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How ICT Supports the Mathematical Problem-Solving Learning Process of Secondary School Students: A Systematic Literature Review

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ABSTRACT

Purpose of the study: This study aims to systematically examine the role of Information and Communication Technology (ICT) in supporting students' mathematical problem-solving processes at the secondary school level. It addresses the current gap in the literature by providing a focused synthesis of how ICT is utilized in mathematics education to enhance students' problem-solving abilities.

Methodology: A Systematic Literature Review was conducted following the PRISMA protocol. Articles were sourced from reputable databases, such as Scopus, Taylor & Francis Online (Tandfonline), and Education Resources Information Center (ERIC). Through a rigorous selection process based on relevance and quality criteria, 25 peer-reviewed articles published within the past ten years were analyzed and synthesized.

Main Findings: The review reveals that ICT is widely employed to improve the quality of instruction and students' problem-solving skills in mathematics. ICT supports learning across various topics such as geometry, calculus, and algebra, mainly through visualization tools and interactive simulations. Furthermore, ICT serves multiple roles: as a medium for ICT-assisted instruction, a complement to instructional materials, a platform for online learning, an assessment tool and a resource for student-directed learning, and as an adaptive and diagnostic learning systems.

Novelty/Originality of this study: This study contributes a focused and systematic analysis of how ICT specifically enhances mathematical problem-solving at the secondary level, a perspective that has been underrepresented in existing reviews. By identifying the specific functions and impacts of ICT in this context, the study lays the groundwork for future research and development of ICT-based pedagogical strategies in mathematics education.

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1. INTRODUCTION

The use of Information and Communication Technology (ICT) in education, especially in mathematics learning, is becoming increasingly widespread. This is particularly true during the COVID-19 pandemic. The pandemic has dramatically changed the educational context, forcing reflection on learning methods and processes, and forcing the transition from in-person to online learning for approximately three years [1]. Chun & Yunus explain that teachers have heavily relied upon ICT during the pandemic to deliver learning content and communicate with students [2]. With the end of the pandemic, the use of ICT has not diminished immediately, as it continues to offer numerous benefits. The utilization of ICT provides support for delivering the teaching

process differently, opportunities for collaboration, and ways to enhance student engagement and participation in the learning process through various channels [3]–[6].

Furthermore, NCTM emphasizes that students can learn more deeply through the responsible use of ICT [7]. In addition, Tatar & Zengin add that using ICT in mathematics learning can enhance students' problem-solving abilities, critical and creative thinking skills, and other mathematical thinking abilities [8]. Therefore, using ICT appropriately is believed to improve the quality of the learning process and students' achievements, especially in mathematics.

Following the latest literature, there has been a literature review that examines the role of ICT in mathematics education and learning [9]–[14]. For example, Asare et al., conducted a systematic literature review (SLR) on the role of ICT in mathematics education at the higher education level [14]. They found that interactive whiteboards, educational software, and online resources effectively improve the quality of mathematics teaching and learning. However, this research also highlights that effective ICT integration requires adequate infrastructure, professional development opportunities, and teacher support. Meanwhile, Rodríguez-Jiménez found that the utilization of ICT in elementary school mathematics education is still low and remains a relatively under-researched domain [13]. The reasons are the need for specific software acquisition, teacher training, and the challenges in operating some complex software. Nevertheless, the research discovered that using ICT in elementary school mathematics education can enhance students' academic performance, and its implementation has extended into various fields.

Based on the study conducted by researchers, it was found that there has not yet been a SLR on the specific role of ICT in mathematical problem-solving, especially at the secondary school level. Problem-solving is a person's process of using the knowledge and skills to meet the demands of a new, unfamiliar situation [15]. This process includes identifying and understanding problems, planning strategies to solve problems, monitoring the problem-solving process, and interpreting solutions to problems [16]. Given the importance of this ability, problem-solving has become a point of focus and attention in mathematics curricula in many countries [7], [17]–[21]. This is because teaching students problem-solving skills can train them to be more analytical in facing life's challenges [22]. Ironically, various previous findings have shown that students often struggle with mathematical problem-solving tasks [23], [24].

It is believed that one of the alternatives that can be a solution is integrating ICT in mathematics learning. This is as indicated by the findings of several previous studies that the integration of ICT in mathematics learning can be an alternative effort to enhance students' mathematical problem-solving abilities [25]–[27]. Therefore, in this research, the researcher synthesizes the findings of studies on the role of ICT in mathematical problem-solving at the secondary school level through an SLR. This SLR aims to provide additional insights into using ICT in mathematical problem-solving, which can offer valuable guidance for other countries striving to enhance their mathematics education. Furthermore, the findings from this research can inspire the development of new learning tools and resources that leverage ICT to support the process of mathematical problem-solving, a skill of paramount importance in the face of global competition.

The research questions become the initial and crucial part of implementing SLR. This is because, besides being the research objectives that need to be answered, they also serve as guidelines in conducting literature searches and extraction. The analysis and synthesis of research data obtained from the literature will later be used to address these research questions. The following are the research questions proposed in this SLR.

1) How is the development of research on the utilization of ICT in facilitating students' learning of mathematical problem-solving in secondary schools viewed based on the year and demographics of the authors?
2) What topic is examined in research that investigates the utilization of ICT in facilitating students' learning of mathematical problem-solving in secondary schools?
3) What type of ICT is used to facilitate students' learning of mathematical problem-solving in secondary schools?
4) What is the role of ICT in facilitating students' learning of mathematical problem-solving in secondary schools?

2. RESEARCH METHOD

This SLR aims to identify, select, evaluate, collect, analyze, and synthesize empirical data from various previous literature on the use of ICT in the mathematical problem-solving processes of secondary school students. This SLR has the potential to support further research efforts based on the findings presented by previous research results. In general, the stages of this SLR adopt three main steps from Hidayat & Mahardiko [28], namely, planning, conducting, and reporting, as presented in Figure 1.

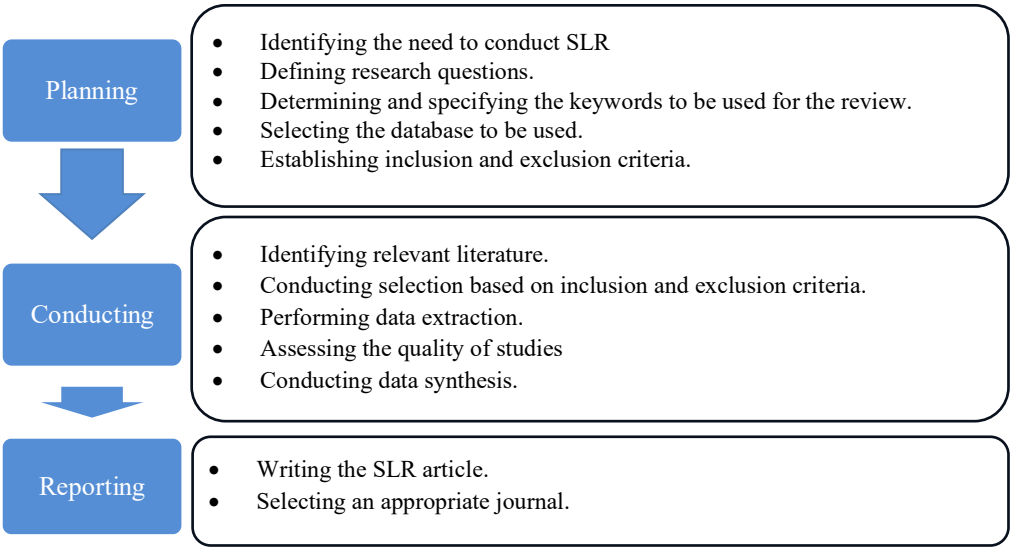

Figure 1. SLR Stages

In the planning stage, armed with the predefined research questions, the researcher identifies keywords, databases, and inclusion-exclusion criteria as guidelines for conducting a relevant literature search. The databases used in this SLR are Scopus, Taylor and Francis Online (Tandfonline), and the Education Resources Information Center (ERIC). Scopus was selected as the search database for this study because it is one of the world's leading citation databases and provides metadata for the documents it covers, commonly used in meta-analysis research [29], [30]. Meanwhile, ERIC and Tandfonline are other databases that are also utilized because they have a strong reputation and contain high-quality journals in the field of education [28], [31].

Using these databases, researchers conducted searches with existing keywords and constructed a comprehensive search string. This was done to increase the likelihood of finding relevant publications in the database for review, as recommended by Okoli, the developed keywords can be utilized with an online thesaurus, keywords from previous research, or keywords provided by the database [32]. In this study, the keywords used are ((“ICT” OR “Information and Communication Technology” OR “IT” OR ”Information Technology” OR “Technology”) AND (“Problem-solving” OR “Problem Solving”) AND (“Secondary School” OR “Middle School” OR “High School” OR “Junior High School” OR “Senior High School” OR “Intermediate School” OR “Preparatory school” OR “College Preparatory School”) AND (“Mathematics” OR “Mathematics Education”)). Meanwhile, the inclusion and exclusion criteria used are presented in Table 1.

Table 1. Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Publication type	Journal article	Conference proceedings, reviews, chapters in book, book series, book, etc
Field	Mathematics education or Mathematics learning	Others
Context	Secondary school	Elementary school, college, or others
Year	2015-2024	2014 or earlier
Language	English	Others
Access	Open access	Preview article or paid

In the implementation phase, the researcher searched relevant literature using the specified keywords in the database determined during the planning phase without applying inclusion and exclusion criteria screening. The researcher obtained 24.322 articles from the search results, which were then subjected to a screening process to select articles for further analysis and synthesis. This screening process includes automatic screening with tools from each database, manual screening of titles and abstracts by researchers, and continues with an eligibility assessment process to obtain final publications that will be reviewed. Further details are outlined in the PRISMA flow chart shown in Figure 2.

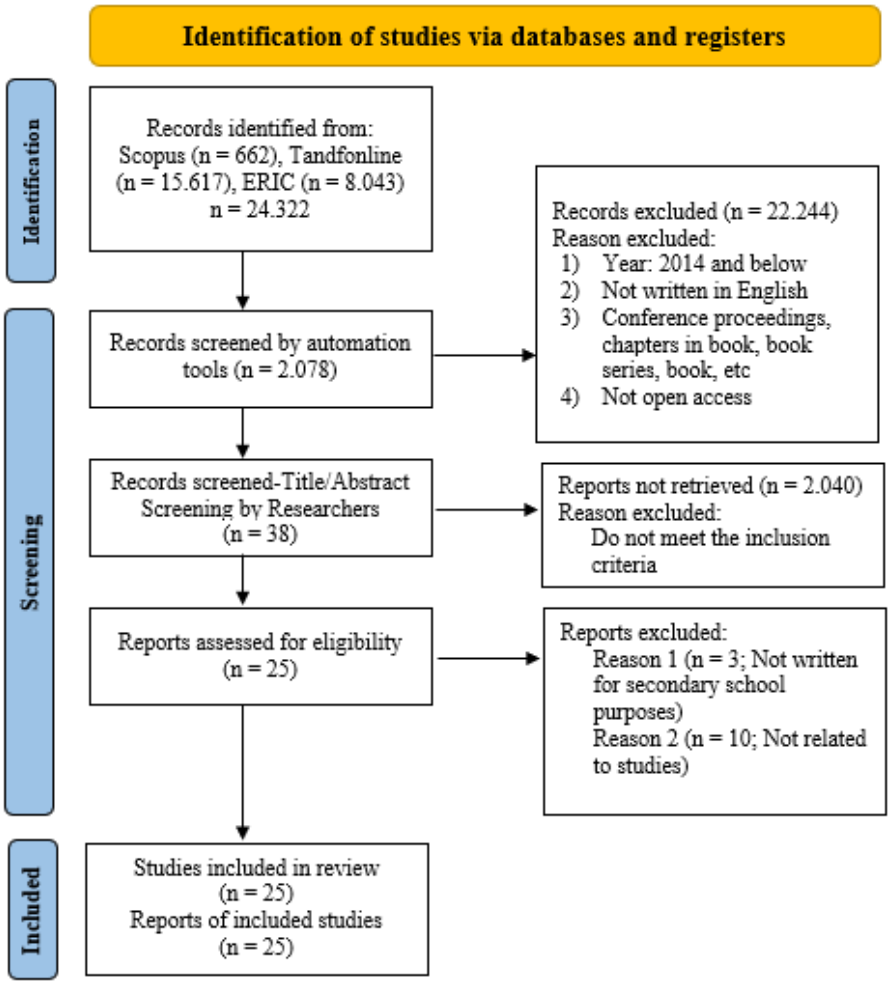

Figure 2. PRISMA Protocol Flow Chart

During the implementation stage, a total of 25 articles were obtained. These articles underwent comprehensive analysis and synthesis during the reporting phase. In this stage, the first step involved the authors carefully reviewing all the articles, paying particular attention to the abstract, results, and discussion sections. The data obtained was then summarized based on the research topics. Data addressing the research questions were collected, summarized, and evaluated into research findings. The findings were documented and discussed in a scientific article, addressing trends, study limitations, and recommendations for further investigation. These articles will be subsequently submitted to an appropriate scientific journal.

3. RESULTS AND DISCUSSION

The main goal of this SLR is to analyze and synthesize the role and utilization of ICT in facilitating students' learning of mathematical problem-solving in secondary school. Based on the identification and screening process results conducted on various research outcomes in the Scopus, Tandfonline, and ERIC databases, 25 selected articles have been obtained for analysis and synthesis. The following will describe the findings and discussions concerning the research questions outlined earlier.

3.1. The Development of Research on the Utilization of ICT in Facilitating Students' Learning of Mathematical Problem-Solving in Secondary Schools Based on the Year and the Researcher's Demographics

The first research question in this SLR focuses on the year distribution and author demographics of 25 papers that examine how ICT supports students' problem-solving learning processes at the secondary school level. Based on the analysis of 25 articles published between 2015 and 2024, it was found that the research trend on ICT utilization in mathematical problem-solving increased in 2018 (Figure 3). This aligns with the research findings of Supinah & Soebagyo [33], which conducted a bibliometric analysis. Their research found that the use of ICT in mathematics education showed an increasing trend between 2017 and 2019. This is suspected to be

related to Japan's promotion of Society 5.0 in 2016 at the G7 Summit as a response to future life challenges through the development and innovation by integrating new technology into various aspects of life [34]. This is also reinforced by the fact that multimedia began to be applied in the PISA 2015 survey [26]. Implementing multimedia in the PISA 2015 survey and the beginning of the promotion of Society 5.0 have prompted the emergence of responses to using ICT in learning, especially in mathematics, in the following years.

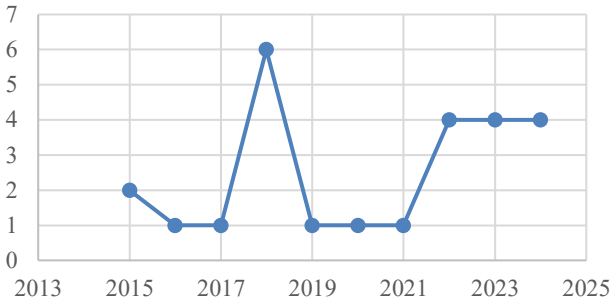

Figure 3. Trends in the Research of ICT Utilization in Mathematical Problem-Solving in Secondary Schools

After experiencing a declining trend in the preceding years, the research examining the utilization of ICT in facilitating students' learning of mathematical problem-solving in secondary schools showed an increase again in 2022 (Figure 3). The COVID-19 pandemic that struck in 2020-2021, affecting nearly the entire world, seems to be linked. Despite the massive shift from face-to-face learning to online learning through various platforms and technologies during the pandemic, teachers and students still encountered numerous challenges and were primarily focused on adapting to and addressing the issues that arose in mathematics education [35], [36]. This finding is also supported by the research of Supinah & Soebagyo [33], who also found a trend of decreasing ICT usage in mathematics education during the COVID-19 pandemic period. With the rising trend in 2022 and the end of the pandemic, the future trend of ICT utilization in mathematical problem-solving at the secondary school level shows an increase in interest.

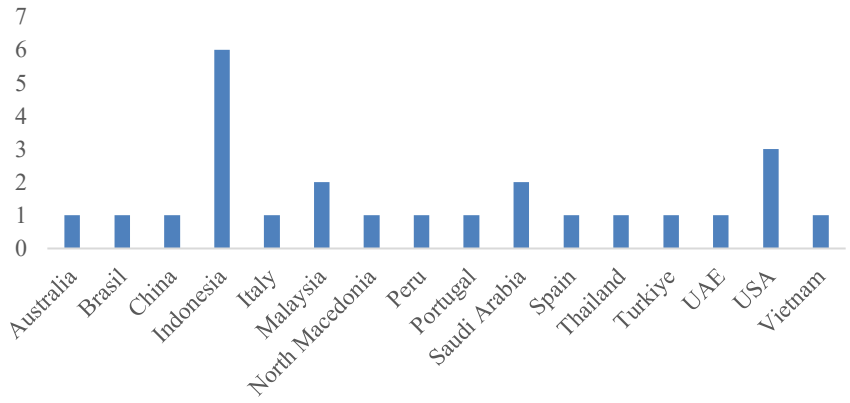

Figure 4. Distribution of Articles Based on Researchers' Demographics

Based on Figure 4, from the 25 articles that have been analyzed and synthesized, it is also obtained that research on the utilization of ICT in facilitating students' learning of mathematical problem-solving in secondary schools has been conducted in many countries around the world, spanning four continents. This is not surprising because the utilization of ICT and problem-solving have become the main aspects of concern in the curriculum and implementation of education, for example, in Indonesia and Malaysia [26], [37]–[40].

One level below Indonesia, the USA is the country with the highest proportion of research on using ICT in solving mathematical problems in secondary schools. This is not surprising because problem-solving in mathematics and the utilization of ICT in mathematics education have long been a focus in the USA [7], [41]. Therefore, the USA has become one of the leading countries in the use of ICT in mathematics education, especially in facilitating its students' learning of mathematical problem-solving.

Furthermore, studies on using ICT to facilitate students' learning of mathematical problem-solving have also been found in other European and Australian countries. This finding indicates that the utilization of ICT become a concern in many countries as an effort to facilitate and enhance the quality of the process and mathematical problem-solving abilities of students in secondary schools. This is in line with the statement of the

NCTM [7], as previously stated, through responsible use of ICT, students can learn more deeply. Furthermore, the use of ICT can also transform, complement, and enrich the learning and education process for the better [3]–[5]. The final result is the capability of increasing student engagement and the quality of mathematical problem-solving.

3.2. The Mathematical Topic Examined in the Research on the Utilization of ICT in Facilitating Students' Learning of Mathematical Problem-Solving in Secondary Schools

For the second research question, attention was paid to the mathematics topic, which was the focus of the study on the use of ICT in solving mathematical problems in secondary schools. Table 2 shows that the integration of ICT in facilitating students' learning of mathematical problem-solving is most frequently done in the topics of Geometry, in addition to mathematics in general. This is because these topics are abstract and often pose difficulties for students in understanding the concepts they learn, especially when applying them to mathematical problem-solving. Yerizon et al. [42] explained that students experience difficulty in visualizing these abstract concepts. An alternative solution that can be taken is by integrating ICT into the learning process. Tatar & Zengin [8] add that using ICT in learning can facilitate the improvement of problem-solving skills, critical and creative thinking, and other mathematical thinking abilities in students.

Table 2. The Topic of Mathematics in the Implementation of ICT in Facilitating Students' Learning of Mathematical Problem-Solving in Secondary Schools

Mathematics Topics	n	Research
Geometry	7	[43]–[49]
Algebra	4	[50]–[53]
Calculus	4	[26], [42], [54], [55]
Statistics	1	[56]
Numbers	3	[25], [27], [57]
General Mathematics	6	[58]–[63]

ICT is often utilized to facilitate the solving of mathematical problems in topics such as geometry, algebra, and calculus because it can help simulate and visualize abstract concepts that are often challenging for students to grasp. Although visual aids such as pictures or concrete models can sometimes help visualize these topics, ICT is often more effective in supporting mathematics learning and problem-solving, particularly in geometry, algebra, and calculus. As previously explained, this is necessary to aid students in simulating and visualizing abstract concepts that often hinder their learning. Interactive simulation and visualization also enables teachers to enhance the quality of the mathematics learning process by involving students in mathematical modeling, problem exploration, and open-ended problem-solving [5].

3.3. The Types of ICT Used to Facilitate Students' Learning of Mathematical Problem-Solving in Secondary School

Following the analysis and synthesis of 25 selected articles, data indicated that researchers use several types of ICT to help students learn to solve mathematical problems in secondary schools. Based on Figure 5, it can be seen that Geogebra is the most widely used type of ICT in facilitating students' learning of mathematical problem-solving in secondary schools [26], [42]–[45], [48], [54]. Meanwhile, other types of ICT are used almost evenly to facilitate students' learning process in solving mathematical problems, such as videos, augmented reality, graphing calculators, learning management systems, mobile apps, web-based computers, phyton program, quizizz, zoom, adaptive learning technologies, and Microsoft PowerPoint.

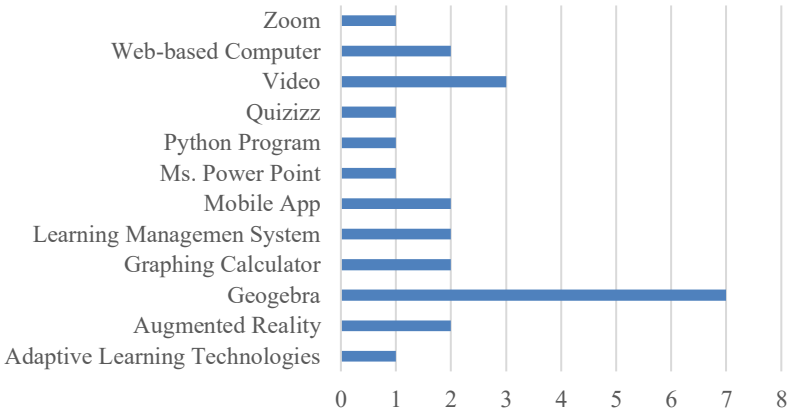

Figure 5. The Types of ICT Used to Facilitate Students' Learning of Mathematical Problem-Solving

The third research question discusses types of ICT used to facilitate students' learning of mathematical problem-solving in secondary school. Based on the findings of this research, Geogebra is the most widely used type of ICT in facilitating students' learning of mathematical problem-solving in secondary schools [26], [42]–[45], [48], [54]. Geogebra is open-source software popularly used by mathematics teachers at various educational levels [64]–[66]. This is closely related to the many advantages of GeoGebra in facilitating students' interactive simulations, thereby enriching and improving the quality of mathematics education and learning. Žilinskiene & Demirbilek [5] explained that Geogebra enables teachers to create interactive learning environments to promote active, experimental, and discovery-based learning in various mathematical topics, such as geometry, algebra, calculus, and statistics.

In addition to its interactive simulation and visual capabilities, GeoGebra is a powerful learning tool for facilitating mathematics education, including mathematical problem-solving. As previously explained interactive simulation and visualization enable teachers to enhance the quality of the mathematics learning process, involving students in mathematical modeling, problem exploration, and open-ended problem-solving [5]. This allows students to engage in learning and problem-solving processes actively. Furthermore, Geogebra's interactive simulation and visualization capabilities also enable students to learn more deeply and understand abstract concepts that were previously difficult to grasp. The importance of visualization in understanding certain abstract mathematical topics has also driven the development of other ICT applications, such as augmented reality, in mathematics learning, particularly in geometry, as highlighted in recent studies [47], [49]. With a solid grasp of these concepts, students can enhance their quality of engagement and activity in mathematical problem-solving processes during their learning. Ultimately, this will also lead to an improvement in students' mathematical problem-solving abilities.

3.4. The Role of ICT in Facilitating Students in Learning Mathematical Problem-Solving in Secondary School

ICT is not limited to just a learning tool but also encompasses more complex dimensions [67]. Therefore, in this SLR, the role of ICT in facilitating students' learning of mathematical problem-solving in secondary schools is also examined. Based on the thematic analysis conducted, this research indicates that ICT is used to facilitate secondary school students' learning of mathematical problem-solving in five categories: as a medium for ICT-assisted learning, as a supplementary teaching material to facilitate ICT-based learning, as an online learning tool, as an assessment tool and independent learning resource for students, and as an adaptive and diagnostic learning systems. The distribution of these findings is shown in Table 3.

Table 3. The Role of ICT in Solving Mathematical Problems in Secondary School

ICT Role	n	Research
ICT-assisted learning media	4	[46], [53], [58], [59]
Companion for ICT-based teaching materials	13	[26], [27], [42]–[45], [47]–[49], [51], [52], [54], [56]
Online learning resources	3	[25], [55], [62]
Assessment tools and self-learning facilities for students	4	[50], [57], [60], [61]
Adaptive and Diagnostic Learning Systems	1	[63]

This research also answers the final research question, which focuses on the role of ICT in supporting students' mathematical problem-solving learning process in secondary schools. This study reports that the most dominant role of utilizing ICT students in facilitating students' learning of mathematical problem-solving in secondary school is serving as a learning foundation, where ICT is used in an integrated manner within the learning process as a complement to teaching materials. In this role, students learn mathematical problem-solving using integrated ICT teaching materials. The teaching materials used include modules and worksheets integrated with Geogebra [26], [42]; interactive learning software, such as Geogebra [43]–[45], [48], [54], Graphing Calculator [52], and Ipad App [51]; learning video [27], [46], [58]; and augmented reality [47], [49]. The integrated ICT teaching materials are designed to provide students with a more active, interactive, and adaptive learning experience. Teachers can use these teaching materials to enrich students' learning experiences and present mathematical concepts in a more engaging and easily understandable way. This is as explained by Nguyen et al. [45], that with ICT integrated teaching material students can have access to real things and visual images that are even difficult to be visualized to build new knowledge and help them to be able to learn more excited about new material. In addition, students can evaluate and identify what they do or do not understand, allowing them to promptly correct any misconceptions they have about the concepts [47]. The ultimate goal is to achieve learning objectives, in this case, the ability to facilitate and enhance the quality of the mathematical problem-solving process for students.

Student performance during the learning process becomes crucial to achieve the learning objectives. Therefore, teachers must facilitate students with teaching materials that allow them to engage and participate in learning actively. One of the efforts that can be taken is to make ICT the basis of learning by integrating ICT into teaching materials. The use of ICT enables students to learn mathematics more interactively and enjoyably. Additionally, students can actively participate in learning, engage in interactive exercises, and receive instant by Yerizon et al. [42], Geogebra's ability to provide instant feedback can provide certainty regarding the correctness of the concepts that students learn and the solutions to the problems they encounter. They added that this certainty is vital because it can motivate and become a basis for students to continue learning about the following material.

The role of ICT as a companion to teaching materials, for example, can be found in [42], which constructed integrated Geogebra worksheets to facilitate PBL. The research revealed that using integrated Geogebra worksheets in high school Calculus education during PBL effectively enhances students' mathematical problem-solving abilities. This is because Geogebra can assist students in visualizing abstract calculus concepts and foster high-level mathematical thinking processes, thereby encouraging the development of their mathematical problem-solving skills. For example, with the help of GeoGebra, students can understand that the solution to the equation $f(x) = g(x)$, where $f(x) = \sin x$ and $g(x) = \log_2 x$, is represented by the intersection points of the graphs of these two functions [68]. These intersection points are the values of x that satisfy the equation, which may be challenging to solve analytically (see Figure 6). Kusumah et al. [69] and Yerizon et al. [42] explained that the visualization capabilities possessed by software tools like Geogebra can assist students in overcoming the difficulties they typically encounter when studying abstract concepts in mathematics. This process will also help students actively engage in learning, construct knowledge independently, gain experience, actively participate in problem-solving processes, and ultimately result in more meaningful learning [70]–[73]. The result is an improvement in the quality of the mathematical problem-solving process and the students' mathematical problem-solving abilities. As stated by NCTM [7], students can learn mathematics more deeply through ICT. Furthermore, Güner & Erbay [74] also emphasize that students' mathematical problem-solving abilities will improve if they can actively participate in the problem-solving process during learning.

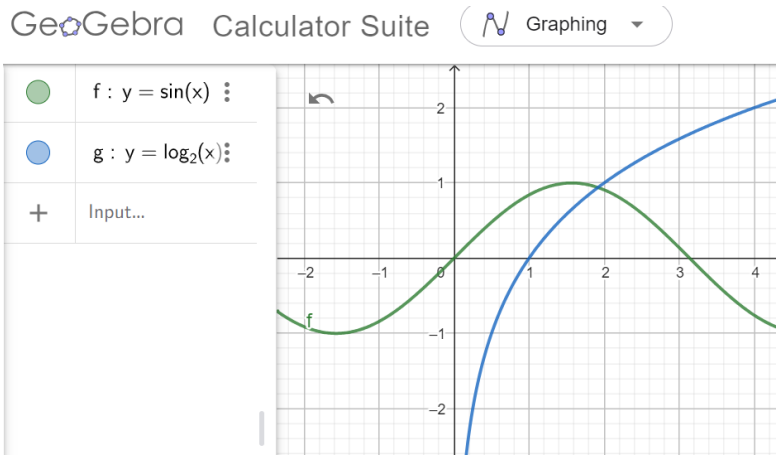

Figure 6. Visualize the Graph of the Function $f(x) = \sin x$ and $g(x) = \log_2 x$

The role of utilizing ICT in mathematical problem-solving further serves as an assessment tool and a means for independent learning for students. As an assessment tool, ICT assists teachers and students in measuring students' understanding of the subject matter and their ability to solve mathematical problems more efficiently. ICT can also serve as a means to provide quicker feedback to students. This is exemplified, for instance, by Fyfe [50], who found that using computer-based tasks is a better medium for facilitating feedback to students when learning problem-solving, especially in algebra. This aligns with Sarıtaş [61], who also found that ICT can serve as an assessment tool to analyze and inform students' difficulties in problem-solving, providing feedback to them on these difficulties.

Furthermore, using ICT can also serve as feedback for teachers regarding the topics that pose difficulties for students, thus providing information for teachers to plan follow-up actions. ICT in computer-based assessment can also effectively measure students' collaborative problem-solving abilities [57]. This media allows virtual students to continue discussing and communicating collaboratively in solving problems. Furthermore, with this media, the communication and collaboration processes carried out by students during the problem-solving process can be recorded and documented. This is important because collaborative mathematical problem-solving involves not only the cognitive domain but also the social domain of students. Therefore, as an assessment tool, ICT can also serve as a learning facility for mathematical problem-solving for students.

In addition to serving as an assessment tool, the utilization of ICT can also serve as a self-learning facility for students to facilitate the improvement of the quality of their mathematical problem-solving processes and abilities. This is as indicated by the research of Barana et al. [60], who found that the utilization of ICT, in the form of facilitating a digital learning environment, helps students to perform self-assessment in mathematical problem-solving better. This is because after receiving feedback and assessing their work in the digital learning environment, they become more confident in the given assessment criteria, improving their problem-solving competencies and enhancing their self-assessment skills.

Becoming an ICT-assisted learning medium in facilitating the mathematical problem-solving process for students in secondary schools is the other finding from this research [53], [58], [59]. Different from the role of ICT as the basis for learning, where students are dominant in learning mathematical problem-solving using ICT, in this role, students learn in a traditional classroom format, but at times, they are allowed to learn with the assistance of ICT. ICT applications as a learning medium, for example, can be found in the research by Setiyani et al. [53], who used the Quizziz application as a tool and medium for mathematics learning. The study found that mathematics learning with the assistance of Quizizz is effective in enhancing students' mathematical problem-solving abilities compared to conventional learning. This is because Quizizz helps increase student engagement and activity in learning, boosts enthusiasm, and encourages mutual assistance and questioning. The research results also indicate that students exhibit a positive attitude toward using Quizizz in learning.

The other role of utilizing ICT found in this SLR is as a means of online learning [25], [55], [62]. ICT enables students to learn online, where they can learn from a distance without needing to be in a physical classroom. Online learning allows for learning flexibility and helps students access course materials anytime and anywhere, as demonstrated by the findings of Martins & Martinho [25], who utilized ICT, such as Zoom, as a means of online learning have found that online learning in a virtual environment based on Zoom results in better mathematical problem-solving abilities compared to in-person learning. This is evidenced by the greater variety of problem-solving strategies developed by students in virtual classes, including previously unexpected strategies. This advantage arises because students find it easier to conduct various simulations that are sometimes challenging to perform physically. This active engagement encourages students to obtain more meaningful learning, better comprehension, and, of course, leads to improved mathematical problem-solving skills.

The integration of ICT into mathematical problem-solving is increasingly embodied through the development of Adaptive and Diagnostic Learning Systems (ADLS) [63]. These systems utilize artificial intelligence and machine learning to personalize instruction by adapting content and learning strategies to students' individual needs, abilities, and cognitive profiles [63], [75], [76]. In mathematics education, especially where learners possess diverse backgrounds and learning preferences, ADLS plays a critical role in fostering student engagement, accelerating conceptual understanding, and providing real-time correction of misconceptions during the problem-solving process [63]. This, in turn, supports the development of students' mathematical problem-solving skills.

Although showing varying roles, ICT can essentially facilitate students' learning of mathematical problem-solving in secondary schools to enhance the quality of the process and their mathematical problem-solving abilities. ICT in mathematics education can also enrich students' learning experiences, enhance their understanding of mathematical concepts, and help prepare them for the demands of an increasingly connected and technology-based world. Therefore, we recommend further research to investigate the broad use of ICT and its impact on the process and mathematical problem-solving at various educational levels.

4. CONCLUSION

This SLR aims to review the role of ICT in mathematical problem-solving in secondary schools. Based on the analysis and synthesis of 25 articles selected from Scopus, Tandfonline, and ERIC, this research found a fluctuating trend in the use of ICT in mathematical problem-solving. However, the utilization of ICT has shown an increase after the Covid-19 pandemic. ICT is widely used to enhance the quality of learning by facilitating the improvement of mathematical problem-solving processes and abilities across various topics in secondary schools. Additionally, ICT has proven effective in supporting problem-solving in topics such as geometry, calculus, and algebra, particularly through the use of visualization tools and interactive simulations. The roles of ICT in mathematical problem-solving in secondary schools include using ICT as a learning aid, supplementing teaching materials to facilitate ICT-based learning, providing online learning resources, serving as assessment tools and self-learning resources for students, and as an adaptive and diagnostic learning systems. The findings of this study contribute to a more comprehensive understanding of the role of ICT in mediating students' mathematical problem-solving skills through various pedagogical functions, such as interactive visualization and personalized feedback. These findings emphasize the importance of investing in ICT in learning, particularly in school mathematics. Furthermore, the findings also underscore the importance of ICT support and integration into the school mathematics curriculum.

Based on these findings, future research may provide valuable insights into the optimal use of ICT to enhance learning processes and improve students' mathematical problem-solving abilities across various academic levels and learning environments. In particular, further investigations into the integration of Adaptive and Diagnostic Learning Systems (ADLS) and AI-driven technologies are essential, as these tools offer the potential to personalize instruction, provide real-time feedback, and support learners with diverse cognitive profiles. By leveraging the capabilities of AI and data-informed systems, future studies can explore how to effectively scale and contextualize adaptive technologies to foster deeper mathematical understanding and support differentiated instruction in increasingly diverse educational settings. This study has certain limitations that should be acknowledged. Some of these limitations include the focus on studies published as journal articles and with open access in the Scopus, Tandfonline, and ERIC databases. Although the selection criteria were designed to ensure the inclusion of high-quality and accessible studies, they may have inadvertently overlooked valuable findings presented in other scholarly formats, such as those published in closed-access journals, book chapters, theses, dissertations, or other forms of literature, potentially limiting the comprehensiveness of the review. Therefore, future research may expand and incorporate a broader and more diverse range of sources to present a wider perspective on how ICT supports the learning process of mathematical problem-solving at other academic levels or in emerging educational contexts.

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