, critical challenges in the educational field are highlighted, such as the lack of adequate teacher training, as well as the need to adapt the pedagogical practices implemented. The study concludes that the teachers' systematic professional development is a necessary prerequisite for meaningful and innovative utilization of ICT in mathematics education.

Keywords: ICT in education, Mathematics teaching, teachers' professional development, primary education

1. Introduction

Information and Communication Technologies (ICTs) have penetrated all areas of human activity, including the field of education, with a view to increasing the effectiveness and quality of the educational work performed by the teachers there (Ersay & Bozkurt, 2015). In fact, ICTs constitute an integral part of the lives of teachers and students. Hence, curricula reforms across all levels of education are linked to incorporating ICTs in the act of teaching (Koustourakis, 2007; Tay et al., 2012; Vrasidas, 2015). Research related to the effective use of ICTs in the educational process has been ongoing for more than four decades in the western world, and research findings reveal that the use of digital tools has a positive impact on the students' learning experience (Hlasna et al., 2017; Hus, 2011).

Today's school, which makes use of innovative pedagogical practices, the school's dynamic and the supportive learning environment that defines it, offers the students an attractive place of learning. Within this framework, the objective is to upgrade the learning process to higher levels through investigative, creative and collaborative learning (Karakostantaki & Stavrianos, 2021). At the same time, the widespread permeation of ICTs on a global scale has brought about important changes in various areas of human activity, including education. The utilization of ICTs in the school environment continually brings to the fore new challenges and opportunities, since they offer a multimodal learning framework through the use of a variety of forms of representation of transmitted school knowledge, such as texts, pictures, sound, video, presentations and the visualization of information (Ersay & Bozkurt, 2015). In addition, ICTs facilitate the teaching process, particularly when the teacher adopts a cross-curricular approach, in accordance with the curriculum directives, thus reinforcing the connection between the subjects taught and the students' overall understanding of the official school knowledge (Gene et al., 2018; Vrasidas, 2015).

Contemporary scientific literature claims that the incorporation of ICTs in the educational process strengthens the development of crucial skills for the students, such as the promotion of critical thought, and contributes to the formation of dynamic and creative learning environments (Ekberg & Gao, 2017). When the students use ICTs they can gather, organize and handle information, present their projects using digital tools and understand and thoroughly assimilate the teaching units thanks to the alternative teaching methods that they offer (Dimitriou & Tzimogiannis, 2016; Kilinc, Tarman & Aydin, 2018). At the same time, the use of ICTs reinforces the students' research potential, promoting forms of investigative learning. In addition, ICTs favor the implementation of a framework of structured and distributed learning, in line with contemporary pedagogical requirements and the fundamental directives of the 21st century model of education (Koustourakis & Panagiotakopoulos, 2008, 2010; Tzimogiannis & Komis, 2004).

The aim of this research paper, which is based on contemporary scientific literature, is the investigation of the use of ICTs in the teaching of Mathematics in Primary Education. The paper aims to highlight the role of ICTs in both the improvement of the students' learning outcomes and in the strengthening of the teachers' professional development, underlining the need for continuing training and adaptation to the pedagogical demands of the 21st century

digital age.

To conduct the present literature review, a systematic search was performed in the Scopus and Google Scholar databases (www.scholar.google.com), employing the keywords "ICT," "Mathematics Teaching," and "Primary Education" or "Elementary Education." From the corpus of peer-reviewed articles retrieved, the analysis was narrowed to those studies that explicitly examine the impact of ICT integration on both students and educators within the context of mathematics instruction at the primary education level. Particular emphasis was placed on identifying empirical evidence regarding pedagogical outcomes, student engagement, and teacher practices influenced by the use of ICT tools (Snyder, 2019; van Wee & Banister, 2024).

Following the section on the theoretical notes, the content of the paper is shaped according to the classification of the review of the scientific literature into particular sections based on the thematic content of the relevant research papers. There is a brief presentation of the findings of certain representative papers in each thematic section so as to shed light on the findings of the particular sections. A section with concluding remarks completes the paper.

2. Theoretical Notes

According to Bernstein (1989), codes are regulatory principles that contain power relations but also principles of social control. The code of educational knowledge, and in particular the subjects taught in Primary education, refers to the fundamental principles that shape the curriculum, the pedagogy, as well as the ways in which the teachers assess their pupils. Consequently, these elements together constitute the actualization of the educational code (Bernstein, 1989, 2003). As a regulatory principle, the code is acquired silently by the subjects, or through an educational process, in this case by the Primary education teachers, shaping the forms of its implementation, as well as the contexts for the expression of their pedagogical practices. From this perspective, we can suppose that Mathematics curriculum in primary Education, due too to the centralized nature of the Greek educational system, constitutes a dominant educational code that defines, shapes and intervenes in the pedagogical practices implemented by the teachers (Koustourakis, 2007; Koustourakis & Zacharos, 2011). Consequently, within this framework, the use and utilization of ICTs does not merely constitute a ‘technical’ addition during the transmission of mathematical school knowledge, but can function as a catalyst to reshape the learning processes at the micro-level of the school classroom.

Closely linked to the concept of code in Bernstein’s theoretical framework, are the concepts of classification and framing (Bernstein, 1989, 2003; McLean et al., 2012). Classification depends on the power that defines what can be placed with what to form a category. Moreover, it is linked to the actualization of certain categories through the imposition of strong – or not – borders and separations between these categories, such as for example the subjects on the curriculum of Primary education (Bernstein, 1989; McLean et al, 2012; Hoadley, 2007; Koustourakis & Zacharos, 2011). Framing refers to the ‘nature’ of the

pedagogical relationship (transmitter – receiver) and to the ability of the transmitter and receiver to select, organize, formulate time restrictions and to pace the knowledge that is transmitted in the communicative framework of the school classroom. When framing is strong, the transmitter's choices take precedence, as he constitutes the most important factor in determining the operational framework of the school classroom in an explicit way. When framing is weak, the choices of the receiver, who is placed at the centre of the learning process, are also accepted (Bernstein, 1989; McLean et al., 2012; Hoadley, 2007). In this research, we assume that the fluctuations in the values that classification and framing may show, will provide us with an opportunity to highlight the 'transformation' of the dominant pedagogical code (curriculum), which constitutes a 'message system' through which the official school knowledge is transmitted. We should point out that in Europe the dominant pedagogical code in Primary education is regulated and actualized by the strong classifications and framings of a collective code depicted in the curricula implemented in the various countries (Bernstein, 1989, 2003; Koustourakis, 2007). Within this framework, the integration and utilization of ICTs in Mathematics may function as a 'lever' for the restructuring of the pedagogical code. Through the use of digital tools, interactive applications, suitable educational software and alternative methods for the transmission and investigation of mathematical concepts, the potential for the weakening of the strong framings of Maths becomes apparent, together with the strengthening of a more open, discursive and investigative approach to the official mathematical knowledge in Primary education. In other words, ICTs can contribute to reshaping the way in which mathematical knowledge is organized, transmitted and experienced, causing 'ruptures' in both the structure of the mathematics curriculum and in the pedagogical relationships that develop within the school classroom.

Closely connected to the concept of code, is the concept of pedagogical practices which, according to Bernstein (1989, 2003) are understood as the social framework through which social reproduction takes place. Bernstein (1989) distinguishes two generative types of pedagogical practices: visible pedagogy, which places emphasis on strict processes for the transmission and evaluation of official school knowledge, as well as on specialized forms of it. This type of pedagogical practice is defined by strong classifications and framings of school knowledge. In contrast, invisible pedagogy is defined by weak classifications and framings and is oriented towards an autonomous course of learning for the acquisition of knowledge as well as more or less unofficial evaluation practices, based on a loosely hierarchical relationship between teacher and students (Bernstein, 1989, 2003).

Bernstein (1989, 2003) assigns especial weight to the nature of the pedagogical relationship between teachers and students, claiming that its internal structure is made up of three interrelated rules. Firstly, there are the hierarchical rules which constitute the foundation for the cultivation of appropriate behavior in the framework of the pedagogical relationship. These rules are related to learning and accepting the roles of teacher (as transmitter) and student (as receiver), through defined models of conduct, morals and social class (Bernstein, 1989). Secondly, there are the rules of sequencing and pacing, which regulate both the temporal and logical order of the transmission of official school knowledge as well as the

progress of the learning process from the students' side (Bernstein, 2003; Koustourakis, 2018). Thirdly, there are the criteria rules through which the student acquires the ability to understand and distinguish, within the framework of the school, which forms of communication, social relationships and positions are acceptable, and which are not (Asimaki et al., 2018; Bernstein, 2003). The use and incorporation of ICTs during transmission of official mathematical knowledge, may bring about material change in the means of teaching, communication and interaction, leading to a redefinition of the criteria rules within the framework of the school. This change is especially apparent in the case of Primary education Mathematics which is defined by strictly delineated and standardized criteria rules that govern the acquisition and evaluation of mathematical knowledge. These rules precisely determine the mathematical language, methodology and forms of thought considered acceptable in the educational context, reinforcing Mathematics' 'strict' character and contributing to the formation of a strong framework for the transmission of knowledge (Bernstein, 2003; Koustourakis & Zacharos, 2011). Nevertheless, the use of ICTs has the potential to bring about modifications to this regulatory framework as it introduces new forms of representation and approach to mathematical concepts, encouraging alternative means for taking in and communicating mathematical knowledge which may be questioned, or recontextualizing traditional teaching and evaluation methods.

The concept of recontextualization, as depicted in Bernstein's work (1989, 2003) constitutes a crucial theoretical category for the understanding of the process of the transfer of knowledge from the field of production (the intellectual field of the educational sciences) to the field of implementation (school classroom). In this framework, the need for the training of Primary Education teachers is linked to the activating of a secondary recontextualization framework, in which theoretical knowledge and pedagogical practices are reformulated so as to be functional and applicable in their day-to-day teaching work (Bernstein, 1989; Moore, 2004). In particular, utilization of ICTs does not only require technological competence, but mainly new cognitive and pedagogical schemata that correspond to the particularities of Mathematics. Hence, training acts as a space for the recontextualization of the transmitted mathematical knowledge where existing pedagogical 'texts' and practices are transformed or replaced by new ones, capable of meeting the demands of digital teaching and creatively incorporating the possibilities of ICTs in Mathematics. Consequently, recontextualization is not a simple 'adaptation' of school mathematical knowledge, but a deeper reorganization of pedagogical discourse and pedagogical practices, that make training a vital and ongoing process for teachers in order to be able to respond to the changing circumstances of today's educational reality (Tsatsaroni & Koulaidis, 2010; Young, 2003).

3. The Incorporation of ICTs into the Teaching of Primary School Mathematics

The teaching of Mathematics in compulsory education aims first and foremost at highlighting the main characteristics of mathematical knowledge, such as generalization, subtraction, accuracy and brevity (Ameen et al., 2019; Arvanitaki & Zaranis, 2020; Baya'a & Daher, 2013; Das, 2019; Fokides, 2017; Gene et al., 2018; Hu et al., 2018; Koustoutakis & Zacharos, 2011).

These characteristics form the foundations for the development of mathematical thought which reinforces the students' ability to handle complex problems in a logical and systematic way. At the same time, the contemporary teaching approach aims at the connection of mathematical knowledge with everyday life, reinforcing the role of mathematics as a tool for comprehension and intervention in the real world (Birgin et al., 2019; Bretscher, 2021; De Witte & Rogge, 2014; Hardman, 2019; Hlasna et al., 2017). In the framework of 21st century educational demands, this approach is further enriched through the incorporation of ICTs which transform the way in which students understand and interact with Mathematics. Hence, ICTs offer opportunities for investigative learning, visualization of abstract and difficult mathematical concepts, as well as simulations of real conditions, making learning more interactive, attractive and connected to today's social and technological reality (Arvanitaki & Zaranis, 2020; Crisan et al., 2007; Das, 2019; Hardman, 2019; Hu et al., 2018; Sivakova et al., 2017).

A study of scientific work that focused on the incorporation of ICTs during the teaching of Mathematics in Primary education revealed that ICTs have made a significant contribution to the improvement of the learning process in a variety of ways. In particular, the use of ICTs facilitates the visualization of abstract mathematical concepts, which is of decisive importance for the cognitive development of younger students (Baya'a & Daher, 2013; Bretscher, 2021; Crisan et al., 2007; Fokides, 2017; Hlasna et al., 2017; Tay et al., 2012). So, through interactive environments such as geometry educational software (for example, GeoGebra), students can investigate mathematical concepts in an active, experimental way. In addition, ICTs promote differentiated teaching and through simulation software, and individualized practice, students have the opportunity to work at their own pace, reinforcing autonomy in Mathematics (Ameen et al., 2019; Baya'a & Daher, 2013; De Witte & Rogge, 2014; Hu et al., 2018; Mailizar & Fan, 2019; Sivakova et al., 2017). It is also worth noting that when Mathematical problems are approached in digital, collaborative environments, collaborative learning is promoted which creates opportunities for teamwork and the development of metacognitive skills (Arhin et al., 2024; De Witte & Rogge, 2014; Gousiou & Grammenos, 2023; Hlasna et al., 2017; Hu et al., 2018; Mailizar & Fan, 2019).

The findings from research by Zakaria and Khalid (2016) are characteristic of this. The main aim of the research was to investigate the benefits and limitations that emerge from the incorporation of ICTs during the teaching of Mathematics in Primary education. In particular, this research aimed to uncover the factors that reinforce the learning process through the utilization of ICTs, as well as the obstacles the teachers encounter during their attempts to incorporate digital technologies into their pedagogical practices. From this research it would appear that the incorporation of ICTs during the transmission of Mathematics highlighted multiple pedagogical and cognitive benefits. Specifically, the strengthening of interaction and teamwork amongst the students was discovered through utilization of modern technological tools such as interactive boards, reinforcing collaborative learning and knowledge through information exchange (Zakaria & Khalid, 2016). Moreover, the use of software such as Microsoft Excel and specialized educational applications for teaching fractions contributed to strengthening understanding, which had a positive influence

on the students' attitude towards Mathematics. Finally, technological applications with immediate feedback and interactive quizzes that were used, promoted strategical thinking for the solution of mathematical problems, reinforcing the students' mathematical skills. A significant finding from Zakaria and Khalid's study (2016) is that the effort to incorporate ICTs into Mathematics teaching is accompanied by obstacles too, such as the limited teaching time and inadequate technical support within the school units. In addition, it was made clear that the teachers face difficulty combining ICTs with the teaching methods they use, something that significantly limits the effectiveness of their utilization (Zakaria & Khalid, 2016).

The review of the scientific literature also revealed that the official educational code concerning the curriculum of Primary education determines strict boundaries, linked to the implementation of strong classifications (Bernstein, 2003), during both the determination of the content of school mathematical knowledge and the recommended pedagogical practices for teaching it (Gene et al., 2018; Koustourakis & Zacharos, 2011). Nevertheless, incorporating ICTs into the educational process in the case of Primary education Mathematics can lead to a transition towards a 'merged' code offering both the teachers (transmitters) and the students (receivers) more flexibility, autonomy and learning in a collaboratively dynamic way (Asimaki et al., 2018; Bernstein, 1989, 2003).

4. The Role of ICTs in the Teaching of Mathematics, and Student Performance

Mathematics in Primary education plays a decisive role in the life of every individual as it makes an essential contribution to the development of knowledge and problem-solving skills in various contexts (Barmby et al., 2025; Dimitriou & Tzimogiannis, 2016). In addition, due to its importance for economic growth and the promotion of science and technology, Mathematics occupies a central position on the curriculum of Primary education (Albeshree et al., 2020; Dimitriou & Tzimogiannis, 2016; Chiu, 2020; Gene et al., 2018; Koustourakis & Zacharos, 2011). According to a number of scientific studies, the teaching of mathematics in primary schools is aimed at the cultivation of abilities that will allow the students to implement mathematical knowledge to effectively deal with everyday challenges (Aytekin & Isiksal-Bostan, 2018; Mensah et al., 2023).

The pedagogical utilization of ICTs has emerged as a fundamental issue globally. To achieve the goals in the fields of scientific and technological progress, reform in the methods for teaching and learning Mathematics is necessary (Albeshree et al., 2020; Chauhan, 2017). In particular, a transition is required from the traditional 'talk and chalk' type of teaching, to a pedagogical approach that makes use of what ICT has to offer (Chiu, 2020; Koustourakis, 2007; Räihä et al., 2013). According to Albeshree et al. (2022), ICT is defined as the process of gathering, retrieving, using and storing information through computer and micro-electronic systems. Meanwhile, Billman et al. (2018) describe ICT as technology that allows for the creation, presentation, storage, processing and exchange of information. In addition, Fathurrohman et al. (2021) highlight that the incorporation of ICT in the teaching process makes the teaching of Mathematics in Primary education more effective and dynamic as it

reinforces the visual, interactive and 'stimulating' nature of learning. Consequently, it should be mentioned that the utilization of ICT makes an essential and catalytic contribution to an increase in the active participation and enthusiasm of the students in the classroom, functioning as a powerful teaching tool (Aytekin & Isiksal-Bostan, 2018; Räihä et al., 2013). The interactive character of ICT is of especial significance and it strengthens interaction, the assimilation of mathematical knowledge, teamwork, and student autonomy (Mensah et al., 2023).

The incorporation of ICT in the teaching of Mathematics in Primary education has been proven, through international and Greek research, to significantly reinforce students' learning outcomes. In particular, studies such as that of Li and Ma (2010) have shown, through meta-analysis, that the use of technological tools in teaching Mathematics has a positive impact on learning performance, with particularly strong results when technology is used to investigate concepts and develop the higher cognitive skills. Similarly, Hattie and Yates (2014) underlined that when ICT is incorporated with clear pedagogical planning, it makes an important contribution to the improvement of understanding and application of difficult mathematical concepts. Meanwhile, Roschelle et al. (2010) demonstrated that the use of interactive technologies, such as mathematical applets and educational simulation software, leads to statistically significant improvements in the deep understanding of mathematical concepts, in comparison to traditional teaching methods.

The findings from research in the state of Utah in the U.S.A. by Brasiel et al. (2016), the main aim of which was to investigate the impact of the use of educational technology during the teaching of Mathematics on the learning outcomes of Primary education students, are representative. The researchers wanted to understand if and how the incorporation of technological tools in mathematics teaching was related to improvement in student performance. This research revealed that the students who participated in lessons that made use of digital platforms, educational learning support software and interactive tools, achieved significantly higher marks in standard tests in relation to their classmates who had either limited exposure to such technologies, or none at all. An important finding from the research was that the mere availability of technological resources within the school unit does not guarantee improvement in learning outcomes (Brasiel et al., 2016). On the contrary, the meaningful incorporation of technological tools in the learning process, combined with appropriate pedagogical practices, were the decisive factors for success. Moreover, it emerged that the active and collaborative use of technology in team-based activities and interactive learning environments, is linked to significantly better learning outcomes, in comparison with passive use (for example watching a video or reading digital material). It also emerged that factors such as socioeconomic background and parents' educational level play a crucial role, influencing both access to technology and effectiveness of its use in the learning process. These findings highlight the fact that the effective incorporation of ICT in Mathematics teaching does not just consist of the introduction of new technological tools, but requires the readaptation of traditional pedagogical practices so as to promote active participation, teamwork and the development of the students' metacognitive skills. Consequently, the utilization of technology in education is shaping a new learning framework

where students are not passive receivers of official mathematical knowledge but rather they are active in its creation (Brasiel et al., 2016).

Study of the scientific literature revealed that in the new learning framework that is being shaped through the utilization of ICTs, students are no longer passive receivers of the official mathematical knowledge, but are instead active participants in shaping mathematical meaning. This shift, according to Bernstein (1989, 2003), entails the weakening of framing and the pedagogical relationships that develop during the educational process between teachers (transmitters) and students (receivers). Hence, control of the educational process is gradually transferred from the transmitter to the receiver, while at the same time the forms of evaluation take on a more 'negotiable' character. From this perspective, the explicit, strict evaluation criteria that accompany Mathematics in Primary education, are not determined exclusively through the achievement of predetermined goals, but include elements of creativity, critical thought and collaborative problem solving. Consequently, the incorporation of ICTs does not only reshape the nature of official mathematical knowledge, but also all the pedagogical practices, introducing a more 'open' and student-centred approach to the explicit and strict evaluation criteria. This change requires the teachers to reexamine their role, and adopt pedagogical practices that favour the students' autonomy and active participation in the learning process (Asimaki et al., 2018; Bernstein, 1989, 2003; McLean et al., 2012).

5. The Need for Teacher Training in the Incorporation of ICTs in the Teaching of Mathematics in Primary Education

In many countries in the western world, Primary education curricula for the teaching of Mathematics require the systematic utilization of ICTs to aid student understanding and consolidate the mathematical content (Agyei & Voogt, 2010; Crisan et al., 2007; De Freitas & Spangenberg, 2019; Dockendorff & Solar, 2017; Koustourakis, 2007; Perienen, 2020; Tran et al., 2020). Although it is vital that Primary education teachers implement the principles and regulations of the curricula, it appears that a large part of them do not possess the necessary technical knowledge for the effective use and integration of ICTs in the teaching of Mathematics. Nevertheless, teachers are called on to incorporate ICTs in their daily teaching practice without being fully aware of the advantages that their use offers. In addition, they are expected to offer their students learning experiences in an environment that they themselves did not have the opportunity to experience as students (Al-Emran et al., 2016; Aslan & Zhu, 2016; Bozkurt, 2016; Kaleli-Yilmaz, 2015; Leendertz et al., 2013; Mailizar & Fan, 2019; Tondeur et al., 2012).

Despite extensive public and private investment in ICT infrastructure in primary and secondary schools, the initiatives often proved inadequate in terms of the actual incorporation of digital technology in the educational process (Ertmer, 1999; Godfrey & Thomas, 2008; Law et al., 2008; Pelgrum, 2001). Research results reveal that even today a huge number of teachers, whether in primary or secondary education, continue to face difficulties in successfully integrating ICTs into the teaching of curriculum subjects, and especially Mathematics (Bingimlas, 2009; Ertmer, 1999; Law et al., 2008; Pelgrum, 2001). As a result,

it is clear that the greatest obstacle to the effective integration of ICTs into school education is the lack of teacher training in technological knowledge and skills. Over the last fifteen years there has been intense dialogue regarding how teachers need to adapt their pedagogical practices so as to effectively incorporate ICTs. However, the research data reveal that the changes required affect all aspects of educational work, including the teaching approaches, as well as the evaluation of student learning (Bingimlas, 2009; Godfrey & Thomas, 2008; Law et al., 2008; Pelgrum, 2001).

More analytically, the findings from a number of scientific studies reveal that the lack of adequate teacher training in the use of technological tools and the inadequacy of the support provided them to achieve this goal, constitute significant obstacles to the effective integration of ICTs into the educational process. Through extensive research in 26 OECD countries, Pelgrum (2001) discovered that the main problem was not the lack of equipment or infrastructure but rather the limited competency of teachers in the pedagogical use of technological tools. Similarly, Ertmer (1999) separated the obstacles to the integration of ICTs into 'first order' (such as the lack of technical equipment) and 'second order' (such as the attitudes, beliefs and knowledge of the teachers). According to him, even when the first order obstacles are removed, successful integration depends, mainly, on the pedagogical knowledge and technological skills of the teachers. The importance of professional development for the effective use of ICTs also emerges from a study by Law, Pelgrum and Plomp (2008) who, through the international research programme SITES, discovered that the viable incorporation of ICTs requires not only technological skills, but also a deeper understanding of the way in which ICTs can reform teachers' pedagogical practices during the transmission of curriculum subjects. In a more specialized framework, Goos and Bennison (2008) focused on Mathematics teaching in Primary education, pointing out that teachers frequently do not have the necessary pedagogical knowledge to incorporate digital tools in the educational process, despite the fact that they may possess basic technological skills. The same research highlighted the fact that training must combine both technological instruction and suitable pedagogical design. Similar findings emerge from Tondeur et al.'s (2012) post-analysis, where it is noted that successful teacher training interventions in ICTs are those that have the following characteristics: focus on and reconstruction of the content of school mathematical knowledge, the alignment of this content with the implemented pedagogical practices, active participation of the teachers and long-term support for them.

The findings of research by Gumiero & Pazuch (2024), the main aim of which was to examine Primary education teachers' use of ICTs in teaching Mathematics and to analyse its impact on the educational process, are characteristic. The results of this research reveal that overall ICTs were not used by teachers when they taught school mathematics knowledge. In particular, the teachers frequently used technological tools and applications to support traditional teaching methods, such as during a more attractive presentation of mathematical content to their students. However, it emerged from this research that they cannot incorporate ICTs in more innovative educational approaches. The factors that affect the effectiveness of ICT use in teaching Mathematics include the lack of availability of suitable technological tools, their scanty technological training, as well as the lack of technological infrastructure in

the various schools. In their conclusions, the researchers emphasize the need for the teachers' professional development for them to be able to effectively incorporate ICTs in their teaching and make use of their potential for reinforcing the students' understanding of mathematical knowledge. The study points to the need for the formation of an educational policy that which will encourage the incorporation of digital tools in the educational process with the aim of creating a learning environment that will support both the development of critical thinking and the implementation of innovative approaches in the teaching of Mathematics.

The study of the scientific literature revealed that the rapid evolution of ICTs has reshaped the demands of today's educational reality, necessitating the professional development of the teachers. ICTs cannot be incorporated into Mathematics teaching simply through providing teacher training in technology. It requires a deeper change in the way the official school knowledge is constructed and transmitted (Al-Emran et al., 2016; Aslan & Zhu, 2016; Bozkurt, 2016; Kaleli-Yilmaz, 2015; Leendertz et al., 2013; Mailizar & Fan, 2019; Tondeur et al., 2012). According to Bernstein (1989, 2003), the recontextualization concerning the way in which knowledge undergoes a reshaping as it moves from the field of production (for example, scientific communities) to the field of teaching (for example, the school classroom) influences both its form and its content. Consequently, it is not a simple 'knowledge transfer', but rather a dynamic process of restructuring and reshaping. Within this framework, the educational community needs new training 'texts' regarding the successful integration of ICTs into the teachers' pedagogical practices, so that these 'texts' can function as forms of recontextualization of knowledge and not just merely pass on techniques for using ICTs. In this way the reshaping of the teachers' pedagogical and teaching background becomes possible, so as to create new perspectives for each subject to be taught (in this case, Mathematics), as well as new ways to organize the teaching act through digital environments (Bernstein, 1989; Moore, 2004).

6. Conclusions

In this study, through a systematic literature review of contemporary scholarly research, we sought to highlight the effects that emerge for both educators and students from the integration of Information and Communication Technologies (ICT) into mathematics instruction at the primary education level. Based on the findings discussed above, we arrive at the following conclusions:

- ICT use makes an essential contribution to the change of the pedagogical code for Mathematics in Primary education, weakening the strong classifications and framings and strengthening more 'open' and investigative learning practices that may come from the principles of a merged code (Bernstein, 1989). Through the use of digital tools, abstract mathematical concepts can be visualized, strengthening Primary education students' cognitive development (Birgin et al., 2019; Bretscher, 2021; De Witte & Rogge, 2014; Hardman, 2019; Hlasna, Klímová & Poulova, 2017). Consequently, it should be highlighted that ICTs can widen the boundaries for the transmission of official school mathematics knowledge, making

the learning process more flexible, differentiated and adapted to the students' needs Ameen et al., 2019; Arvanitaki & Zaranis, 2020; Baya'a & Daher, 2013; Das, 2019; Fokides, 2017; Hu et al., 2018).

- The incorporation of ICT during the transmission of Mathematics in Primary education reinforces the students' active participation and autonomy, and contributes to the development of metacognitive skills, critical thinking and teamwork for solving difficult mathematical problems (Albeshree et al., 2020; Barmby et al., 2025; Dimitriou & Tzimogiannis, 2016; Chiu, 2020). The results of ICT use in the teaching of Mathematics reveal a statistically significant improvement in learning outcomes, particularly when the technology is used for investigating mathematical concepts and not simply as a means to present official mathematical knowledge (Albeshree et al., 2020; Dimitriou & Tzimogiannis, 2016; Chiu, 2020). Consequently, ICT use appears to promote the creation of new, student-centred learning frameworks which recontextualize traditional pedagogical practices and relationships, and alter the strict, explicit evaluation criteria for Mathematics, placing greater emphasis on understanding and solving everyday problems (Aytekin & Isiksal-Bostan, 2018; Mensah et al., 2023).

- The effective incorporation of ICT into the teaching of Mathematics in Primary education requires the systematic and ongoing professional development of the teachers, and this development needs to go beyond the standard technological training and focus more on the transformational utilization of ICT in their teaching (Agyei & Voogt, 2010; Crisan et al., 2007; De Freitas & Spangenberg, 2019; Dockendorff & Solar, 2017; Perienen, 2020; Tran et al., 2020). Consequently, it is essential that training functions as a framework for the recontextualization of official mathematical knowledge and pedagogical practices, making teachers capable of designing and implementing innovative learning experiences through digital environments (Bernstein, 1989, 2003). The absence of meaningful training appears to lead to limited use of ICT, or no use at all, something that subtracts from the potential of technological tools to transform the teaching of Mathematics and improve learning outcomes (Al-Emran et al., 2016; Aslan & Zhu, 2016; Bozkurt, 2016; Kaleli-Yilmaz, 2015; Leendertz et al., 2013; Mailizar & Fan, 2019; Tondeur et al., 2012).

Concluding this paper, we believe that an ongoing review of scientific papers that address the analysis of the training needs of teachers in Primary education for the creative and innovative utilization of ICTs in the teaching of more curriculum subjects, with the aim of drawing up proposals for targeted training programmes, would be of interest to the scientific community.

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