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Review Article

In-service mathematics teachers' beliefs and instructional practices in integrating ICTs into teaching: A systematic review

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ABSTRACT

Many studies have been conducted on in-service mathematics teachers' beliefs and instructional practices regarding integrating information and communication technologies (ICTs) into teaching. This systematic review study investigates in-service mathematics teachers' beliefs, instructional practices, and the relationship between them in integrating ICTs into their instruction. Based on the systematic review methodology and the guidelines for preferred reporting items for systematic reviews and meta-analyses, with descriptive statistics and qualitative analysis data processing methods, 15 studies published from 2014 to 2023 were selected to perform the analysis. These results indicate that many studies show teachers' positive beliefs about ICTs, including their ability to facilitate teaching and learning, improve students' understanding, and promote student-centered learning. At the same time, teachers use multiple forms of technological tools in many different teaching activities. However, difficulties in practice, from teachers' technological skills and knowledge to pedagogical skills in classroom management, are also analyzed from selected studies. Furthermore, this study shows

that the conclusions about a correlation between beliefs and instructional practices in integrating ICTs into teaching in previous studies are relatively diverse. From these results, the study offers recommendations to stakeholders on professional development for in-service mathematics teachers, indicates its limits, and identifies potential future research areas.

Keywords: beliefs, ICTs, in-service mathematics, teachers, instructional practice, systematic review

INTRODUCTION

The rapid development and spread of information and communication technologies (ICTs) in recent years have diversified the possibilities to enrich the teaching and learning environment (Bütün & Karakuş, 2021; Serin, 2017). Teachers lead technology-enhanced mathematics instruction, which significantly differs from traditional paper-and-pencil methods (Wahyu et al., 2019). This enabled both teachers and students to use digital resources and social networks in the teaching and learning process (Gudmundsdottir & Hatlevik, 2018; Leonard et al., 2018; Nagasubramani & Femi, 2018; Park et al., 2017; Pourdavood & Song, 2021; Serin, 2017). For mathematics education, teachers can enhance the effectiveness of ICT by using various technological tools (Das, 2019) and operate comprehensive software to achieve learning objectives effectively (Fatahillah et al., 2020). Technology-enhanced learning environments also allow students to improve their ability to explore, reconstruct, and explain mathematical concepts by connecting graphical representations with formal definitions and engendering group work or problem-solving activities using computers (Das, 2019; Dockendorff & Solar, 2018). Therefore, ICTs are practical tools for reshaping how teachers structure instruction and how students learn in mathematics education (Das, 2019).

Incorporating technological tools into the mathematics classroom depends on the teacher, while one of the factors influencing their use of technology is belief (Eickelmann & Vennemann, 2017; Kul, 2018; Misfeldt et al., 2016). Many studies have examined teachers' beliefs about teaching and learning to understand their instructional practices better. Gurer and Akkaya (2022) conducted a study of 714 pre-service mathematics teachers to clarify the influence of constructivist and traditional teacher beliefs on their acceptance of technology. The results showed that the pedagogical beliefs of the participants were more constructivist-oriented than the traditional ones, and constructivist beliefs significantly influenced their acceptance of technology (Gurer & Akkaya, 2022). However, a survey study of more than a thousand teachers by Hatlevik and Hatlevik (2018) confirmed that teachers' self-efficacy in integrating ICTs into their instructional practice is closely related to their use of ICTs in teaching and their general self-efficacy of ICTs. These research findings help educators and educational managers to enhance and refine their pre-service training and professional development programs (Aljaberi & Gheith, 2018). Therefore, investigating teaching beliefs and practices is the first step in improving teachers' instructional effectiveness (Aljaberi & Gheith, 2018; Kul, 2018; Safrudiannur et al., 2021).

Regarding this topic, several systematic reviews have been conducted to provide an overview of the research results on teachers' teaching beliefs and practices. The study by Mertala (2019) provided an overview of the role and diversity of teachers' beliefs about integrating technology into teaching. Consequently, the study synthesized 35 qualitative empirical research studies using the meta-ethnography method and focused on early childhood education. The findings revealed that goals such as education, socialization, and care play a significant role in teachers' beliefs about the use of technology. These roles and dimensions were identified based on teachers' beliefs about or against integrating technology into their practices. The study by Minarni et al. (2018) discussed the relationship between teachers' teaching beliefs and practices in mathematics and between teachers' teaching beliefs and practices in student learning outcomes, which was reported in several research studies. This study confirmed that mathematics teachers' beliefs guide teachers in determining appropriate instructional practices; student-centered learning approaches improve student learning outcomes; and teachers' beliefs and instructional practices in a student-centered approach can motivate students to build mathematical knowledge and improve mathematics learning outcomes actively. Furthermore, many studies have examined beliefs and instructional practices related to the application of information technology in teaching different subjects, including STEM education. The study by Hasim et al.

(2022) analyzed peer-reviewed publications published between 2017 and 2021 to examine changes in teacher instructional practices after receiving professional development in STEM education, including mathematics.

It can be observed that these reviews examined the relationship between teachers' beliefs and instructional practices separately in education, mathematics education, and STEM education, and no systematic review has investigated mathematics teachers' beliefs and instructional practices regarding integrating information technology into teaching and their relationship, especially in recent years. Therefore, through systematic analysis and review from 2014 to 2023, this paper aimed to fill this research gap on the relationship between the beliefs of in-service mathematics teachers and their ICT-integrated instructional practices. Notably, this systematic review study was deployed to provide an overview of the results of previous studies on teachers' beliefs and practices regarding the application of ICTs in mathematics teaching and to point out the relationship between teachers' beliefs and instructional practices described in these studies.

LITERATURE REVIEW

The Integration of ICTs in Teaching Mathematics

In mathematics education, ICTs have been changing mathematics teaching and learning processes through teachers' adding technological components to classroom learning environments and virtual learning environments with different combinations of hardware, software, multimedia, and delivery systems (Das, 2019). Specifically, research on mathematics education has shown four functions of digital information technology for teachers:

(1) a tool to support the organization of their work (producing worksheets and keeping grades),

(2) tools to support innovation in problem-solving methods and mathematical representation,

(3) tools to connect with the community, communicate, and share documents, and

(4) tools to support students' independent learning, focusing on practicing and evaluating the knowledge and skills achieved in an online format (Clark-Wilson et al., 2020; Yao & Zhao, 2022).

In the study by Trgalova et al. (2018), Thurm and Barzel (2022), and Yao and Zhao (2022), the digital technology employed in mathematics classrooms includes general technology (e.g., authoring tools, online exercise platforms, online video clips, social media, and learning management systems [Drijvers et al., 2021]) are used to communicate, create, share, and store documents, present, and create learning environments (Thurm & Barzel, 2022; Yao & Zhao, 2022); and mathematical technology that allows students to explore, create, manipulate, and transform mathematical objects (Trgalova et al., 2018; Yao & Zhao, 2022) such as function plotters, geometry packages, spreadsheets, dynamic geometry systems and computer algebra systems (Thurm & Barzel, 2022). The software and hardware devices operated in mathematics learning have features that display mathematical objects precisely, making mathematics learning more efficient without reducing the meaningfulness of the learning process (Pradana et al., 2020). Therefore, teachers' awareness of the need for digital learning media to bridge teachers' delivery and students' understanding of mathematical concepts is fundamental (Ishartono et al., 2023).

Many studies have shown that integrating ICTs into mathematics teaching can improve teaching and learning quality (Lawrence & Tar, 2018; Rani & Anisha, 2018). According to Baya'a et al. (2019), the advantages of ICTs in education are divided into two categories: benefits for mathematics teachers and students. For students, ICTs place students at the center of the learning process (Perienen, 2021), contributing to changing their knowledge formation process through constructivist pedagogy, allowing students to use technology to explore and understand mathematical concepts (Baya'a et al., 2019; Kreijns et al., 2013), as well as to increase student interaction with each other and with technology (Becta, 2003; as cited in Baya'a et al., 2019). Meanwhile, ICTs promote innovative pedagogical practices and improve teachers' teaching effectiveness thanks to the ability to enable, improve, and reinforce the use of new pedagogical practices that correspond to the educational demands of the 21st century knowledge society (Aslan & Zhu, 2018; Baya'a et al., 2019; Kreijns et al., 2013; Rani & Anisha, 2018; Serin, 2017).

However, integrating information technology into math teaching poses many challenges for the relevant parties. In addition to difficulties at the management level of schools, teachers and students who directly

operate and use the technology also face challenges in many aspects (Das, 2019; de Freitas & Spangenberg, 2019; Gesta et al., 2023; Kundu et al., 2020). Many studies have shown that the main barriers that lead to teachers' hesitation in applying information technology to teaching include

(1) teachers' trust in technology (Clark-Wilson et al., 2020; de Freitas & Spangenberg, 2019) and teachers' lack of confidence (Baya'a et al., 2019; Billman et al., 2018; Clark-Wilson et al., 2020; Umugiraneza et al., 2018),

(2) ineffective professional development on information technology projects (Baya'a et al., 2019; de Freitas & Spangenberg, 2019),

(3) lack of knowledge about how to integrate information technology in the curriculum (Baya'a et al., 2019; Billman et al., 2018),

(4) difficulties in integrating and using technology tools in class (Baya'a et al., 2019; Billman et al., 2018; de Freitas & Spangenberg, 2019),

(5) lack of technical support and resources (Baya'a et al., 2019; Billman et al., 2018; Das, 2019; Stein et al., 2020),

(6) curriculum-related time constraints in the school schedule for projects when teaching with technology (Baya'a et al., 2019; Billman et al., 2018; de Freitas & Spangenberg, 2019),

(7) students lack available resources to access learning materials (Baya'a et al., 2019; Billman et al., 2018), and

(8) institutional support, inadequate resources and limited access to technology (Kholid et al., 2023).

Consequently, trust, confidence, and knowledge are internal factors that also play a role in the decision-making process and the integration of technology into teacher education (Kundu et al., 2020), combined with external factors such as technical support, resources, time, and access to technology. Fullan (2012) also asserts that internal factors are intrinsic to teachers, and beliefs about teaching with information technology, classroom practices, and willingness to change instructional practices can be seen as barriers to integrating information technology in teachers' teaching.

Mathematics Teachers' Beliefs in Integrating ICTs into Teaching

Teacher beliefs are defined as "the individual conceptions about desirable ways of teaching and conceptions about how students come to learn" (Beijaard, 1998; as cited in Havelková et al., 2022, p. 138) and an ability to shape their instructional practice (Kul, 2018). In mathematics education, teachers' beliefs are considered in two aspects: beliefs about the nature of mathematics and beliefs about mathematics teaching and learning (Kul, 2018). Teachers' beliefs about the nature of mathematics are divided into three categories: instrumentalist, Platonist, and problem-solving (Ernest, 1989; as cited in Kul, 2018). While teachers with instrumentalist beliefs view mathematics as a collection of discrete principles and truths, teachers with Platonist beliefs view mathematical knowledge as based on related, immutable truths and structures of each other and knowledge that is not created but is preexisting and found. On the contrary, teachers with problem-solving beliefs view mathematics as a dynamic, problem-based, and knowledge-producing process that is constantly expanding (Burte et al., 2020; Kul, 2018). The research indicates that teachers' beliefs about teaching and learning mathematics can be divided into traditional and constructivist categories (Ernest, 1989; as cited in Aljaberi & Gheith, 2018). Traditional beliefs view teaching as the process of transferring knowledge from teacher to student, and students passively receive transformed knowledge during the learning process; this makes traditional beliefs associated with teacher-centered approaches (Kim, 2018). Meanwhile, constructivist beliefs view learners as subjects who create mathematical understanding and knowledge as products of their experiences (Kim, 2018). Therefore, constructivist beliefs are associated with the student-centered approach because students are the main factors in the learning process and participate in interactive activities (Kim, 2018). Many studies have shown that teachers' beliefs influence teachers' teaching effectiveness and students' learning outcomes (Tassell et al., 2019).

In particular, by integrating technology into mathematics teaching, teachers' beliefs are the basis of teachers' technology acceptance and thus affect the effectiveness of teaching with technology (Chiu & Churchill, 2015; Kim et al., 2013; Ndlovu et al., 2020; Smith et al., 2016). Mathematics teachers' beliefs about

technology include aspects of self-efficacy, beliefs about using technology (Thurm & Barzel, 2020, 2022), beliefs about using technology in learning and teaching mathematics (Eickelmann & Vennemann, 2017; Thurm & Barzel, 2020, 2022), beliefs about its ease of use, accessibility, and usefulness (Eickelmann & Vennemann, 2017) and beliefs about the nature of mathematics and teaching and learning mathematics (Mataka et al., 2019; Thurm & Barzel, 2020, 2022), also known as epistemological beliefs (Uzuriaga López, 2021). Self-efficacy beliefs in teaching with technology are expressed in the frequency of using technology, positive beliefs about teaching with technology, and confidence in teaching with technology (Thurm & Barzel, 2020). Regarding the application of technology in mathematics teaching and learning, several studies have shown that teachers believe that technology makes students more interested in learning mathematics and supports students in exploring mathematical concepts (Thurm & Barzel, 2022) to understand knowledge and solve practical problems deeply (Hill & Uribe-Florez, 2020; Stein et al., 2020) through dynamism and diverse representational capabilities (Thurm & Barzel, 2022), thus improving mathematical skills and academic performance (Eickelmann & Vennemann, 2017). However, this aspect also includes the belief that using technology is too time-consuming; technology contributes to losing students' by-hand skills when they rely too much on computers (Thomas & Palmer, 2014). On the other hand, studies also indicate that teachers with constructivist ideas and dynamic perspectives on math tend to employ technology more actively, considering it as a teaching tool as opposed to merely a tool for learning and calculating, which has a more student-centered approach to teaching (Ertmer & Ottenbreit Leftwich, 2010). Although some teachers can implement technology in the classroom, research indicates that some teachers tend to restrict their use of technology or hold teacher-centered or traditional beliefs (Kim, 2018; Thurm & Barzel, 2022). Consequently, in the teaching process, they use technology primarily to develop handouts, save scores and attendance, synthesize information, or attract students' attention instead of using technology to facilitate student-centered learning (Kim, 2018). As a result, it is possible to conclude that teachers' beliefs play an essential role in making decisions about incorporating technology into teaching (Kim, 2018; Ndlovu et al., 2020; Pape & Prosser, 2018; Rubach & Lazarides, 2021; Thurm & Barzel, 2020, 2022).

Mathematics Teachers' Instructional Practices of Integrating ICTs into Teaching

In teachers' instructional practices, technology can be used as a teaching tool while also being part of the student learning process (DeCoito & Richardson, 2018). Teachers' instructional practices with technology can be divided into teacher-centered and student-centered (Rubach & Lazarides, 2021). In teacher-centered practice, the teacher is the presenter and controller of the learning process, and the technology is used for instructional purposes (Rubach & Lazarides, 2021). Meanwhile, student-centered practices are described as the technology used to create an interactive and collaborative learning environment between teachers and students, in which the teacher guides students to practice independently, representing the knowledge discovery process (Rubach & Lazarides, 2021). Many studies suggest that teachers' traditional or constructive beliefs are expressed in their strategies and instructional practices (Aljaberi & Gheith, 2018; Belbase, 2015). Furthermore, teachers' beliefs about teaching with technology are the basis for judging their practice of applying technology in teaching (Mertala, 2019). Studies show that teachers who believe in the value of technology in their classrooms tend to use technology more in their instructional practices, and teachers' high self-efficacy beliefs are necessary for effective teaching and learning with their technology (Ertmer & Ottenbreit-Leftwich, 2010; Thomas & Palmer, 2014). However, some reviews also note that many studies did not report a correlation between the two (Aljaberi & Gheith, 2018; Belbase, 2015; Crompton, 2015). That is, teachers' instructional practices are not influenced by their beliefs about the value or effectiveness of the technology. Heterogeneity in the research results on the relationship between teacher beliefs and instructional practices with technology has also been observed in many previous studies (Aljaberi & Gheith, 2018; Belbase, 2015; Mertala, 2019).

Purpose of the Study and Research Questions

This systematic review investigated in-service mathematics teachers' beliefs and practices in integrating ICTs into teaching reported in research over the last ten years. The following research questions determine the focus of this study.

1. What are the essential characteristics of the included studies (such as year of publication, research context, research method, and sample size)?
2. What are teachers' beliefs in integrating ICTs into teaching mathematics?
3. What are teachers' instructional practices in integrating ICTs into teaching mathematics?
4. What is the relationship between teachers' beliefs and instructional practices in integrating ICTs into teaching mathematics?

METHODS

Design

This study conducted a systematic review to provide an overview of related studies and investigate mathematics teachers' beliefs and instructional practices about technology integration in teaching, as reflected in previous studies. The research was carried out scientifically based on a widely used general protocol to collect and synthesize data with the lowest possible level of bias (Hanley & Cutts, 2013), and the procedure was built around the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines (Moher et al., 2010). The research selection process protocol was described in the following order:

(1) inclusion criteria and exclusion criteria for including studies,

(2) databases for including studies,

(3) search terms for retrieving relevant studies, and

(4) methods for study selection, screening, eligibility assessment, data extraction, and analysis.

In terms of data analysis methods, data extracted from the selected studies were analyzed qualitatively and descriptively with Excel software. The software was also used to extract data and visualize results.

Search Methods

The search for relevant studies was conducted based on online databases, including Google Scholar, Mendeley, ScienceDirect, and Scopus, with free online access and updates on the latest research in mathematics education. However, to ensure the quality of the reviewed studies, this study limits the selected studies to those listed on the Scopus index. To identify pertinent research studies, we use the following search terms in these online databases: ("mathematics teachers" OR "in-service teachers") AND ("beliefs" OR "instructional practices") AND ("ICTs" OR "technology"). In addition, to limit bias in the study selection process, the authors independently conducted the search processes, title and abstract screening, full-text review, and eligibility assessment. After each stage, the research team conducted discussions to draw general conclusions about the selected studies based on ensuring the inclusion and exclusion criteria and the eligibility assessment checklist. Mertala (2019) and Hasim et al. (2022) took similar approaches in their studies.

Search Limits

The search only included peer-reviewed journal articles published in English between 2014 and 2023. In academic publishing, peer review aims to assess the quality of articles submitted for publication in a scholarly journal (LibGuides, 2024), ensuring the quality of the selected studies in this research. On the other hand, as the search was conducted in April 2024, a period of ten years from 2014 to 2023 was determined to be the time limit of this research to provide an overview of relevant studies in recent years.

Inclusion Criteria

Selected studies are studies that meet the following criteria:

(1) are experimental studies or survey studies,

(2) research subjects that are in-service mathematics teachers, and

(3) the research objective is mathematics teachers' beliefs and/or instructional practices regarding the integration of ICTs in teaching.

Table 1. Eligibility assessment checklist (Mertala, 2019)

No	Appraisal question
1	Was there a clear statement of the aims of the research?
2	Was the methodology appropriate?
3	Was the research design appropriate to address the aims of the research?
4	Was the recruitment strategy appropriate to the aims of the research?
5	Was the data collected in a way that addressed the research issue?
6	Has the relationship between the researcher and participants been adequately considered?
7	Have ethical issues been taken into consideration?
8	Was the data analysis reported in a sufficiently detailed manner?
9	Is there a clear statement of findings?
10	Does the paper provide information about the research context?

Exclusion Criteria

Studies that met the criteria listed below were excluded:

(1) are book chapters, dissertations, reviews or reports,

(2) the research design was not experimental or survey,

(3) the research subjects were not in-service mathematics teachers,

(4) the research objectives did not include mathematics teachers' beliefs and/or instructional practices in integrating information technology into teaching.

Eligibility Assessment

The studies were selected based on meeting the inclusion criteria and eligibility evaluation. Research quality assessment questions are the basis for this study's eligibility assessment checklist (see **Table 1**). This checklist assessed the eligibility and risk of bias in each relevant study area, such as research aim, methodology, research design, participants, data analysis, findings, and research context, as shown in **Table 1**. The reviewers were required to report the studies' assessment in the predesigned spreadsheet and provide a rationale for their assessment. After completing the assessments independently, the reviewers convened to discuss the findings until an agreement was reached. This strategy ensured that the systematic review was objective and thorough and that the conclusions drawn from the evidence were robust and reliable. For each item, a study scored either 1 (if the answer is "yes") or 0 (if the answer is "no"). Total methodological quality scores were calculated by summing the individual item scores of each study. The reviewers considered the eligibility as "high" if the total score ≥ 7, "moderate" if the total score = 6, and "low" if the total score ≤ 5. Studies with high and moderate scores would be considered for selection.

Search Results

Figure 1 shows the process of selecting included studies based on PRISMA guidelines and creating a database to extract data on the title, authors, year of publication, journal of publication, and abstracts on the Mendeley platform (https://www.mendeley.com) of 104 studies. Studies were selected from databases based on search keywords (as of April 2024), with 54 unique studies selected for screening. The title and abstract screening process produced 27 studies that matched the criteria established by the study. Then, a full-text review and eligibility assessment process is conducted based on a checklist of study selection or exclusion criteria (see **Table 1**). Some studies that were not indexed in the Scopus database were excluded, though they met the inclusion criteria, such as Wong (2016), Uzuriaga López (2021), and Gesta et al. (2023). Additionally, in the process of selecting and reviewing a database that includes titles, authors, research design and methods, sample size, data collection tools, and research results on beliefs and practices, teachers' teaching materials were also created with Excel software to examine the relevance of these studies to the goals of this review. The study by Mertala (2019) also had a similar approach. As a result of the selection process, 15 studies were obtained that were suitable for the scope of the analysis of this study.

Data from these 15 selected studies by individuals in the research team were gathered and analyzed. Discussions were made during these processes to avoid missing information and limit bias. Data were analyzed qualitatively and descriptively and visualized using Excel software, and each researcher then examined the results independently to ensure the certainty of the analysis outcomes. Data about essential

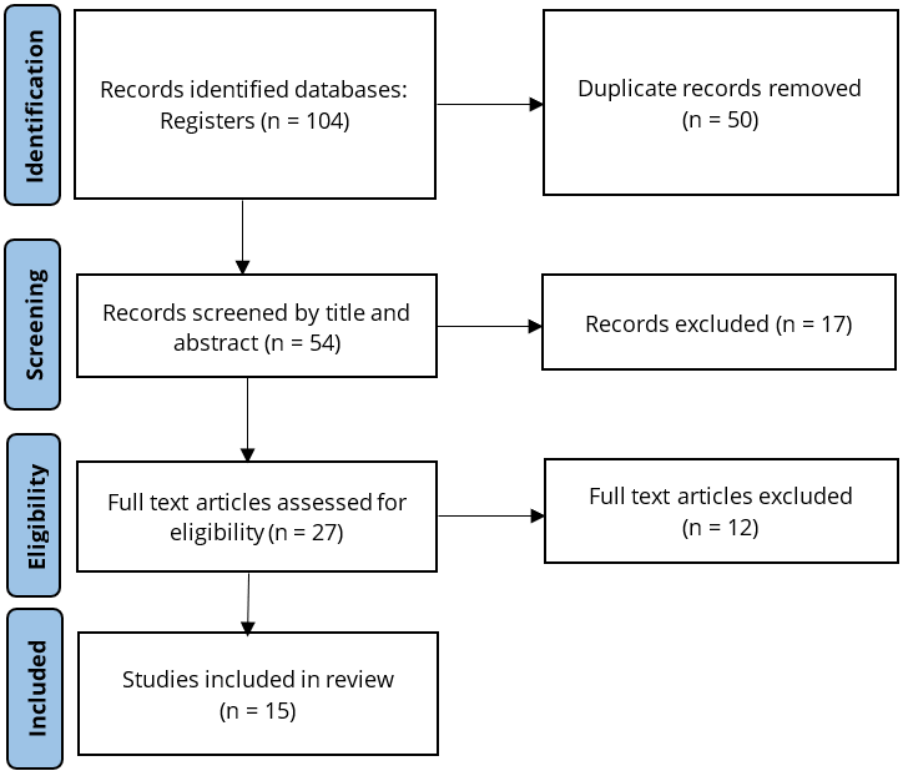

Figure 1. Selection process based on PRISMA (Moher et al., 2010)

Table 2. Demographic characteristics of the included studies

Location	Publication year									
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Africa					South Africa		Mauritius	Mauritius		
America			USA					Chile		
Asia		China			Turkey	China		Turkey	China	
Europe			Danmark				Germany	Netherlands	Germany & Czech Republic	

characteristics of the included studies (such as year of publication, research context, research method, and sample size) were measured by descriptive statistics. In contrast, data about teachers' beliefs and instructional practices in integrating ICTs into teaching mathematics were qualitatively analyzed. Additionally, since data in the review were analyzed descriptively and qualitatively, and the number of selected studies was relatively small, no measure of effect sizes or mean differences was conducted.

RESULTS

Research Question 1. What Are the Essential Characteristics of the Included Studies?

Demographic characteristics

Table 2 displays the essential characteristics of the included studies, including the publication year and the context of the study. The statistical results show that of the 15 included studies, more than 50% were conducted in 2020-2022. Furthermore, the COVID-19 pandemic still affects most countries, and the surge in demand for remote learning has led educators to consider incorporating technology into the classroom (Meletiou-Mavrotheris et al., 2023). In addition, the included studies are also conducted in many countries with different levels of development, which shows that integrating information technology into mathematics teaching is a topic of interest in many backgrounds and education worldwide, in both developed and developing countries.

Table 3. Research designs and research methods of the included studies

Research methods	Research designs		
	Survey	Experimental study	Case study
Quantitative	5 (studies)	2	0
Qualitative	0	1	3
Mixed-methods	3	1	0

Table 4. Sample size of the included studies

Sample size	Included studies
Less than 50	Havelková et al. (2022) (3), Misfeldt et al. (2016) (3), Perienen (2021) (5), Kul (2018) (6), Blanchard et al. (2016) (20), Thurm and Barzel (2020) (39)
More than 50	Chiu and Churchill (2015) (62), Umugiraneza et al. (2018) (75), Bütün and Karakuş (2021) (133), Perienen (2020) (155), Thurm and Barzel (2022) (198), Saadati et al. (2021) (423), Li et al. (2019) (902), Yao and Zhao (2022) (1,083), Drijvers et al. (2021) (1,719)

Research designs

Table 3 shows the different research designs used in the selected studies to investigate teachers' beliefs and practices in applying information technology to mathematics teaching. Eight out of 15 selected studies were surveyed, four were experimental, and three were case studies. Survey studies were conducted with a reasonably large sample size, consistent with the objective of a general assessment of the beliefs and practices of mathematics teachers in applying ICTs. Meanwhile, interventional experimental studies and case studies allow the collection of longitudinal data sets and/or actual observations to examine teachers' beliefs and practices (Kul, 2018; Yang et al., 2023).

Research methods

Many different research methods were used to analyze the data collected in the selected studies, including quantitative, qualitative, mixed methods, and descriptive and inferential statistics; see **Table 3**. Consequently, seven of the 15 selected studies are quantitative, four are qualitative, and four are mixed methods.

Sample size

The research subjects of the selected studies were mathematics teachers in high schools, and the sample sizes of the studies varied significantly depending on different research designs. **Table 4** shows that six studies included fewer than 50 teachers, among which four involved only six teachers and were primarily case studies and experimental studies. Furthermore, most of the remaining studies were conducted with sample sizes larger than 50, with four studies having substantial sample sizes (more than 400, the largest being 1,719). Most of these studies are survey studies and analyzed using quantitative methods, thus providing representative results for the research question about teachers' teaching beliefs and practices in the classroom and applying ICTs to teaching mathematics.

Data collection instruments

The selected studies used various tools to collect data on mathematics teachers' beliefs and practices regarding integrating information technology in teaching, including questionnaires, interviews, lesson observations, and teachers' reflections. However, to collect data that met different research objectives, most included studies used more than one instrument (see **Table 5**). The questionnaires were the most important among the 15 included studies. The most commonly used tool in survey and experimental research has 11 studies. Additionally, interviews were used in five studies, both face-to-face and online. Additionally, three studies investigated teachers' instructional practices and beliefs about information technology by observing lessons directly or through video, and two studies examined teachers' reflections. Specifically, in these studies, teacher lessons are observed or recorded over a long period and analyzed in many aspects, such as teaching style, communication between teachers and students, and activities. Students' activities on the board and the computer, the information technology used, the teacher's activities, programs, and technological applications were used, and the form of assessment (Havelková et al., 2022).

Table 5. Data collection instruments applied in the included studies

Instruments	Included studies	n
Questionnaires	Bütün and Karakuş (2021), Chiu and Churchill (2015), Drijvers et al. (2021), Li et al. (2019), Misfeldt et al. (2016), Perienen (2020), Saadati et al. (2021), Thurm and Barzel (2020), Thurm and Barzel (2022), Umugiraneza et al. (2018), Yao and Zhao (2022)	11
Interviews	Perienen (2021), Blanchard et al. (2016), Havelková et al. (2022), Kul (2018), Misfeldt et al. (2016)	5
Lesson observations	Blanchard et al. (2016), Havelková et al. (2022), Kul (2018)	3
Teachers' reflection	Blanchard et al. (2016), Thurm and Barzel (2022)	2

Research Question 2. What Are Teachers' Beliefs in Integrating ICTs Into Teaching Mathematics?

Teachers' beliefs about the application of information technology in teaching were surveyed in 15 selected studies, including qualitative and quantitative studies (see **Table 6**). Of these, nine out of 15 studies showed teachers' beliefs about the role of information technology in facilitating lesson planning and teaching (Blanchard et al., 2016; Bütün & Karakuş, 2021; Chiu & Churchill, 2015; Havelková et al., 2022; Li et al., 2019; Perienen, 2020, 2021; Umugiraneza et al., 2022; Yao & Zhao, 2022). This view is clearly shown in the following conclusions of some studies.

Table 6. Overview of the included studies

Study	Title	Key features	Design	Methods	n	Country	Journal
Blanchard et al. (2016)	Investigating technology-enhanced teacher professional development in rural, high-poverty middle schools	Beliefs and practices	Experimental study	Mixed-methods	20	USA	Educational Researcher
Bütün and Karakuş (2021)	Mathematics teachers' views on distance education and their beliefs about integrating computer technology in mathematics courses	Beliefs	Survey	Mixed-methods	133	Turkey	Journal of Pedagogical Research
Chiu and Churchill (2015)	Adoption of mobile devices in teaching: Changes in teacher beliefs, attitudes, and anxiety	Beliefs	Experimental study	Quantitative	62	China	Interactive Learning Environments
Drijvers et al. (2021)	Distance mathematics teaching in Flanders, Germany, and the Netherlands during COVID-19 lockdown	Beliefs and practices	Survey	Quantitative	1,719	Netherlands	Educational Studies in Mathematics
Havelková et al. (2022)	Analysis of approaches to the use of ICT in the teaching of mathematics	Beliefs	Case study	Qualitative	3	Czech Republic	Proceedings of the European Conference on E-Learning
Kul (2018)	Influences of technology integrated professional development course on mathematics teachers	Beliefs and practices	Case study	Qualitative	6	Turkey	European Journal of Educational Research
Li et al. (2019)	Exploring mathematics teachers' TPACK competency development	Beliefs and practices	Survey	Mixed-methods	902	China	Proceedings of the 8th International Conference of Educational Innovation Through Technology
Misfeldt et al. (2016)	Teachers' beliefs about the discipline of mathematics and the use of technology in the classroom	Beliefs	Case study	Qualitative	3	Danmark	Mathematics Education

Table 6 (Continued).

Study	Title	Key features	Design	Methods	n	Country	Journal
Perienen (2020)	Frameworks for ICT integration in mathematics education–A teacher's perspective	Beliefs and practices	Survey	Mixed-methods	155	Mauritius	Eurasia Journal of Mathematics, Science and Technology Education
Perienen (2021)	Acceptance of technology in the classroom: A qualitative analysis of mathematics teachers' perceptions	Beliefs and practices	Experimental study	Qualitative	5	Mauritius	Intelligent System Design
Saadati et al. (2021)	Beliefs and practices about remote teaching processes during the pandemic: A study with Chilean mathematics teachers	Beliefs and practices	Survey	Quantitative	423	Chile	Eurasia Journal of Mathematics, Science and Technology Education
Thurm and Barzel (2020)	Effects of a professional development program for teaching mathematics with technology on teachers' beliefs, self-efficacy and practices	Beliefs and practices	Experimental study	Quantitative	39	Germany	ZDM - Mathematics Education
Thurm and Barzel (2022)	Teaching mathematics with technology: A multidimensional analysis of teacher beliefs	Beliefs and practices	Survey	Quantitative	198	Germany	Educational Studies in Mathematics
Umugiraneza et al. (2018)	Exploring teachers' use of technology in teaching and learning mathematics in KwaZulu-Natal schools	Beliefs and practices	Survey	Quantitative	75	South Africa	Pythagoras
Yao and Zhao (2022)	Chinese mathematics teachers' use of digital technologies for instruction: A survey study	Beliefs and practices	Survey	Quantitative	1,083	China	Eurasia Journal of Mathematics, Science and Technology Education

Note. n: Number of samples

> "They could see technology facilitating effective lesson planning, where future lessons can be easily enhanced, edited and updated. These interviews demonstrated that teachers were able to appreciate the worth of ICT as a teaching tool that could ease the teaching of abstract and difficult concepts. One teacher considered the computer as a convenient tool for managing student's personal data, marks and grades" (Perienen, 2021, p. 6).

> "Teachers with productive beliefs were more likely to use technology in their lesson preparation for activities, such as downloading resources for lesson preparation, searching for inquiry-based learning activities, and searching for or creating interactive mathematics applets. They were also more likely to use technology during their classroom instruction for activities, such as motivating students, presenting knowledge and information, modeling problem situations dynamically, visualizing mathematical concepts and relations, supporting mathematical abstraction and induction, and carrying out mathematical actions" (Yao & Zhao, 2022, p. 13).

Furthermore, four of the 15 selected studies highlighted teachers' beliefs about the effectiveness of ICTs in supporting student learning and improving their mathematical understanding. This was achieved through teachers' incorporating ICTs in their teaching and leading students to use these technologies independently (Havelková et al., 2022; Kul, 2018; Li et al., 2019; Umugiraneza et al., 2018). This view is clearly shown in the following conclusions of some studies.

> "Teachers averted their focus from the use of technology to teaching practices and were more focused on teaching practice in the technical context. Teachers began to reconsider technology from a pedagogical perspective and understood the issue of teaching in a technology-equipped context, attempting to use technology to effectively support students' learning" (Li et al., 2019, p. 105).

> "[Teacher]'s beliefs were related to the fact that dynamism can make it easier for pupils to understand the topic, to the belief they need drill, and to the fact that pupils' independent control of programs leads to more precision" (Havelková et al., 2022, p. 142).

> "Using GeoGebra in lesson makes the teaching of the geometry easier, interesting and attractive [...] Two participants became aware of the potential for using GeoGebra as a didactical tool for development of the quality of mathematics education [...]" (Kul, 2018, 239).

Additionally, a critical observation of six selected studies on teachers' beliefs about mathematics and teachers' beliefs about the integration of ICTs in teaching showed that teachers had constructivist beliefs about mathematics learning and promoted a more student-centered learning environment with the integration of ICTs (Kul, 2018; Misfeldt et al., 2016; Perienen, 2021; Saadati et al., 2021; Thurm & Barzel, 2020, 2022).

> "In general, teachers opined that this mode of instruction provided more class time to attend to needy students while high performers proceeded with further work. This was seen as convenient to work with mixed ability students, offering teachers the ability to transform the quality of instruction and promote a more student-centered learning environment [...]" (Perienen, 2021, p. 6).

> "In terms of technology use, her [teacher's] beliefs system is centered around post-mastery and pre-mastery, with a few digressions to exploratory beliefs" (Misfeldt et al., 2016, p. 413).

> "More constructivist beliefs about the learning of mathematics showed significant associations with some of the teachers' self-reported modes of technology use" (Thurm & Barzel, 2022, p. 54).

Moreover, an aspect closely related to teacher belief is teacher confidence and self-efficacy in integrating ICTs in teaching, which was investigated in 6 selected studies (Blanchard et al., 2016; Bütün & Karakuş, 2021; Drijvers et al., 2021; Thurm & Barzel, 2022; Umugiraneza et al., 2022). According to Umugiraneza et al. (2018), teachers stated that having access to online teaching resources increased their confidence in teaching and expanded their beliefs about the nature of mathematics and the purpose of mathematics instruction, compared to those who did not use technology in their teaching. Studies indicate that the COVID-19 pandemic's impact on remote education significantly increased teachers' confidence in using ICTs for teaching (Drijvers et al., 2021). Meanwhile, Thurm and Barzel (2022) point out that self-efficacy is a central construct for higher-level aspects of teaching mathematics with technology, which, along with teachers' beliefs about the benefits of technology, can outweigh negative beliefs and their attitudes toward the use of technology in teaching. As mentioned above, teachers' confidence and self-efficacy in applying information technology are also demonstrated by using various technology tools in lesson preparation, teaching, and student management.

However, the selected studies also noted teachers' negative beliefs about applying information technology in teaching mathematics. Perienen's (2021) research results show that some teachers think that teaching with technology takes much time, thus not ensuring the completion of lessons on time. Furthermore, teachers also believe that using ICTs in teaching and learning will lead to the erosion of hand skills (Thurm & Barzel, 2020), even with their ability to access technology quickly. Some teachers are concerned about losing control of the class, as students might demonstrate greater mastery of the tool than the teacher (Perienen, 2021). On the other hand, teachers participating in the survey in Perienen's (2021) study, especially older teachers, are not confident in applying technology to teaching due to their unpreparedness regarding the skills required to channel the affordances of technology in their teaching.

Research Question 3. What Are Teachers' Instructional Practices in Integrating ICTs Into Teaching Mathematics?

The practice of mathematics teachers applying ICTs in teaching was surveyed in 11 of 15 selected studies (see **Table 6**). According to Blanchard et al. (2016), most teachers participate in research to apply ICTs to improve teaching efficiency and effectiveness, transforming teachers' roles and instructional practices. Specifically, the study by Li et al. (2019) confirmed that teachers could integrate technology into mathematics teaching and were aware of teaching with technology. Through innovative strategies, teaching designs, and assessment forms, teachers have actively and effectively integrated technology to support student learning (Li et al., 2019).

Selected studies have shown that the technology is used in various roles in teachers' instructional practices (Perienen, 2020; Thurm & Barzel, 2020; Yao & Zhao, 2022). The technology effectively allows teachers to manage student data, such as personal information and scores (Perienen, 2020, 2021). Educators can use technology for instructional planning to search for and download educational materials, find innovative approaches to structuring lessons, or develop interactive math applets (Perienen, 2020; Yao & Zhao, 2022). Technology is utilized in the classroom to engage students in learning, provide material dynamically, model mathematical problems, and illustrate mathematical relationships and concepts. It also helps to perform mathematical operations and concretize abstract or deductive concepts (Thurm & Barzel, 2020; Yao & Zhao, 2022). According to the survey results of the selected studies, a variety of technological tools were used to perform these functions, including mathematical manipulation tools such as interactive mathematics applets and dynamic mathematics software; communication tools such as courseware and smartboard; learning resource platforms such as online support resources from textbook publishers; and a national educational resource platform (Yao & Zhao, 2022). This result can be specified by some of the following conclusions from the selected studies.

> "The use of video conferencing tools increased massively" (Drijvers et al., 2021, p.35).

> "… search engines, self-accumulated digital resources, courseware, and smartboard were frequently used by the majority of participants. In lesson preparation, the majority of participants used technologies to download resources, make courseware, and search for practicing problems. Most participants used technologies to motivate students and present knowledge and information during classroom instruction" (Yao & Zhao, 2022, p. 1).

> "Microsoft Word (68.4%) was the most commonly used application software. The PowerPoint presentation program was ranked second, revealing that approximately 1 out of 2 teachers was using this software. Coupled with the fact that 38.7% reported they were using a math software, this indicated teachers' attempt or willingness to integrate ICT in their teaching" (Perienen, 2020, p. 4).

> "Sixty one percent confirmed using ICT to record students' information including marks. Use of the computer for exchanging documents was reported by only 42% of teachers. Many teachers reported frequent use of technology for teaching practices like lesson preparation and searching the Internet for new teaching methodologies and materials" (Perienen, 2020, p. 6).

> "Mathematical software like GeoGebra helps students construct mathematical concepts themselves during online learning. It can help online mathematics learning run more effectively and efficiently" (Ishartono et al., 2022).

On the other hand, the selected studies also showed teachers' difficulties in practicing mathematics teaching with information technology (four out of 15 selected studies). Teachers' difficulties come mainly from the aspects of teaching skills with technology, technical skills, ability to control the classroom and students, as well as issues with technical facilities (Perienen, 2020, 2021; Umugiraneza et al., 2018). Specifically, the survey results and interviews with the teachers who participated in the study indicate the teachers have the following difficulties:

Table 7. Correlation between teachers' beliefs and instructional practice about ICT integration in mathematics teaching

Study	Correlation	Findings
Blanchard et al. (2016)	Positive	As teachers' confidence in mathematics teaching increased, teachers' comfort with using the technology increased, and all teachers participating in the study used technology.
Drijvers et al. (2021)	Positive	Teachers' beliefs played a specific role in motivating teachers to participate in distance learning with technology. Practicing distance learning with technology significantly increased teachers' confidence in using digital technology in teaching.
Havelková et al. (2022)	Positive	Teachers' beliefs in all observed cases significantly impacted how teachers used technology in teaching in practice.
Kul (2018)	Complex	The relationship between teachers' beliefs and their intention to practice technology applications was quite complex. Although teachers tended to be more sensitive to their beliefs, they were also more open to new ideas that could contradict them.
Saadati et al. (2021)	Positive	The correlation between teacher beliefs and instructional practices shows that teachers who perceive fewer difficulties and have confidence in their ability to use technology in the teaching process are likelier to use these strategies. Teaching strategies were implemented in the direction of knowledge discovery, and therefore, students actively participated in online learning activities.
Thurm and Barzel (2022)	Positive	Teachers' constructivist beliefs about mathematics learning showed significant associations with teachers' use of technology.
Yao and Zhao (2022)	Positive	Teachers' beliefs influenced how often they used technology and the specific activities for which they used it. Specifically, teachers with productive beliefs in mathematics, mathematics learning and teaching, student, and self-efficacy tended to increase the frequency of using technology in lesson preparation and classroom teaching.
Umugiraneza et al. (2018)	Not correlated	Although more than 80% of the teachers who participated in the survey had a favorable view of using technology to improve students' mathematical understanding, they said that they did not often use technology in teaching and learning mathematics.

> "ambiguity of what technology integration means" (Perienen, 2020, p. 4).

> "inability to attend to hardware malfunctioning during classes, lack of specific teaching skills and strategies to integrate ICTs in the curriculum, restricted access to the latest technology and appropriate logistics, challenges of managing a digital classroom, with ICTs equipment and students working more independently, the uptake of ICTs will discard the prevailing teaching methods completely, and lack of traceability of work done by students … the tablet left no trace of work accomplished by the student" (Perienen, 2021, p. 8).

Given these difficulties, several studies have concluded that teachers participating in their surveys have a relatively limited frequency of using technology in teaching (Kul, 2018; Perienen, 2020; Umugiraneza et al., 2018). According to Perienen (2020), in a survey of 155 high school teachers, only 25.8% used 10-25% of their teaching time to teach with technology, and only 18% of teachers regularly used technology for direct teaching. In addition, teachers' instructional practice with technology in the above studies shows that some teachers tend to apply teacher-centered or traditional beliefs when using technology (Thurm & Barzel, 2022). Consequently, they primarily use technology in the teaching process for lesson preparation and student management, as well as a teaching and classroom management tool, rather than creating a student-centered learning environment.

Research Question 4. What Is the Relationship Between Teachers' Beliefs and Instructional Practices in Integrating ICTs Into Teaching Mathematics?

Regarding the relationship between mathematics teachers' beliefs and instructional practices with technology, the results of the analysis of selected studies are shown in **Table 7**. Among the 15 selected studies, there were eight survey studies. Regarding the correlation between teachers' beliefs and practices, six studies reported a positive relationship (Blanchard et al., 2016; Drijvers et al., 2021; Havelková et al., 2022; Saadati et al., 2021; Thurm & Barzel, 2022; Yao & Zhao, 2022), one study found no significant correlation (Umugiraneza et al., 2018), and another study confirmed the complexity of determining the relationship between these two factors (Kul, 2018). These studies employed technology to explore the correlation between the two factors by

surveying teachers' beliefs, observing and/or surveying their instructional practices, implementing interventions, such as the professional development program (Kul, 2018), and evaluating how changes in teachers' beliefs influence their practices. Most studies on this topic focus on teachers' constructivist beliefs, beliefs about the potential of technology in teaching, ability to use technology in teaching, and confidence. Teachers' beliefs are essential in motivating teachers to incorporate technology into lesson planning and classroom activities and increasing technology use in their teaching practices. Meanwhile, the study by Umugiraneza et al. (2018) found no significant relationship between teachers' beliefs and their instructional practices with technology, noting that even teachers who believe in the usefulness of technology in teaching do not use it regularly.

DISCUSSION

This study investigated aspects of mathematics teachers' beliefs and practices regarding integrating information technology in teaching reported in research over the last ten years. A systematic literature review was based on the PRISMA guidelines to achieve the objectives of this study and address research questions, including

(1) What are the essential characteristics of the included studies (such as year of publication, research context, research method, and sample size)?

(2) What are teachers' beliefs about applying information technology in teaching mathematics?

(3) What are teachers' practices when integrating information technology into teaching mathematics?

(4) What is the relationship between mathematics teachers' beliefs and instructional practices in teaching with information technology?

This systematic review study has returned results based on qualitative analysis and descriptive statistics of 15 studies selected from online databases, including Google Scholar, Mendeley, ScienceDirect, and Scopus, and selected according to specific criteria to answer the research questions posed.

The first research question includes the essential characteristics of the study, such as publication year, research context, and research method. Statistical results showed that more than half of the selected studies were conducted in 2020-2022, with the outbreak of the COVID-19 pandemic and the increased demand for distance learning, specifically in 2020-2022. Furthermore, the contextual statistical results of the included studies show that integrating ICTs into mathematics teaching is a topic of interest in many educational systems in many countries with different levels of development, both in developed and developing countries. Bütün and Karakuş (2021) also asserted that ICTs are increasingly crucial in mathematics education practices in most countries, as they are integrated into curricula and innovative educational approaches, enhancing learning and teaching environments. Regarding possible heterogeneity among study results, data on the context in which the research is deployed are also used in cases where it is necessary to compare the results of studies based on practical factor analysis (Ashraf et al., 2021).

Regarding research methods, statistical results show that surveys, experimental studies, and case studies are the main research designs used with various data processing methods, including quantitative, qualitative, and mixed methods. Statistical results also show that one-third of the studies conducted with fewer than 50 teachers, which are case studies and experimental studies, allow the collection of longitudinal data sets and/or actual observations to survey teachers' beliefs and practices (Kul, 2018; Yang et al., 2023). Meanwhile, most of the remaining studies were deployed with quite large sample sizes (the largest being 1,719) with a survey research design and analyzed using quantitative methods, so the results are used to answer research questions about teachers' beliefs and instructional practices. Additionally, to collect data that meet the various research objectives of examining mathematics teachers' instructional practices and beliefs about technology integration, most selected studies used multiple tools, mainly questionnaires, interviews, observations, and teacher reflections.

The second research question examined the results of previous studies on teachers' beliefs about technology integration in mathematics teaching. First, a large number of the selected studies reported that teachers have beliefs about the role of technology in facilitating lesson planning and teaching. Specifically, teachers think technology helps facilitate adequate lesson preparation, motivate students, ease the teaching

of abstract and complex concepts, carry out mathematical operations, and manage students' data. Second, the selected studies also indicate teachers' beliefs about the effectiveness of information technology in supporting student learning and improving their mathematical understanding by incorporating it into teaching and encouraging students to use it independently in practice. Third, six of the nine studies noted that teachers have constructivist beliefs about mathematics learning and promote a more student-centered learning environment with ICT integration. Teachers believe integrating technology into teaching enhances the quality of instruction and promotes a more student-centered learning environment (Perienen, 2021). Finally, studies show that self-efficacy is a central construct for higher-level aspects of teaching mathematics with technology, which, along with teachers' beliefs about the benefits of technology, can outweigh their negative beliefs about teaching mathematics with technology and using technology in teaching (Thurm & Barzel, 2022). After the remote teaching period, due to the impact of the COVID-19 pandemic, the confidence of most teachers in teaching with information technology news increased significantly (Drijvers et al., 2021). This result is similar to the conclusions of some studies (Clark-Wilson et al., 2020; Getenet, 2019; Hill & Uribe-Florez, 2020; Meletiou-Mavrotheris et al., 2023; Ndlovu et al., 2020; Stein et al., 2020). The studies by Reinhold et al. (2021) and Yeo et al. (2022) on the beliefs and motivation of in-service mathematics teachers regarding ICT integration in teaching also stated that teachers' beliefs, including self-efficacy, along with motivation and positive emotions, are vital aspects affecting influence their intentions and ways of using technology. On the other hand, some selected studies also recorded negative beliefs of teachers about using ICTs in teaching mathematics, such as concerns about preparation time and lesson duration (Perienen, 2021), adverse effects on students' manual skills development (Thurm & Barzel, 2020), and challenges in managing the classroom and students (Perienen, 2021). Other research reported similar findings (Crompton, 2015; Gesta et al., 2023; Kim, 2018).

Regarding the third question, about the in-service mathematics teachers' instructional practices with technology, 11 of the 15 studies reached conclusions. These studies have shown that technology plays various roles in improving teaching efficiency and effectiveness and transforming teacher roles and practice. Specifically, the technology is used in instructional practice such as:

(1) an effective tool for managing student data, including personal information and scores,

(2) support for instructional planning, and

(3) a means to boost students' learning motivation, present lesson content, dynamically model mathematical problems, visualize mathematical concepts and relationships, and make abstract concepts more tangible by visualizing, interpreting, and performing mathematical operations.

Many technological tools have been used to perform these functions, including mathematical manipulation tools such as interactive mathematics applets and dynamic mathematics software; communication tools such as courseware and smartboard; and learning resource platforms such as online support resources from textbook publishers and national education resource platforms. However, the selected studies also highlight the difficulties teachers face in practicing mathematics teaching with information technology, including difficulties in teaching skills with technology, technical skills, and control ability of classrooms and students, as well as issues of technical facilities. Given these difficulties, several studies have concluded that teachers participating in their surveys have a relatively limited frequency of using technology in teaching. Gesta et al. (2023) and Hollebrands and Lee (2020) also pointed out similar challenges. Furthermore, the instructional practices of teachers with technology in the above studies also show that some teachers tend to apply teacher-centered or traditional beliefs when using technology (Thurm & Barzel, 2022). The study by Kim (2018) reached a similar conclusion, in which teachers mainly used technology to prepare lessons, teaching tools, classroom management, and student management instead of creating lessons and a student-centered exploratory learning environment.

For the fourth research question on the correlation between teachers' beliefs and practices in teaching with technology, six of the 15 selected studies reported that a correlation exists between the two. However, Umugiraneza et al. (2018) did not find a significant correlation, and Kul (2018) confirmed that the relationship between these two factors is relatively complex. Various research designs have been employed to investigate this correlation, including surveys on teachers' beliefs, surveys and/or observations of instructional practices, and intervention research through professional development programs to influence teachers' beliefs about

using technology, thus examining how belief changes impact practices. Most studies show that teachers' constructivist beliefs, beliefs about the potential of technology in teaching, the ability to use technology in teaching, and teachers' self-confidence have a positive impact on their use of technology in lesson planning activities and the classroom process, as well as increasing the frequency of technology use in teaching. This conclusion is consistent with the results of Aljaberi and Gheith (2018). The study revealed a significant correlation between teachers' beliefs and instructional practices. Meanwhile, the study by Umugiraneza et al. (2018) did not find a significant relationship between teachers' beliefs and instructional practices when teachers who believe in the usefulness of technology in teaching do not regularly use it. This result is similar to the conclusions of Aljaberi and Gheith (2018), Belbase (2015), and Crompton (2015). However, according to Kul (2018), the relationship between teachers' beliefs and their intention to teach is relatively complex. Although some teachers have traditional beliefs about teaching and learning mathematics, they still intend to incorporate constructivist approaches into their teaching practice. In such a case, the researchers suggested that teachers' beliefs should not be analyzed separately from their context (Kul, 2018). The uniformity and heterogeneity of conclusions about the relationship between teachers' beliefs and instructional practices are mentioned in some previous studies (Aljaberi & Gheith, 2018; Belbase, 2015; Mothobi et al., 2021). This might prove to be an intriguing research topic in future studies when considering the factors that affect teachers' beliefs and instructional practices. Regarding this topic, technology acceptance model can be used as a framework and can be expanded with different variables, including facilitating conditions, subjective norms, and technology self-efficacy (Perienen, 2020), which stresses above all the relevance of teachers' attitudes and beliefs about the implementation of digital technologies in educational settings, and can thus be regarded as the most influential model in this field (Eickelmann & Vennemann, 2017). Additionally, in the relationship with teachers' knowledge, the TPACK framework can be used to provide a lens for exploring or understanding the knowledge needed by teachers to effectively integrate technology into their teaching, which could serve as another factor that affect teachers' beliefs and instructional practices (Karakuş, 2018; Kim, 2018).

On the other hand, in-service mathematics teachers face challenges in adapting their teaching activities to combine pedagogical practices, technology, and curriculum so that changes can meet the standards and expectations of mathematics education. However, teachers often have limited resources to support professional development and learn how to make these changes (Hollebrands & Lee, 2020). For example, Hew and Brush (2007; as cited in Blanchard et al., 2016) and Perienen (2021) also noted that many teachers lack opportunities to engage in professional development through the use of technology in transformative ways, which could alter their roles, instructional practices, and how students learn in the classroom. Backfisch et al. (2020), Brouwer et al. (2022), Hasim et al. (2022), and Zambak and Tyminski (2023) clarified the effectiveness of professional development in enhancing teachers' understanding of aspects of collaborative teaching and changing teachers' beliefs about teaching toward student-centered learning. Wong (2016), Blanchard et al. (2016), Rutherford et al. (2017), and Benning et al. (2023) found that engaging, individualized, sustained, and embedded in content professional development that employs instructional technology tools is significantly effective in improving teachers' technology integration.

Professional development not only influences teachers' beliefs, orientation, and instructional practices, but as noted by Lui and Bonner (2016), it also prompts stakeholders in mathematics education to take actions that align mathematics teachers' instructional practices with school and classroom norms, routines, obligations, and available resources. At the teacher training level, research suggests designing pre-service teacher training programs and offering professional development courses for in-service teachers to build a balanced and coherent system regarding the nature of mathematics teaching and learning, as well as to enhance their constructive beliefs while transforming traditional beliefs and practices (Alkhateeb, 2019; Chiu & Churchill, 2015; da Silva Bueno & Niess, 2023; Saadati et al., 2021). In addition, teacher training programs should equip mathematics teachers with the appropriate knowledge to integrate technology into teaching as a learning tool (da Silva Bueno & Niess, 2023; & Niess, 2023). Furthermore, building a collaborative teacher community is also considered an effective method because constructive and behavioral teachers have acquired a mix of beliefs from their colleagues (Alkhateeb, 2019). From an educational management perspective, providing technical support (Perienen, 2021), access to technological resources and infrastructure such as the Internet, mobile tablets or laptops (Saadati et al., 2021; Umugiraneza et al., 2018), reducing class size (Perienen, 2021), managing additional workload, alleviating teacher anxiety, and

motivating teachers to integrate new technologies (Chiu & Churchill, 2015; Saadati et al., 2021) are crucial factors for successful integration of technology into teaching.

In addition to the results obtained, this study also has some limitations. First, the limited range of databases used in the search for research resulted in a relatively small number of studies (15). Second, although with 15 selected studies and relatively diverse research objectives, qualitative tools are appropriate, a quantitative analysis result can serve as a basis for reliable conclusions and limit bias. Furthermore, in addition to the themes used to clarify the investigation, this study did not analyze the influence of subjective factors, such as age, sex, and experience, on teachers' beliefs and instructional practices among the selected studies, as mentioned in a study by Wang and Degol (2017). If implemented, these results can be considered reference materials for researchers on teachers' beliefs and practices in teaching with technology.

Based on the results and limitations of this study, it proposes some new research directions for future systematic reviews. Regarding research selection methods, new systematic review studies can expand the scope of the database and conduct quantitative research. Future review studies could analyze subjective and objective factors affecting mathematics teachers' beliefs and instructional practices with technology, mainly targeting mathematics pre-service teachers as research subjects. Furthermore, the uniformity and inconsistency of conclusions about the relationship between teachers' beliefs and instructional practices can also be considered in new studies to build a scale to evaluate teachers' instructional practices and teachers' beliefs and practices (Yilmaz, 2014). Additionally, many studies have confirmed the positive impact of professional development, especially technology-enhanced professional development, on mathematics teachers' beliefs and practices in teaching with technology (Blanchard et al., 2016). Prospective review studies on this topic might be worthwhile.

CONCLUSION

This study examined in-service mathematics teachers' beliefs and instructional practices in teaching with technology, as reported in previous related studies. Based on the systematic review methodology and the PRISMA guidelines, 15 studies published from 2014 to 2023 were selected for analysis. Statistical results indicate that the studies were conducted mainly in the period 2020-2022 and have contexts in many countries with different levels of development. The results of the analysis of teachers' beliefs reveal that they believe in the role of technology in facilitating teaching and learning, improving students' understanding, and promoting student-centered learning. Conversely, concerns have been raised about time constraints, classroom management skills, the potential decline in students' hands-on skills, and a lack of teacher confidence. In terms of instructional practice, teachers use various technology tools to support teaching activities, such as lesson planning, lesson organization, and student information management. Besides, difficulties in practice, from teachers' technological skills and knowledge to pedagogical skills in classroom management, are also analyzed from selected studies. In particular, the study also presents the results of selected studies on the correlation between teachers' beliefs and instructional practices, although the results have different conclusions about whether or not this correlation exists. From these results, the study makes recommendations to stakeholders on professional development and training for mathematics teachers. In addition to the results achieved, the study also points out the limitations of this systematic review and suggests some future research directions.

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