

A Phenomenological Study of Pre-service Teachers' Readiness in Integrating Digital Literacy for Mathematics Assessment

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ABSTRACT

Digital literacy has become an essential competence for mathematics educators, particularly in the domain of assessment. This study aims to explore the lived experiences and readiness of pre-service mathematics teachers in integrating digital literacy into mathematics assessment practices. The research employed a transcendental phenomenological approach to capture the essence of participants' experiences in designing and implementing digital-based assessments. The participants consisted of six final-year pre-service mathematics teachers from two Indonesian universities who had experience developing digital assessment tasks during their teaching practice. Data were collected through semi-structured interviews, classroom observations, and analysis of digital assessment artifacts, including GeoGebra-based activities and Quizizz assessments. The data were analyzed using a phenomenological reduction process involving epoché, horizontalization, clustering of meaning units, and synthesis of the essence of the phenomenon. The findings reveal that although pre-service teachers demonstrate strong operational skills in using digital tools, their readiness to design meaningful digital mathematics assessments varies. Three main themes emerged from the analysis: technological fluency, pedagogical considerations in digital assessment design, and alignment between digital tools and assessment rubrics. The results indicate that readiness to integrate digital literacy in mathematics assessment involves not only technical competence but also the integration of pedagogical reasoning and assessment literacy. These findings highlight the importance of integrating digital assessment training within teacher education programs to better prepare future mathematics teachers for technology-supported assessment practices.

Keywords: *Pre-service teachers, Digital literacy, Mathematics assessment, Phenomenological study, Qualitative research*

Studi Fenomenologi Kesiapan Mahasiswa Calon Guru dalam Mengintegrasikan Literasi Digital untuk Asesmen Matematika

ABSTRAK

Literasi digital telah menjadi kompetensi penting bagi pendidik matematika, khususnya dalam pelaksanaan asesmen pembelajaran. Penelitian ini bertujuan untuk mengeksplorasi pengalaman hidup serta kesiapan mahasiswa calon guru matematika dalam mengintegrasikan literasi digital ke dalam praktik asesmen matematika. Penelitian ini menggunakan pendekatan fenomenologi transendental untuk menangkap esensi pengalaman partisipan dalam merancang dan mengimplementasikan asesmen berbasis digital. Partisipan penelitian terdiri atas enam mahasiswa tingkat akhir program pendidikan matematika dari dua universitas di Indonesia yang memiliki pengalaman mengembangkan tugas asesmen digital selama praktik mengajar. Data dikumpulkan melalui wawancara semi-terstruktur, observasi kelas, serta analisis artefak asesmen digital, termasuk aktivitas berbasis GeoGebra dan asesmen menggunakan Quizizz. Analisis data dilakukan melalui proses reduksi fenomenologis yang meliputi tahap epoché, horizontalisasi, pengelompokan unit makna, serta sintesis esensi fenomena. Hasil penelitian menunjukkan bahwa meskipun mahasiswa calon guru memiliki keterampilan operasional yang baik dalam menggunakan berbagai perangkat digital, kesiapan mereka dalam merancang asesmen matematika digital yang bermakna masih bervariasi. Tiga tema utama yang muncul dari analisis data meliputi kelancaran penggunaan teknologi, pertimbangan pedagogis dalam desain asesmen digital, serta keselarasan antara perangkat digital dan rubrik penilaian. Hasil penelitian ini menunjukkan bahwa kesiapan dalam mengintegrasikan literasi digital pada asesmen matematika tidak hanya berkaitan dengan kompetensi teknis, tetapi juga melibatkan integrasi penalaran pedagogis dan literasi asesmen. Temuan ini menegaskan pentingnya integrasi pelatihan asesmen digital dalam program pendidikan guru untuk mempersiapkan calon guru matematika dalam mengembangkan praktik asesmen berbasis teknologi.

Kata Kunci: *Mahasiswa calon guru, Literasi digital, Asesmen matematika, Studi fenomenologi, Penelitian kualitatif*

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1. Introduction

The global educational landscape is currently navigating a profound paradigm shift, catalyzed by the rapid integration of digital technologies into every facet of teaching and learning. In the twenty-first century, digital literacy has transcended its status as a peripheral skill, evolving into a fundamental competency that defines the efficacy of modern educators across disciplines (Guri-Rosenblit & Gros, 2011; Ng, 2012; Redecker, 2017). Within the specific domain of mathematics education, this digital transformation offers unprecedented opportunities to visualize abstract concepts, foster interactive problem-solving, and personalize student learning paths (Heitink et al., 2016; Scherer et al., 2021). Dynamic mathematical software and digital learning environments have been shown to support teachers in creating more interactive and exploratory mathematics learning experiences (Masriyah et al., 2024). However, the most critical yet complex application of digital literacy lies within the realm of assessment. Assessment in mathematics is no longer viewed merely as a tool for grading but as

a dynamic and diagnostic process that guides instruction and captures the intricacies of student reasoning (Heitink et al., 2016; Tondeur et al., 2017). Despite these advancements, the utilization of technology often halts at the content delivery stage, while the domain of assessment remains largely dependent on traditional methods that have yet to fully optimize the transformative potential of digital tools.

The core research problem identified in this study is the persistent “readiness gap” among pre-service mathematics teachers regarding the pedagogical integration of digital literacy into assessment. There is a prevailing, albeit flawed, assumption that because today’s students are often characterized as “digital natives,” they automatically possess the readiness to integrate technology into their professional practice (Bennett et al., 2008). However, empirical evidence suggests a different reality. Although pre-service teachers are generally familiar with digital technologies in their daily lives, they frequently experience difficulties when attempting to integrate these tools into meaningful pedagogical practices (Instefjord & Munthe, 2017; Tondeur et al., 2018). In particular, when asked to design valid digital-based mathematics assessment instruments, many pre-service teachers experience what has been described as “pedagogical anxiety,” reflecting uncertainty about whether digital assessments can accurately capture students’ mathematical reasoning (Schmidt et al., 2009; Tondeur et al., 2017). This situation indicates that technical proficiency in using digital devices does not necessarily translate into the pedagogical ability required to synthesize information and communication technology (ICT) within mathematics classroom contexts (Lawless & Pellegrino, 2007). The issue is further exacerbated by teacher education programs that often treat ICT skills and mathematics pedagogy as separate domains, leaving students to struggle with integrating these competencies in authentic assessment situations.

Insights from previous studies provide a diverse but predominantly quantitative picture of this phenomenon. Early research by Ertmer (1999) categorized barriers to technology integration into “first-order barriers,” such as technological infrastructure and institutional support, and “second-order barriers,” which include teachers’ beliefs, attitudes, and pedagogical knowledge. Although improvements in technological infrastructure have reduced many external barriers, internal factors such as pedagogical beliefs and professional confidence remain critical determinants of successful technology integration (Ertmer & Ottenbreit-Leftwich, 2010; Hsu, 2016). Recent studies also indicate that developing technological pedagogical content knowledge among pre-service teachers remains a significant challenge in mathematics teacher education (Hanifah et al., 2024; Hanifah et al., 2025). Despite the contributions of these studies, most research relies on Likert-scale surveys to measure teachers’ readiness, which often fails to capture the nuances of lived experiences, the specific nature of pedagogical anxieties, and the meaning-making processes experienced by pre-service teachers during their professional formation. This gap highlights the need for qualitative research that explores how pre-service teachers actually experience the process of integrating digital literacy into mathematics assessment.

To address this limitation, the present study adopts a phenomenological perspective to explore the lived experiences of pre-service mathematics teachers in integrating digital literacy into assessment practices. Phenomenological research aims to understand how individuals experience a particular phenomenon and how meaning is constructed from those experiences (Creswell & Poth, 2018). By examining the lived experiences of pre-service teachers during their teaching practice, this study seeks to reveal the essential structure of their readiness when designing and implementing digital-based mathematics assessments.

Theoretically, this research is grounded in the Technological Pedagogical Content Knowledge (TPACK) framework developed by Mishra and Koehler (2006). This framework emphasizes that effective technology integration requires the intersection of technological

knowledge, pedagogical knowledge, and content knowledge (Koehler & Mishra, 2009). In the context of mathematics assessment, teachers must integrate these knowledge domains to design digital assessment tasks capable of evaluating students' higher-order thinking skills and mathematical reasoning processes (Chai et al., 2013). Furthermore, this study also draws upon the concept of digital literacy as the critical ability to evaluate, create, and communicate digital information within academic and instructional environments (Guri-Rosenblit & Gros, 2011).

Based on the issues described above, the objective of this study is to describe the essential structure of pre-service mathematics teachers' readiness in integrating digital literacy into mathematics assessment practices. Unlike previous studies that focus primarily on measurable outcomes such as test scores or technical product quality, this research emphasizes the internal processes, reflections, and challenges experienced by pre-service teachers when designing digital assessment activities. The novelty of this research lies in its collaborative context involving two teacher education institutions, Universitas Nahdlatul Ulama Pasuruan and Universitas Negeri Surabaya, which allows for a broader exploration of the phenomenon across different educational settings.

The importance of the problem addressed in this study is closely aligned with the ongoing transformation of teacher education in Indonesia, particularly in the context of the implementation of the Kurikulum Merdeka. This curriculum emphasizes the integration of digital technologies to create more flexible and inclusive learning environments. If pre-service teachers do not develop sufficient readiness to integrate digital assessment during their professional preparation, innovations in digital assessment may remain superficial and fail to enhance the quality of mathematics learning. Therefore, the findings of this study are expected to provide both practical and theoretical contributions. Practically, the results may inform mathematics education programs in designing more integrative curricula that combine digital literacy, pedagogical competence, and assessment literacy. Theoretically, this study contributes to enriching the literature on qualitative perspectives of TPACK, particularly in the domain of mathematics assessment. Ultimately, the transition toward digital assessment should not be viewed merely as the adoption of technological tools but as a deeper transformation of the professional identity and pedagogical practices of future mathematics teachers.

2. Research Method

2.1 Research Design and Phenomenological Approach

This study employed a qualitative research design using a transcendental phenomenological approach to explore the lived experiences of pre-service mathematics teachers in integrating digital literacy into mathematics assessment. Phenomenology aims to understand how individuals experience a particular phenomenon and how meaning is constructed from those experiences. The transcendental phenomenological approach emphasizes describing the essence of participants' experiences by setting aside the researcher's prior assumptions and focusing on participants' subjective interpretations (Moustakas, 1994; Creswell & Poth, 2018).

In this study, the phenomenon under investigation is the readiness of pre-service mathematics teachers to integrate digital literacy into mathematics assessment practices. Through this approach, the researchers sought to capture participants' reflections, perceptions, and experiences when designing and implementing digital assessment activities during their teaching practice. By focusing on participants' lived experiences, the study aims to reveal the essential structure that characterizes their readiness in integrating digital technologies into assessment contexts.

2.2 Participants and Sampling Technique

The participants were selected using purposive sampling, a technique commonly employed in qualitative research to identify individuals who possess rich and relevant experiences related to the phenomenon being studied (Patton, 2015; Merriam & Tisdell, 2016). The study involved six final-year students from mathematics education programs at two Indonesian higher education institutions: Universitas Nahdlatul Ulama Pasuruan and Universitas Negeri Surabaya.

The selection criteria required that participants had completed core courses in mathematics pedagogy and content knowledge and were currently involved in designing digital-based assessment instruments during their teaching practice. These criteria ensured that participants had direct experience with the phenomenon under investigation.

In phenomenological research, the researcher acts as the primary instrument of data collection and interpretation. Therefore, the researchers maintained a phenomenological attitude, which involves consciously suspending personal assumptions and prior beliefs in order to focus on the participants' perspectives (Moustakas, 1994). This approach enabled the researchers to capture participants' authentic experiences related to digital assessment readiness.

2.3 Data Collection Techniques and Instruments

Data were collected using multiple qualitative techniques to obtain a comprehensive understanding of the phenomenon. The primary data collection method was semi-structured in-depth interviews, which allowed participants to describe their experiences, perceptions, and challenges when integrating digital literacy into mathematics assessment (Brinkmann & Kvale, 2015). The interviews were conducted conversationally to encourage reflection on learning experiences, decisions, and pedagogy.

To complement interview data, participant observations were conducted during the design and implementation of digital assessment activities. These observations focused on how participants utilized digital tools such as GeoGebra (Version 6.0) to create dynamic mathematical representations and Quizizz to design interactive formative assessments. Observational data provided insight into participants' practical engagement with digital technologies in assessment contexts.

In addition, digital artifacts produced by participants were collected as secondary data sources. These artifacts included digital assessment rubrics, feedback records, and instructional design documents developed during their teaching practice. The analysis of these artifacts allowed researchers to examine how participants translated their technological and pedagogical knowledge into actual assessment practices.

To ensure the trustworthiness of the research findings, several validation strategies were implemented. Data triangulation was conducted by comparing information obtained from interviews, observations, and digital artifacts to identify consistent patterns in participants' experiences. In addition, member checking was carried out by inviting participants to review the preliminary interpretations of the data to ensure that the researchers' interpretations accurately reflected their experiences (Merriam & Tisdell, 2016).

2.4 Data Analysis and Scientific Rigor

Data analysis followed the procedures of phenomenological reduction, commonly referred to as the Stevick–Colaizzi–Keen method as adapted by Moustakas (1994). This method is

widely used in transcendental phenomenological research to identify the essential structure of a phenomenon based on participants' lived experiences.

As illustrated in Figure 1, the analysis process consisted of several systematic stages.

First, the researchers conducted epoché (bracketing) by intentionally setting aside their prior assumptions and personal interpretations regarding digital literacy in mathematics assessment. This step ensured that the analysis remained grounded in the participants' perspectives rather than the researchers' preconceived ideas.

Second, the researchers performed horizontalization, in which all significant statements from the interview transcripts were identified and treated with equal value. These statements represented participants' descriptions of their experiences in designing and implementing digital assessment activities.

Third, the significant statements were grouped into clusters of meaning, where related statements were organized into thematic categories that reflected key aspects of pre-service teachers' readiness. These thematic clusters formed the basis for identifying the core dimensions of the phenomenon.

Fourth, the researchers developed textural and structural descriptions of the participants' experiences. The textural description explains what participants experienced, while the structural description explains how the experiences occurred within specific contexts.

Finally, the analysis culminated in the development of an essential description, which synthesizes the fundamental meaning of the phenomenon by integrating the identified themes into a coherent representation of pre-service teachers' readiness to integrate digital literacy into mathematics assessment.

Through these systematic procedures, the analysis ensures that the findings are grounded in participants' lived experiences while maintaining methodological rigor in accordance with phenomenological research standards.

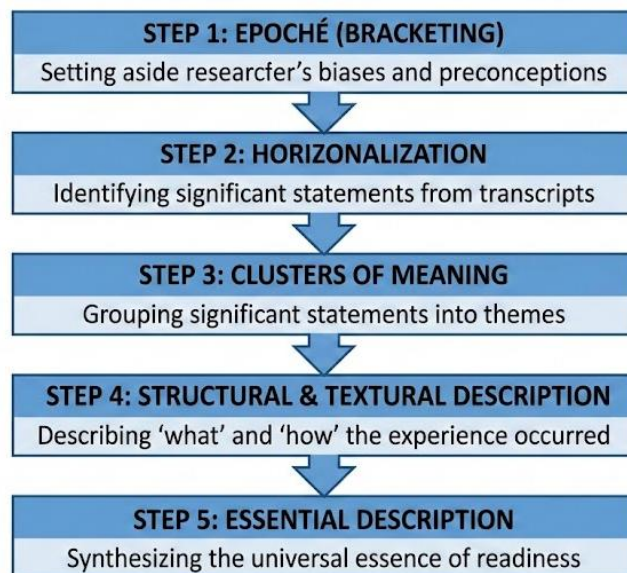


Figure 1. Phenomenological Data Analysis Procedure Based on Moustakas (1994)

3 Results and Discussion

This section presents the results of the phenomenological analysis focusing on the lived experiences of pre-service mathematics teachers as they integrated digital literacy into their assessment practices. Consistent with qualitative research standards, the findings are organized

into thematic categories that represent the essential structure of participants' professional readiness in designing digital-based mathematics assessments.

3.1 The Dissonance Between Operational Fluency and Pedagogical Validity

The primary finding reveals a significant cognitive tension between participants' operational fluency in using digital tools and their readiness to utilize these tools for meaningful mathematical assessment. While participants demonstrated high levels of confidence in operating digital applications, this technical competence was frequently accompanied by what they described as "pedagogical anxiety." This anxiety emerged from concerns about whether digital assessment tools could genuinely capture students' mathematical reasoning rather than merely encouraging guessing behaviors.

The following interview excerpts illustrate this internal conflict:

Researcher: "How did you feel when you first integrated digital tools like Quizizz or GeoGebra into your student assessment?"

Participant A: "Actually, I feel very comfortable just using the applications, like creating quizzes in Quizizz or Google Forms. But I often feel anxious about whether the quizzes I create truly measure students' mathematical reasoning, or if they are just guessing because of the game-like interface."

Participant B: "The biggest challenge is not the technology, but how to align the features in GeoGebra with the assessment rubric I design so that it remains objective and does not diminish the essence of the mathematics content."

These narratives indicate that readiness in digital assessment is not merely determined by technical competence. Instead, it involves a complex negotiation between technological possibilities and pedagogical responsibility. Participants recognized that digital tools may increase student engagement through gamification, yet they also expressed concerns about maintaining the rigor and validity of mathematical assessment. Similar concerns have been reported in previous research, which indicates that teachers often struggle to ensure that digital assessment activities measure deep conceptual understanding rather than superficial engagement (Heitink et al., 2016; Tondeur et al., 2017). Therefore, the phenomenon observed in this study suggests that pre-service teachers must develop not only technological skills but also strong assessment literacy to ensure that digital tools serve pedagogical objectives.

3.2 Structural Transformation of Assessment Perspectives

Another important finding concerns the transformation in how participants conceptualized assessment practices when digital technologies were introduced. The integration of digital tools encouraged participants to move beyond traditional assessment models that focus primarily on final answers toward more dynamic and process-oriented approaches.

Table 1 illustrates the shift in assessment perspectives experienced by the participants.

Table 1. Comparative Evolution of Assessment Perspectives

Dimension	Traditional Perspective	Digital-Integrated Perspective
Primary Focus	Final Answer Accuracy and procedural steps.	Visualization of the Problem-Solving Process.
Feedback Loop	Delayed; manual grading of physical scripts.	Real-time and Automated feedback during tasks.
Student Role	Passive receiver of teacher-led scores.	Active explorer within the digital environment.
Data Handling	Individual paper storage; difficult to track.	Automated data logs and detailed analytics.

As shown in Table 1, digital environments enable teachers to capture aspects of students' learning processes that are often invisible in traditional assessments. Participants highlighted that features such as automated feedback and response analytics allowed them to identify students' misconceptions more quickly and adapt instructional strategies during the lesson. This finding supports previous research demonstrating that digital assessment tools can facilitate formative assessment practices by providing immediate information about students' learning progress (Heitink et al., 2016; Scherer et al., 2021).

However, participants also acknowledged that digital assessment requires greater pedagogical judgment. Teachers must carefully design tasks that encourage meaningful mathematical exploration rather than merely interactive engagement. This suggests that the integration of digital technologies in assessment requires teachers to rethink the fundamental purposes and design principles of assessment in mathematics classrooms.

This structural transformation is also reflected in the digital artifacts produced by the participants. One example is presented in Figure 2, which shows a GeoGebra-based assessment task designed to encourage students to explore geometric transformations dynamically. Unlike traditional paper-based questions that emphasize procedural accuracy, this task requires students to manipulate geometric objects, analyze relationships between original and transformed figures, and explain their reasoning. The artifact illustrates how digital tools can support process-oriented assessment and promote deeper mathematical understanding.

TUGAS ASESMEN: GEOMETRI TRANSFORMASI

Masalah:

1. Di dalam GeoGebra, buatlah segitiga ABC dengan koordinat titik-titik $A(1, 1)$, $B(4, 1)$, dan $C(2, 4)$.
2. Gunakan perkakas GeoGebra untuk merefleksikan (mencerminkan) segitiga ABC terhadap sumbu- y . Berilah label bayangannya sebagai segitiga $A'B'C'$. Tuliskan koordinat bayangan titik A' , B' , dan C' pada kotak jawaban yang disediakan.
3. Gunakan perkakas GeoGebra untuk mentranslasikan (menggeser) segitiga $A'B'C'$ dengan vektor translasi $T = (3, -2)$. Berilah label bayangannya sebagai segitiga $A''B''C''$. Tuliskan koordinat bayangan titik A'' , B'' , dan C'' pada kotak jawaban yang disediakan.
4. Bandingkan koordinat segitiga asal ABC dengan koordinat segitiga akhir $A''B''C''$. Kesimpulan apa yang dapat Anda tarik mengenai hubungan antara kedua segitiga ini? Tuliskan dalam bentuk kalimat.

Kotak Jawaban:

Koordinat A' (_____), B' (_____), C' (_____)

Koordinat A'' (_____), B'' (_____), C'' (_____)

Kesimpulan: _____

Figure 2. Example of a GeoGebra-based assessment task designed by a participant focusing on process visualization.

3.3 Thematic Dimensions of Professional Readiness

Through the processes of horizontalization and clustering of meanings, three major themes were identified as the pillars of participants' readiness in integrating digital literacy into mathematics assessment.

Table 2. Thematic Pillars of Digital Readiness Found in the Field

Category	Finding	Lived Experience Essence
Technological Knowledge	Tool Fluency	High confidence in operational software usage.
Pedagogical Anxiety	Assessment Validity	Concern over measuring "logic" vs "guessing."
Assessment Logic	Rubric Alignment	Difficulty in maintaining objectivity with dynamic tools.

These findings indicate that digital readiness is a multi-dimensional construct rather than a linear progression of technological skills. While participants quickly developed operational

fluency with digital tools, deeper challenges emerged when they attempted to integrate these tools into meaningful assessment practices.

Participants' concerns about maintaining assessment validity demonstrate their awareness of the importance of aligning technological tools with pedagogical objectives. This awareness reflects the intersection of technological knowledge and pedagogical knowledge described in the TPACK framework (Mishra & Koehler, 2006). In this context, the participants' "pedagogical anxiety" can be interpreted as a productive professional tension that encourages teachers to critically evaluate the pedagogical implications of technology use.

3.4 Summary of Essential Structure

The phenomenological synthesis of participants' experiences suggests that digital readiness in mathematics assessment involves the ability to navigate the tension between technological engagement and mathematical rigor. Participants consistently emphasized that mastering digital tools alone does not guarantee effective assessment practices. Instead, readiness emerges when teachers are able to design digital learning environments that reveal students' reasoning processes rather than conceal them behind technological features.

This finding reinforces the view that technology integration in education is fundamentally a pedagogical challenge rather than a purely technical one. By interpreting participants' lived experiences, this study highlights that readiness involves a combination of technological competence, pedagogical reflection, and assessment literacy

3.5 The Synthesis of TPACK and Pedagogical Anxiety

The dissonance between operational fluency and pedagogical anxiety observed in this study can be interpreted through the lens of the TPACK framework. While participants demonstrated strong technological knowledge (TK), their pedagogical content knowledge (PCK) related to assessment design was still developing. As a result, the integration of these knowledge domains into full TPACK competence had not yet been fully achieved.

This finding supports previous studies indicating that pre-service teachers often possess technological skills but struggle to integrate these skills into pedagogically meaningful instructional practices (Tondeur et al., 2017). In this study, participants' pedagogical anxiety functioned as an indicator of developing professional awareness regarding the complexity of digital assessment design.

3.6 Shifting Paradigms and the Formative Potential of Digital Tools

The shift toward process-oriented and formative assessment observed in this study highlights the transformative potential of digital technologies in mathematics education. Participants recognized that digital platforms allow teachers to capture students' reasoning processes through interactive tasks and automated data collection. Such capabilities enable teachers to provide timely feedback and adjust instructional strategies based on students' responses.

These findings align with previous research suggesting that digital assessment environments can support formative learning by providing continuous insights into students' understanding (Heitink et al., 2016). When used effectively, digital tools can therefore enhance the diagnostic role of assessment in mathematics learning.

This formative potential can also be observed in the digital artifacts designed by the participants. Figure 3 presents an example of a Quizizz-based assessment item created to evaluate students' understanding of linear equations. Through interactive multiple-choice

questions and immediate feedback features, the platform enables teachers to quickly identify students' misconceptions and adjust their instructional strategies accordingly. The artifact illustrates how pre-service teachers utilized digital platforms not only to deliver assessments but also to support ongoing formative evaluation in mathematics learning.



Figure 3. Quizizz Item for Formative Math Assessment

3.7 The Role of Institutional Mentorship as a Catalyst

The findings highlight the importance of institutional support and collaborative mentorship in developing teachers' readiness for digital assessment. Participants reported that discussions with peers and guidance from faculty members played a significant role in helping them refine their assessment designs and overcome pedagogical uncertainties.

This observation confirms the notion that professional identity development is a socially constructed process shaped by collaborative learning environments. Mentorship from teacher educators served as an important bridge between theoretical knowledge and practical classroom application, helping participants overcome the internal barriers described by Ertmer and Ottenbreit-Leftwich (2010).

Ultimately, the transition toward digital assessment should not be viewed simply as the adoption of technological tools but as a deeper transformation of teachers' professional identity and pedagogical thinking. By integrating participants' experiences with existing theoretical perspectives, this study provides insights that may inform the development of more integrative teacher education programs aimed at preparing future mathematics teachers for technology-supported assessment practices.

4 Conclusion and Suggestions

This study concludes that pre-service mathematics teachers' readiness to integrate digital literacy into mathematics assessment is a multidimensional phenomenon that extends beyond mere technical proficiency. Referring to the research objectives, the findings reveal that although pre-service teachers demonstrate strong operational fluency in using digital tools, their professional readiness is shaped by their ability to navigate the pedagogical challenges associated with maintaining mathematical rigor in digital assessment environments. The results indicate that digital readiness should not be viewed simply as the mastery of technological tools, but rather as the capacity to balance technological engagement with valid mathematical assessment practices.

The phenomenological analysis shows that readiness emerges from the interaction between three interconnected dimensions: technological fluency, pedagogical considerations regarding assessment validity, and the ability to align digital tools with appropriate assessment rubrics.

These findings suggest that readiness involves not only technical competence but also pedagogical reasoning, assessment literacy, and the capacity to critically evaluate the implications of digital technologies for measuring students' mathematical understanding. In this sense, digital readiness represents a professional capability in which teachers must reconcile the opportunities offered by digital technologies with the demands of maintaining rigorous mathematical evaluation.

Practically, the findings imply that teacher education programs should move beyond generic ICT training and instead provide integrated professional preparation that combines technological, pedagogical, and assessment competencies. In particular, teacher training institutions should consider implementing TPACK-oriented workshops that focus on the design of digital assessment tasks and rubrics for dynamic learning environments such as GeoGebra and Quizizz. Such programs should also incorporate collaborative reflection and peer mentorship to support pre-service teachers in addressing pedagogical concerns that arise when integrating digital technologies into assessment.

From a theoretical perspective, this research contributes to the understanding of teacher readiness by highlighting the role of pedagogical reflection and professional judgment in digital assessment practices. The findings suggest that future research may benefit from exploring a qualitative perspective of TPACK that includes emotional and social dimensions of professional readiness, particularly in contexts where teachers must balance technological innovation with disciplinary rigor.

This study has several limitations that should be acknowledged. First, the number of participants involved in this study was limited to six pre-service mathematics teachers from two institutions, which may limit the generalizability of the findings to broader educational contexts. Second, the study focused on participants' experiences during their teaching practice, which may not fully represent how their readiness develops during their early years of professional teaching. Therefore, future research is recommended to conduct longitudinal studies that examine how pre-service teachers' readiness evolves as they transition into their professional careers, particularly in diverse school environments with varying levels of technological infrastructure.

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