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# ICT-Based Mathematics Learning Assessment: A Systematic Review of Effectiveness, Challenges, and Pedagogical Impacts

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**Abstract**

The importance of integrating Information and Communication Technology (ICT) into mathematics learning lies in its potential to enhance students' critical thinking, problem solving, and logical reasoning skills. Conventional assessments often face limitations in providing personalized and dynamic feedback. This study aims to examine the effectiveness, challenges, and pedagogical impacts of ICT-based mathematics assessment through a systematic review of literature published between 2020 and 2025. The research method employed is a Systematic Literature Review (SLR) following the PRISMA guidelines. Data were collected from the Scopus, WoS, ERIC, and Google Scholar databases using relevant keywords. The selection process involved identification, screening, eligibility assessment, and inclusion, result (n=15) articles for comprehensive analysis.The findings indicate that ICT-based assessment is effective in measuring cognitive domains, particularly conceptual understanding (33.3%), problem solving (26.7%), and learning outcomes (26.7%), while other aspects remain limited mathematical reasoning and self-assessment (13.3%). Furthermore, challenges in implementing ICT-based mathematics assessment include the design and development of instruments, technical and infrastructural limitations, teachers' readiness and competencies, as well as student characteristics and the context of online learning. ICT-based assessment in mathematics also provides five main pedagogical impacts: enhancing student engagement and motivation, offering feedback and self-reflection, fostering cognitive and problem solving skills, improving learning efficiency, and promoting pedagogical innovation.

**Keywords:** Mathematics Assessment; ICT; Effectiveness; Challenges; Pedagogical Impact.

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## INTRODUCTION

Mathematics education plays a crucial role in developing critical thinking, problem solving, and logical reasoning skills, thereby equipping individuals with essential competencies that can be applied across various fields (Szabo et al., 2020). The significance of mathematics extends beyond the academic domain, encompassing various aspects of life, including science, technology, engineering, economics, and everyday decision-making (Alabdulaziz, 2021).

Mathematics, as a subject that demands logical, analytical, and systematic problem-solving skills, requires an assessment model that can capture the complexity of students' abilities comprehensively (Ukobizaba et al., 2021; Yayuk et al., 2020). According to Buzick et al., (2019); Rakoczy et al., (2019), assessment of students must align with established assessment standards, as these standards are closely related to the procedures, mechanisms, and instruments used in evaluating learning outcomes. Such assessments are intended to measure students' cognitive abilities. Meanwhile, the efforts made by educators to collect, analyze, and process information are essential in determining the achievement of students' learning outcomes. However, assessment in mathematics learning still tends to be conventional, often facing limitations such as static evaluations, a lack of flexibility in accommodating diverse student abilities, and restricted capacity to provide constructive and personalized feedback (Mesa & Monzón, 2021).

Along with the advancement of time, the integration of information and communication technology (ICT) in mathematics learning has become increasingly relevant and essential, as ICT supports interactive learning processes, enhances motivation, facilitates conceptual understanding, and expands access to learning (Gamit, 2023; Mohamadou et al., 2020). The integration of ICT in mathematics learning has emerged as a transformative force, offering remarkable opportunities to enhance teaching methods, assessment strategies, and student engagement (Davies et al., 2021; Swiecki et al., 2022). ICT provides educators with a wide range of tools and resources to create dynamic and interactive learning environments, thereby deepening students' understanding of mathematical concepts (Davies et al., 2021; Li, 2023; Mailizar & Fan, 2020).

The use of ICT in mathematics assessment enables the implementation of more modern and adaptive forms of evaluation, such as computer-based tests, digital portfolios, and technology-assisted formative assessments (Arslan et al., 2022; González-Calatayud et al., 2021). Computer-based tests facilitate the administration of digital examinations, accelerate grading, and are capable of presenting adaptive question variations according to students' abilities (Febriati, 2021; Nurjanah et al., 2020). Meanwhile, digital portfolios allow teachers and students to continuously document learning progress through applications or platforms, making assessment more comprehensive and not solely dependent on final tests (Marinho et al., 2021). In addition, technology-assisted formative assessment can provide instant feedback through online quizzes, interactive applications, or learning management systems (LMS), helping teachers monitor students' conceptual understanding in real time (Desai et al., 2022; Fatmi et al., 2021).

These diverse ICT-based assessment formats enable the measurement of cognitive aspects such as problem solving skills, conceptual understanding, and creative thinking, as well as affective aspects such as motivation and self-confidence (Safonova & Guner, 2023). Therefore, the quality of ICT-based assessments must be carefully designed to ensure that they measure students' mathematical abilities accurately and validly. Assessments should be fair and inclusive, while also taking into account the needs of students with different learning styles (Palomares-Ruiz et al., 2020; Suryawan et al., 2023).

The implementation of ICT-based assessment in mathematics learning also presents a number of challenges. One of the main challenges is the gap among students, teachers, and schools. Not all students have equal access to devices or reliable internet connections, which may lead to inequities in implementation (Arbelaez Ossa et al., 2024; Palomares-Ruiz et al., 2020; Saha et al., 2020). In addition, not all teachers possess sufficient skills and knowledge to use ICT effectively in the learning process. Schools also need to invest in adequate infrastructure and training to support the implementation of ICT-based mathematics assessment (Cirneanu & Moldoveanu, 2024; Delcker et al., 2024).

ICT-based assessment offers a more authentic and engaging way to evaluate students' understanding of mathematical concepts, leading to improved learning outcomes and a deeper appreciation of the subject (Mesa & Monzón, 2021; Rakes et al., 2022). Students who engage with interactive simulations, virtual manipulatives, and dynamic visualizations are more likely to develop conceptual understanding of mathematics rather than merely memorizing formulas and procedures. The immediate feedback provided by digital assessment tools helps students identify errors and learn in real time, fostering structured and reflective learning, as well as cultivating a growth mindset oriented toward continuous improvement in understanding concepts and solving mathematical problems effectively (Arbelaez Ossa et al., 2024; Vittorini et al., 2021).

Several previous studies Hernández-Martínez et al., (2025); Klemer et al., (2023); Msafiri et al., (2023); Perienen, 2020; Verschaffel et al., (2019), several previous studies have positioned ICT as a medium for mathematics learning to enhance interactivity, motivation, or conceptual understanding. However, these studies have not thoroughly examined the role of ICT in the domain of assessment, particularly in terms of how technology is utilized to measure, monitor, and provide feedback on mathematics learning outcomes. The limited scope of research on the use of ICT-based assessment in mathematics learning highlights a research gap that still needs to be explored in greater depth.

This study offers novelty by aiming to conduct a systematic review focused on ICT-based mathematics assessment, emphasizing three main aspects: effectiveness, challenges, and pedagogical impact. The scope of this review focuses on indexed journal articles published between 2020-2025, considering their relevance, methodological quality, and contribution to the development of ICT-based mathematics assessment. In addition, the inclusion criteria encompass primary studies focusing on secondary and higher education levels. The primary focus of this review is the use of ICT within the context of mathematics assessment, rather than the general application of technology in teaching. With these delimitations, this study is expected to provide a sharper and more evidence-based synthesis to inform mathematics assessment practices in the digital era.

## METHOD

### Study Design

This study employs a Systematic Literature Review (SLR) approach to analyze existing research on ICT-based mathematics assessment. The SLR approach was chosen for its ability to provide a comprehensive and systematic analysis of relevant studies, thereby enabling the selection of high-quality research and producing more reliable findings (Snyder, 2019). This systematic review follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, which serve as the international standard for reporting systematic reviews. PRISMA was chosen to ensure a systematic structure in identifying, selecting, and synthesizing the literature, while minimizing bias and ensuring transparency in the process of identifying relevant studies (Page et al., 2021).

### Study Search Procedure

#### *Identification*

Identification in the SLR involves selecting and diversifying keywords to locate relevant articles. The use of keywords in the search process helps ensure that only the most appropriate and relevant articles are retrieved from the databases. Based on the research questions, the three keywords used were Mathematics assessment and ICT-based mathematics assessment. Synonyms, related terms, and variations of the main keywords were also included to broaden the search, identified through online thesauruses, previous studies, the Scopus database, and expert opinion. Specific keywords and combinations of terms related to the research topic were used to formulate a standardized search query as follows: (“mathematics assessment” OR “math assessment” OR “math test”) AND (“information and communication technology assessment” OR “technology-assisted assessment” OR “ict assessment” OR “digital assessment” OR “e-assessment” OR “computer-based assessment” OR “online assessment”) AND (“kahoot” OR “quizizz” OR “moddle”) AND (“effectiveness” OR “challenges” OR “pedagogical impact”).

The article search was conducted from March 10, 2025, to May 15, 2025, in the databases Web of Science, Scopus, ERIC, and Google Scholar, which were selected for their advantages. First, according to Gusenbauer & Haddaway, (2021) databases such as Web of Science, Scopus, ERIC, and Google Scholar provide more comprehensive and stable search results with more advanced features compared to other databases. In addition, these databases excel in article quality control and systematic indexing (Martín-Martín et al., 2021).

Advanced search techniques, including Boolean operators (AND, OR), phrase searching, truncation, wildcards, and field codes, were employed to search for articles in the Scopus, ERIC, and Google Scholar databases. This search strategy resulted in the identification of 130 articles from Web of Science, Scopus, ERIC, and Google Scholar that were relevant to the keywords. In the second stage of the systematic search process, all identified articles were thoroughly screened.

***Screening***

Through a systematic screening process, a total of 130 initial articles were identified from various scientific databases. This process was conducted to ensure that only relevant, high-quality articles aligned with the research focus were included in this Systematic Literature Review (Mohamed Shaffril et al., 2020). The screening stage involved establishing inclusion and exclusion criteria designed to determine the eligibility of each article. The inclusion criteria were as follows: (1) scientific articles on ICT assessment in mathematics learning, published in indexed journals (not proceedings) and open access; (2) studies published between 2020 and 2025; (3) students at secondary and undergraduate education levels; (4) articles written in English or Indonesian; and (5) studies evaluating the use of ICT in mathematics assessment, including computer-based testing platforms, digital applications, electronic portfolios, or specialized mathematics assessment software. Each article obtained from the initial search was thoroughly reviewed based on topic relevance, methodological quality, and its contribution to the development of ICT-based mathematics assessment practices. After a rigorous screening process, 92 articles were eliminated for not meeting the established criteria, leaving 30 eligible articles for further analysis in this study.

**Table 1.** Inclusion and Exclusion Criteria for Articles

| Category | Inclusion | Exclusion |
|---|---|---|
| Article Type | Scientific articles on ICT assessment in mathematics learning, published in indexed journals (not proceedings) and open access. | Articles not using quantitative, qualitative, or mixed methods. |
| Time Frame | Studies published between 2020 and 2025. | Studies published before 2020. |
| Sample | Students at secondary and undergraduate education levels. | Students not at secondary or undergraduate levels. |
| Language | Articles in English or Indonesian. | Articles in languages other than English or Indonesian. |
| Research Focus | Studies evaluating the use of ICT in mathematics assessment, including computer-based testing platforms, digital applications, electronic portfolios, or specialized mathematics assessment software. | Studies that do not focus on the use of ICT or digital tools in mathematics learning assessment. |

***Eligibility***

The next step is to assess the eligibility of the 30 articles identified during the initial screening. This eligibility assessment involves a second round of screening to ensure the accuracy and relevance of each article for inclusion in the systematic literature review (SLR). At this stage, all selected articles were carefully evaluated to verify their suitability and relevance to the SLR. The process began with reviewing the title and abstract of each article to assess relevance. If relevance was not clearly established from these sections, a more detailed examination of the methodology, results, and discussion was conducted. Through this process, 15 articles were excluded because they addressed topics outside the scope of ICT-based assessment in mathematics learning, focusing instead on other fields. Consequently, 15 articles were retained for further quality assessment (Page et al., 2021).

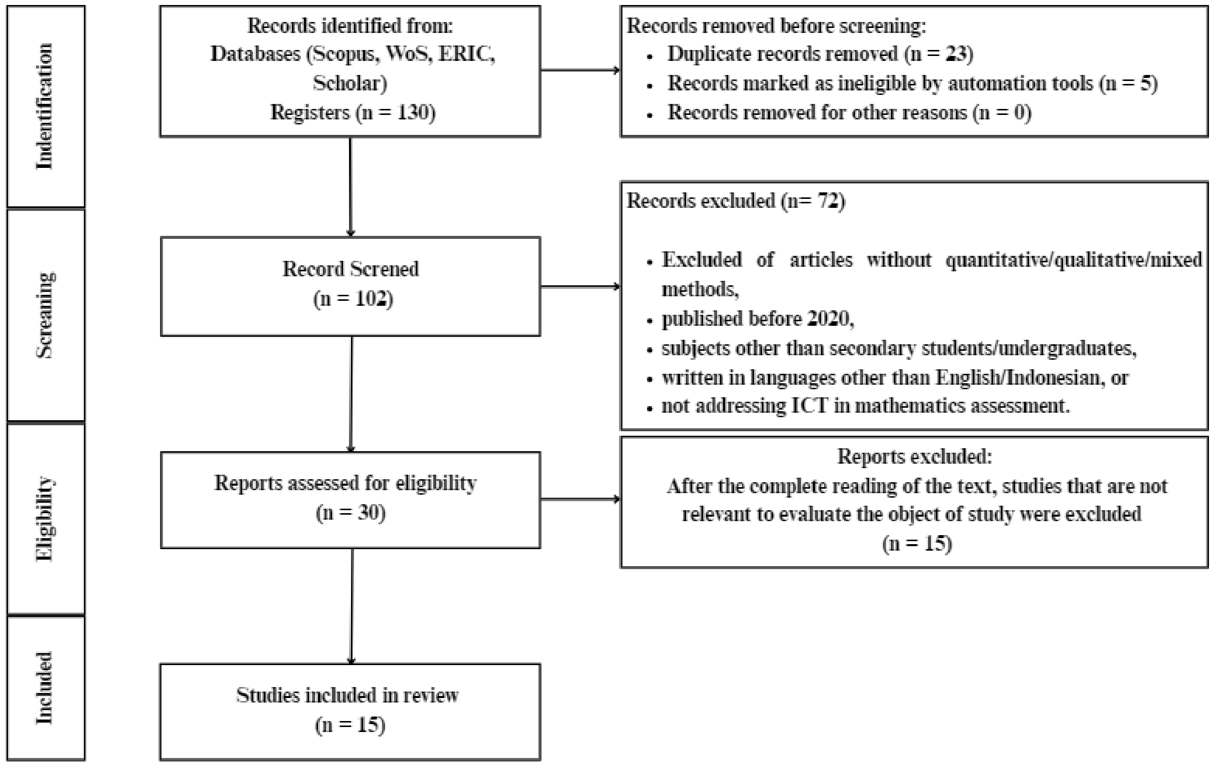


**Figure 1.** Article Selection Process

## Article Quality Assessment

The selected articles then underwent a rigorous quality assessment process, which is essential for reducing bias and identifying methodological limitations (Kraus et al., 2020). This evaluation was conducted by two members of the research team. Since the systematic literature review (SLR) includes studies with various designs quantitative, qualitative, and mixed methods the assessors used the Mixed Methods Appraisal Tool (MMAT) as a guide for evaluation (Edwards et al., 2019).

Each article was assessed based on two fundamental criteria, along with five additional criteria specific to its research design. The initial phase of this process involved evaluating the quality of the articles against two basic criteria: *"Are the research questions clearly stated?"* and *"Can the data obtained answer the research questions?"* Articles were required to meet both criteria before proceeding to the next stage, where they were categorized according to study design (qualitative, quantitative, or mixed methods).

Subsequently, the articles were evaluated against five specific criteria. For each criterion, the assessors could choose from three options: *Yes*, *No*, or *Cannot tell* if the evaluation results were uncertain or unclear. The three assessors were required to reach a consensus on each article's assessment. If consensus could not be reached, a second opinion was sought.

## Data Extraction and Analysis

The next step in this process is to perform data extraction from each selected article, which was carried out by two researchers. The primary objective of this SLR is to review previous studies on ICT-based assessment in mathematics learning. Therefore, the data extraction focused on three main sections: the abstract, research findings, and discussion. Nevertheless, all articles were thoroughly read to gain a comprehensive understanding of the topics under investigation.

The extracted data were then organized into a table to facilitate the analysis process, which was conducted once all data had been collected. Given that this SLR employs an integrative review approach encompassing various research designs (quantitative, qualitative, and mixed methods), qualitative synthesis was selected as the most appropriate method of analysis. Within this framework, various analytical techniques, such as thematic analysis, can be applied in the synthesis process. As noted by Flemming et al., (2019), thematic analysis aims to identify patterns in previous studies based on the similarity or relevance of their findings. The extracted findings were individually reviewed to identify relevant themes. Findings with similar or related content were grouped into a single data set.

**Table 2.** Quality scores for included studies rated using the Mixed Methods Appraisal Tool (MMAT)

| Study design | Criteria met | Criteria not met | Overall MMAT score (%) |
|---|---|---|---|
| **Quantitative descriptive** | | | |
| Joshi et al., (2023) | 4.1, 4.2, 4.3, 4.5 | 4.3, 4.4 | 75% |
| Divjak et al., (2024) | 4.1, 4.3, 4.5 | 4.2, 4.4 | 75% |
| de Schipper et al., (2025) | 4.1, 4.3, 4.5 | 4.2, 4.4 | 75% |
| Moral-Sánchez et al., (2023) | 4.1, 4.3, 4.5 | 4.2, 4.4 | 75% |
| **Quantitative non-randomized** | | | |
| Nurjanah et al., (2020) | 3.2, 3.3, 3.4 | 3.1, 3.5 | 75% |
| Doz et al., (2025) | 3.2, 3.4, 3.5 | 3.1, 3.3 | 75% |
| Qualitative | | | |
| Slobodsky & Durcheva, (2023) | 1.2, 1.3, 1.4, 1.5 | 1.1, 1.5 | 75% |
| Haj-Yahya & Olsher, (2022) | 1.2, 1.3, 1.4, 1.5 | | 100% |
| **Mixed methods** | | | |
| Caspari-Sadeghi et al., (2022) | 5.1, 5.2, 5.3, 5.4, 5.5 | | 100% |
| Azevedo et al., (2022) | 5.1, 5.2, 5.3, 5.4, 5.5 | | 100% |
| Kinnear et al., (2025) | 5.1, 5.2, 5.3, 5.4, 5.5 | | 100% |
| Sikurajapathi et al., (2020) | 5.2, 5.3, 5.4, 5.5 | | 100% |
| Valdez & Maderal, (2021) | 5.1, 5.2, 5.3 | 5.4, 5.5 | 75% |
| Hadjerrouit, (2020) | 5.1, 5.2, 5.3, 5.4, 5.5 | | 100% |
| Zegowitz, (2022) | 5.1, 5.2, 5.3, 5.4, 5.5 | | 100% |

Quality assessment result of selected articles based on Mixed Methods Appraisal Tool (MMAT) version 2018 criteria (HONG et al., 2018). Based on the quality assessment conducted using the Mixed Methods Appraisal Tools (MMAT) version 2018, as shown in Table 2 above, 7 out of the 15 selected articles met 100% of the criteria, while 8 articles met 75% of the requirements. Overall, the articles can be used in this study.

## RESULTS AND DISCUSSION

### Result

The peer-reviewed articles in this study covered twelve countries, with three studies from the United Kingdom, two from Israel, and the remaining from Nepal, Croatia, Germany, Portugal, Indonesia, France, Italy, the Philippines, Spain, and Norway, thereby providing diverse contexts of ICT-based assessment in mathematics learning. The data extracted from various studies were categorized to analyze subgroups and to explore the effectiveness, challenges, and pedagogical impacts of using ICT in mathematics assessment. This review methodology ensures a rigorous and comprehensive evaluation of the literature concerning the effectiveness, challenges, and pedagogical impacts of ICT-based mathematics assessment among learners from secondary to higher education levels, thereby providing a solid foundation for the synthesis and analysis of findings. Based on the analysis, the findings in Table 3 indicate that several studies reveal the effectiveness of ICT-based assessment in mathematics learning on students' cognitive abilities.

**Table 3.** Main Finding Effectiveness of ICT-based Mathematics Assessment Measuring Students Cognitive Domains

| Author | Effectiveness of ICT-based mathematics assessment |
|---|---|
| Joshi et al., (2023); Doz et al., (2025); Hadjerrouit, (2020); Sikurajapathi et al., (2020) | Problem Solving |
| Divjak et al., (2024); Azevedo et al., (2022); Kinnear et al., (2025); Valdez & Maderal, (2021) | Learning Outcomes |
| Nurjanah et al., (2020); de Schipper et al., (2025); Moral-Sánchez et al., (2023); Zegowitz, (2022); Haj-Yahya & Olsher, (2022) | Conceptual Understanding |
| Caspari-Sadeghi et al., (2022) | Self-Assessment |
| Slobodsky & Durcheva, (2023) | Mathematical Argumentation |

Based on these findings, Figure 2 illustrates the percentage distribution of the effectiveness of ICT-based mathematics assessment in measuring students' cognitive domains. Based on the analysis, it was found that ICT-based mathematics assessment most frequently measured conceptual understanding (33.33%). This indicates that ICT is effective in evaluating the extent to which students deeply understand mathematical concepts. Furthermore, problem solving skills (26.67%) and overall learning outcomes (26.67%) were also relatively dominant, suggesting that ICT-based assessment provides insights into students' skills in applying concepts to solve problems as well as their overall academic achievement. Meanwhile, other categories (mathematical reasoning and self-assessment) accounted for only 13.33%, indicating that these aspects remain relatively less emphasized in ICT-based assessment.

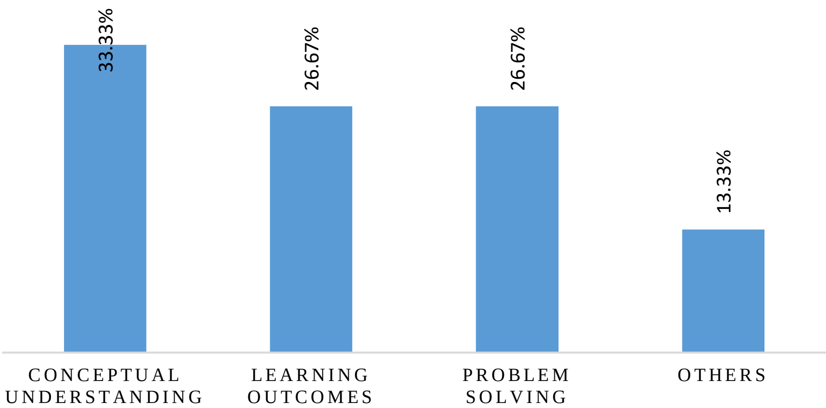


**Figure 2.** Effectiveness of ICT-Based Mathematics Assessment in Measuring Students' Cognitive Domains

Table 4 presents the results of the analysis focusing on the various challenges that arise in the planning and implementation of ICT-based mathematics assessment. With the growing integration of technology in education, digital assessment is expected to offer more effective and efficient alternatives to traditional evaluation methods.

**Table 4.** Challenges of ICT-Based Assessment in Mathematics Learning

| Author | Challenges of ICT-Based Mathematics Assessment |
|---|---|
| Azevedo et al., (2022); Haj-Yahya & Olsher, (2022); Kinnear et al., (2025); Nurjanah et al., (2020); Slobodsky & Durcheva, (2023) | Assessment design and development |
| Divjak et al., (2024); Doz et al., (2025); Valdez & Maderal, (2021); Zegowitz, (2022) | Technical and infrastructural aspects |

| Author | Challenges of ICT-Based Mathematics Assessment |
|---|---|
| de Schipper et al., (2025); Hadjerrouit, (2020); Joshi et al., (2023); Moral-Sánchez et al., (2023); Sikurajapathi et al., (2020) | Teachers' readiness and competence |
| Caspari-Sadeghi et al., (2022) | Student characteristics and the online context |

Based on these challenges, after being grouped, they are presented in a table containing categories, descriptions, and their percentages to facilitate understanding and analysis in the context of challenges in ICT-based assessment in mathematics learning.

**Table 5.** Category, Description and Studies Challenges of ICT-Based Mathematics Assessment

| Category | Description | Studies |
|---|---|---|
| Assessment Design & Development | Difficulties in designing digital instruments, creating test items, preparing online materials, and adapting exercises into electronic formats. | 33.3% |
| Technical & Infrastructural Aspects | Limited devices, unstable internet connections, and challenges of e-learning systems in handling mathematical notation and diagrams. | 26.67% |
| Teachers' Readiness & Competence | Teachers require training in the use of digital platforms and the design of ICT-based assessments. | 33.3% |
| Student Characteristics & Online Context | Students struggle to construct quality questions, while asynchronous online learning provides limited support for mathematics. | 6,7% |

Based on the analysis results, the pedagogical impacts of ICT-based assessment in mathematics learning are categorized according to the findings. These categories are presented in Table 6 to provide a clear overview.

**Table 6.** Pedagogical Impacts of ICT-Based Mathematics Assessment

| Author | Category |
|---|---|
| Azevedo et al., (2022); Nurjanah et al., (2020); Valdez & Maderal, (2021); Zegowitz, (2022) | Enhancement of Student Engagement & Motivation |
| Divjak et al., (2024); D. Doz et al., (2025); Hadjerrouit, (2020); Haj-Yahya & Olsher, (2022) | Feedback & Self-Reflection |
| Caspari-Sadeghi et al., (2022); Kinnear et al., (2025); Sikurajapathi et al., (2020) | Development of Cognitive Skills & Problem Solving |
| de Schipper et al., (2025); Moral-Sánchez et al., (2023); Slobodsky & Durcheva, (2023) | Efficiency of the Teaching-Learning Process |
| Joshi et al., (2023) | Pedagogical Innovation |

Based on these challenges, after being grouped, they are presented in a table containing categories, descriptions, and their percentages to facilitate understanding and analysis in the context of the pedagogical impacts of ICT-based assessment in mathematics learning.

**Table 7.** Category, Description and Studies Pedagogical Impacts of ICT-Based Mathematics Assessment

| Category | Description | Studies |
|---|---|---|
| Enhancement of Student Engagement & Motivation | ICT-based assessment can stimulate interest, increase active participation, and make learning more dynamic and meaningful. | 26.67% |
| Feedback & Self-Reflection | ICT-based assessment plays a key role in providing formative evaluation, informative feedback, and opportunities for reflection for both students and teachers. | 26,67% |
| Development of Cognitive Skills & Problem Solving | ICT encourages students to connect theory with practice, practice tests, and independently adjust learning strategies. | 20% |

| Category | Description | Studies |
|---|---|---|
| Efficiency of the Teaching-Learning Process | ICT helps teachers manage the classroom, reduce academic dishonesty, classify students' solution strategies, and handle repetitive tasks. | 20% |
| Pedagogical Innovation | ICT supports the development of digital resources and the implementation of approaches such as flipped classrooms. | 6,67% |

The findings of this systematic review are summarized in the graphs and tables presented in Figure 2, Table 5 and Table 7, referencing selected studies that discuss the effectiveness, challenges, and pedagogical impacts of ICT-based mathematics assessment. The synthesis results indicate that ICT-based assessment has the potential to enhance the measurement of students' mathematical abilities, although several challenges need to be addressed. Additionally, its implementation exerts a significant pedagogical influence on the learning process. The presentation of data in graphs and tables is intended to facilitate understanding, interpretation, and systematic and comprehensive analysis of the research findings.

**Effectiveness of ICT-Based Mathematics Assessment in Measuring Students' Cognitive Skills**

Conceptual understanding is one of the aspects most frequently measured in ICT-based mathematics assessment. The role of ICT is significant in evaluating the depth of students' understanding and mastery of mathematical concepts. Through technology-based assessments, students can be tested not only on their computational skills but also on their comprehension of the meaning behind a concept (de Schipper et al., 2025; Haj-Yahya & Olsher, 2022; Moral-Sánchez et al., 2023; Nurjanah et al., 2020; Zegowitz, 2022). One form of assessment used to measure conceptual understanding is interactive questions delivered through applications or digital platforms (Nurjanah et al., 2020). With features such as visualization, simulation, and instant feedback, these assessments help teachers identify the extent to which students truly understand concepts rather than merely memorizing procedures.

Suppose farmers have a garden whose s urface is shaped like a rectangular field. The garden will plant vegetables. To facilitate the watering of his plants, he made a small ditch from the river next to his garden, as shown in Figure 3.

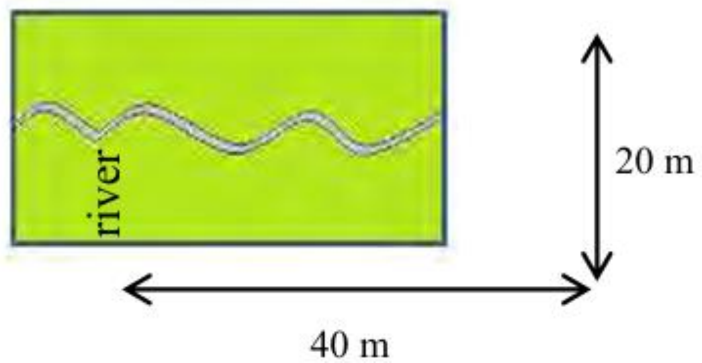


**Figure 3.** Rectangular shaped garden.

If the width of the ditch is 0.5 m, determine the area of the garden where vegetables are only planted!

Problem-solving skills and learning outcomes are two main aspects measured through ICT-based assessment according to the analysis results. In assessing problem-solving ability, ICT enables the development of assessments that are interactive and dynamic, so that students are not only limited to multiple-choice questions but are also confronted with open-ended problems that require reasoning, exploration, and reflection (Joshi et al., 2023; Doz et al., 2025; Hadjerrouit, 2020; Sikurajapathi et al., 2020). One form of assessment used to measure this ability is tasks that require students to solve problems systematically by demonstrating logical and structured mathematical reasoning steps (Doz et al., 2024).

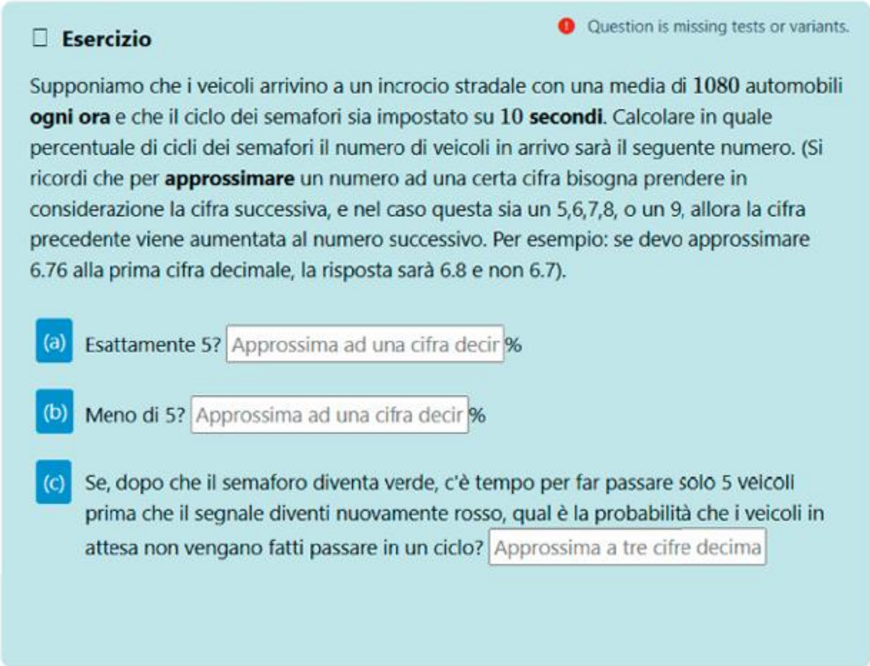


**Figure 4.** ICT-Based Assessment Items for Measuring Problem-Solving Skills

In measuring student learning outcomes more effectively, efficiently, and accurately, the use of ICT through digital platforms enables assessment results to be obtained in *real-time*, allowing teachers to immediately analyze students' achievements (Divjak et al., 2024; Azevedo et al., 2022; Kinnear et al., 2025; Valdez & Maderal, 2021). ICT also supports the delivery of various types of items, ranging from multiple-choice questions to simulation-based or interactive tasks, which reflect both conceptual and procedural skills. Moreover, learning outcome data can be recorded and analyzed automatically, assisting teachers in diagnosing students' weaknesses while also monitoring their learning progress continuously (Kinnear et al., 2025).

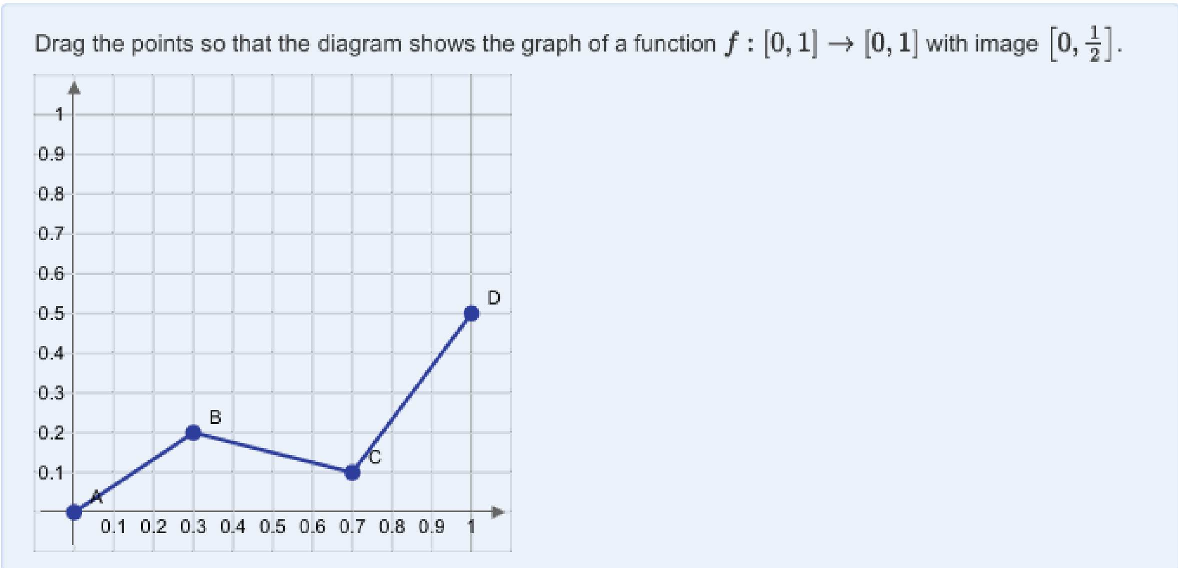


**Figure 5.** ICT-Based Assessment Items for Measuring Learning Outcomes

ICT can also be used to assess students' argumentation in solving problems, as it enables the presentation of open-ended questions that require students not only to provide answers but also to explain their reasoning and solution strategies (Slobodsky & Durcheva, 2023). Through digital platforms, teachers can evaluate students' argumentation more comprehensively since the system can record their thought processes, including the steps written or selected during problem solving. With the support of automatic analysis features and instant feedback, ICT makes assessment more efficient, objective, and capable of highlighting both the strengths and weaknesses of students' argumentation.

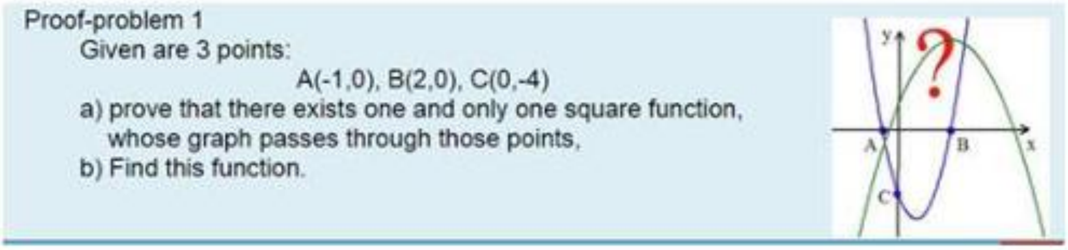


**Figure 6.** ICT-Based Assessment Items for Measuring Student Argumentation

The effectiveness of ICT in mathematics assessment is also reflected in measuring students' self-assessment (Caspari-Sadeghi et al., 2022). Through digital platforms, students can engage in self-reflection on their mathematical understanding and skills, for instance by completing interactive quizzes, reflective journals, or application-based surveys. ICT systems provide instant feedback that helps students evaluate the extent of their achievement toward learning objectives. In addition, self-assessment data can be analyzed to identify error patterns and areas that require improvement. Thus, ICT functions not only as an evaluation tool but also as a means of fostering metacognition and learner autonomy.

**Challenges in Implementing ICT-Based Mathematics Assessment**

The implementation of ICT-based assessment in mathematics learning faces various challenges, including design, technical issues, and the readiness of both teachers and students. The main challenge lies in the design and technical aspects of assessment, where the consistency of results is often hindered by limitations in design, technology, and teacher competence. Many teachers encounter difficulties in developing digital instruments, constructing test items, and adapting materials into electronic formats. In addition, technical obstacles such as limited devices, unstable internet connections, and e-learning systems that insufficiently support mathematical notation and diagrams may lead to inconsistent assessment results and increase students' cognitive load (Azevedo et al., 2022; Haj-Yahya & Olsher, 2022; Kinnear et al., 2025; Nurjanah et al., 2020; Slobodsky & Durcheva, 2023; Divjak et al., 2024; Doz et al., 2025; Valdez & Maderal, 2021; Zegowitz, 2022).

ICT-based assessment is also prone to issues of cheating and weak supervision during examinations. The limited availability of security features or proctoring systems in digital platforms can reduce the validity of assessment results, as students' recorded performance may not fully reflect their actual abilities. This challenge highlights the importance of pedagogical skills complemented by technological literacy, as well as the need for teacher training in the use of digital platforms and the design of ICT-based assessments, so that assessments do not merely replicate paper-based formats in digital form but are also able to facilitate more interactive learning (de Schipper et al., 2025; Hadjerrouit, 2020; Joshi et al., 2023; Moral-Sánchez et al., 2023; Sikurajapathi et al., 2020)..

In addition, not all students have equal access to adequate devices, stable internet connections, or a conducive learning environment. This digital divide creates disparities in the implementation of ICT-based assessments, which may reduce students' opportunities to demonstrate their competencies on an equal footing. Furthermore, student characteristics and the online learning context such as difficulties in formulating high quality questions and the limited support for mathematical interaction in asynchronous learning also influence the extent to which assessments can be conducted fairly (Caspari-Sadeghi et al., 2022). Therefore, solutions are required that include improving infrastructure, strengthening teacher competencies, implementing adequate supervision systems, and developing digital learning strategies that take into account the principles of reliability, integrity, and fairness in alignment with the characteristics of mathematics as a discipline.

### Pedagogical Impacts of ICT-Based Mathematics Assessment

ICT-based assessment in mathematics learning makes a significant contribution to enhancing pedagogical quality. One of the primary impacts is the increase in student engagement and motivation. Through interactive assessments, students are encouraged to participate more actively, making learning more meaningful (Azevedo et al., 2022; Nurjanah et al., 2020; Valdez & Maderal, 2021b; Zegowitz, 2022). Moreover, ICT-based assessment plays a crucial role in providing feedback and fostering self-reflection. Formative and informative feedback helps students understand their strengths and weaknesses, while teachers can adjust instructional strategies based on assessment results (Divjak et al., 2024; D. Doz et al., 2025; Hadjerrouit, 2020; Haj-Yahya & Olsher, 2022). Additionally, the use of ICT in assessment supports the development of cognitive skills and problem-solving abilities. Students are encouraged to connect theory with practice, engage in intensive practice, and independently adjust their learning strategies. For teachers, digital assessment facilitates classroom management and enhances the efficiency of the teaching-learning process (Caspari-Sadeghi et al., 2022; Kinnear et al., 2025; Sikurajapathi et al., 2020). Another important impact is the promotion of pedagogical innovation, such as the use of digital resources that enable the implementation of innovative learning models, for example, the flipped classroom (de Schipper et al., 2025; Joshi, Adhikari, Khanal, & Belbase, 2023; Moral-Sánchez et al., 2023; Slobodsky & Durcheva, 2023).

## CONCLUSION

ICT-based mathematics assessment is effective in supporting the evaluation of students' cognitive skills, particularly conceptual understanding and problem-solving, while enhancing assessment quality through rapid feedback and active engagement. However, its effectiveness remains limited to certain dimensions, with reflective thinking and mathematical reasoning yet to be fully optimized. The main challenges lie in instrument design, infrastructure, and the readiness of both teachers and students, highlighting the need to strengthen technological literacy and adopt assessment strategies aligned with the characteristics of mathematics. Pedagogically, ICT-based assessment positively impacts motivation, self-reflection, and critical thinking skills, while also fostering innovative learning approaches such as the flipped classroom, making it highly relevant to 21st-century educational needs.

The quality of evidence in this study is dominated by mixed methods research, which provides rich data but requires careful integration of quantitative and qualitative findings. Future research is recommended to broaden the focus on enhancing reflective thinking and mathematical reasoning in ICT-based assessment, examine effective implementation strategies in various educational contexts, and explore its long-term impacts on student learning outcomes.

## RECOMMENDATION

Future research is recommended to develop more adaptive and context-relevant ICT-based mathematics assessment models. The focus should be directed toward evaluating the effectiveness of digital platforms in assessing students' cognitive and affective aspects. Moreover, teacher training and technological infrastructure improvement are essential to ensure optimal implementation. Challenges such as limited access, digital literacy, and assessment validity should be addressed in future research and practice.

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| Syarif Hidayatullah | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
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**Conflict of Interest Statement**

Authors state no conflict of interest.

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