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Mathematics teachers' perception of formative e- assessment for sustainable education

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A B S T R A C T

Sustainable education aims to create equitable and accessible learning environments that support lifelong learning and adaptability, with digital tools playing a key role in achieving these goals. Formative e-assessment is increasingly recognized as a sustainable practice that enhances student engagement and learning outcomes by providing timely feedback and facilitating continuous improvement. The mixed-method study examines mathematics master's students' perceptions of formative e-assessment using survey data and reflective responses based on their experiences as learners and assessment designers. The 62 purposively selected participants were enrolled in the researcher-taught Analysis 1 course. The results showed varying perceptions among mathematics teachers regarding different aspects of formative e-assessment. The highest mean was found in the item "*Feedback given is fast"* (M=4.40, SD=0.89), while the lowest mean was found in the item "*formative e-assessment benefit more students than from paper-based assessment"* (M= 3.44, SD= 0.91). Respondents reported challenges in designing higher-order thinking questions, balancing difficulty, and concerns that Google Classroom's question shuffling could disrupt assessment structure. Despite concerns, statistical analysis found no significant link between the teachers' actual use or comfort levels and their perceptions of the contribution and efficacy of formative e-assessment. Still, the findings highlight key insights into its perceived benefits and practical challenges, supporting sustainable assessment practices in graduate mathematics education. Nevertheless, the results support sustainable assessment practices in graduate mathematics education by shedding light on important insights into its perceived advantages and real-world difficulties.

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R E S U M O

A educacão sustentável visa criar ambientes de aprendizagem equitativos e acessíveis que apoiem a aprendizagem ao longo da vida e a adaptabilidade, com as ferramentas digitais desempenhando um papel fundamental na realizacão desses objetivos. A avaliacão desses objetivos. A avaliacão formative electronica é cada vez mais reconhesida como uma prática sustentável que melhora o engajamento dos alunos e os resultados de aprendizagem, fornecendo feedback oportuno e facilitando a melhoria continua. O estudo de métodos mistos examina as percepcões dos alunos de mestrado em matemática sobre a avaliacão formativa electrônica, utilizando dados de pesquisa e respostas reflexivas baseadas em suas experiências como aprendizes e designers de avaliacões. Os 62 participantes selecionados intencionalmente estavam matriculados no curso de Análise 1 ministrado pelo pesquisador. Os resultados mostraram percepcões variadas entre os professors de matemática em relacão a diferentes aspectos da avaliacão formativa electronica. A média mais alta foi encontrada no item "O feedback dado é rápido" (M=4.40, DP=0.89), enquanto a media mais baixa foi encontrado no item "a avaliacão formative online beneficia mais alunos do que a avaliacão em papel" (M=3.44, DP=0.91). Os respondents relataram desafios em projetar perguntas de pensamento de ordem superior, equilibrar a dificuldade e preocupacões de que a aleatorizacão de perguntas de Google Classroom poderia desestruturar a avaliacão. Apesar das preocupacões, a análise estatística não encontrou uma ligacão significativa entre o uso real ou os níveis de conforto dos professors e suas percepcões sobre a e a eficácia da avaliacão formativa electronica. Ainda assim, os achados destacam percepcões importantes sobre seus beneficíos percebidos e desafios práticos, apoiando práticas de avaliacão sustentáveis na educacão matemática de pós-graduacão. No entanto, os resultados apoiam práticas de avaliacão sustentáveis na educacão matemática de pós-graduacão ao lancer luz sobre importantes percepcões sobre suas vantagens percebidas e dificuldades no mundo real.

Palavras-chave:
Educação matemática de pós-graduação, ferramentas digitais de aprendizagem, desafios na elaboração de avaliações, avaliação reflexiva.

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Introduction

Recent years have seen a significant shift in the global educational landscape due to technological advancements and the expanding use of digital technologies in the teaching and learning process. One significant shift has been the use of formative e-assessment. Around the world, educational institutions are beginning to recognize the potential of formative e-assessments to enhance learning outcomes, customize instruction, and support data-driven classroom decision-making.

International organisations such as UNESCO and the Organisation for Economic Cooperation and Development (OECD) have emphasized the importance of using technology into evaluation procedures in order to promote high-quality, accessible, and equitable education. UNESCO (2021) pointed out the importance of digital assessment tools in achieving Sustainable Development Goal 4 (SDG 4, Quality Education), particularly in ensuring that everyone has access to high-quality education and opportunities for lifelong learning. According to OECD (2020), formative digital assessments can also improve student learning by promoting metacognition, enabling rapid feedback, and bolstering differentiated instruction.

In mathematics education, where conceptual understanding and timely feedback are essential, the efficient use of digital formative assessments can greatly increase student progress and engagement. In the Philippines, national Education authorities have promoted digital teaching and assessment as part of broader education reforms accelerated by the COVID-19 pandemic. The Department of Education has launched initiatives to support technology-driven learning, but their success depends on teachers' readiness, motivation, and attitudes toward integrating technology. Similarly, CHED Memorandum Order No. 4, Series of 2020, supports flexible learning in higher education through diverse assessment methods, learning management systems (LMS), and ICT-tools. Additionally, *CHED Memo Series of 2019* mandates that students acquire 21st-century skills , including critical thinking and problem-solving, communication and teamwork information literacy, and technology and digital literacy, to succeed in their careers.

Mathematics plays a significant role in 21st- century thinking, requiring logical and methodical problem-solving. Consequently, acquiring mathematical competencies is essential, and should be integrated into an individual's knowledge, abilities, and attitudes. Assessment therefore, must be capable of capturing instances where learning contributes to the development of mathematical competencies to the twenty-first century (Dewanti et al., 2020). As a result, the assessment method is considered a key determining factor in this process.

In this context, Azharini et al. (2023), describe e-assessment tools as applications designed to assess students' competencies in both soft and hard skills within thematic learning environments. Moreover, e-assessment provides real-time feedback that facilitates and monitors students' progress (Dy et al, 2021). Supporting this, Divjak et al. (2024) confirmed that students valued the student-centered approach in mathematics e-assessment, especially when all instructional elements are pedagogically aligned.

Over the last decade, the use of electronic devices and technologies has increased for both teaching and learning, as well as in the assessment of activities. As e-learning approaches become a more prominent topic in educational research, understanding how these technologies can be applied in assessment and evaluation has become essential. Various words, including electronic assessment and electronic evaluation, are frequently used in the literature to describe this kind of assessment (Doğan et al.,2020).

A range of digital technologies and techniques are used in e- assessment with the goal of improving the evaluation process at various stages. Deeper student engagement and self-regulation may be encouraged by its timely, automated feedback and various assessment methods. According to recent research, well-crafted digital tests can greatly increase student autonomy and motivation, particularly when they incorporate interactive features and provide fast, focused feedback (Sayet al, 2024; Deeva et al., 2021).

In this more comprehensive context, formative e-assessment has become a particularly useful approach. It is a useful instrument for tracking student development and promoting ongoing academic involvement, expanding comprehension, and promoting active involvement (McCallum & Milner, 2020). Serving as a digital substitute for traditional formative assessment, it upholds the significance of teacher-student interaction. Additionally, formative e-assessment overlaps with virtual learning settings. Teachers can track progress using data created in digital learning platforms. These platforms frequently include automated evaluations, and interactive resources, which facilitate insights into students' learning in real time (Barana et al., 2019).

Adequate infrastructure, expert training, technical assistance, and high-quality materials are necessary for e- assessment procedures to be successful (Ghouali et al.,2020). Additionally, collaborative or problem-based assessment assignments should be used in conjunction with multiple choice questions to promote the development of deeper skills and higher-order thinking (Babo, 2021). According to Al Beiki et al. (2023), teachers preferred feedback methodologies over other formative assessment methods. By incorporating cutting-edge digital tools, e- assessment typically seeks to enhance more than other types of assessment techniques. Typically, e-assessment also aims to improve assessment design through the integration of advanced digital tools (Bearman et al.,2023).

According to Al-Hattami's (2020) study, online assessment of students' performance during virtual instruction can be a useful strategy for assisting with higher education, even in

the face of some difficulties. Additionally, e-assessment pairs well with online instruction, enhancing the learning process as a whole. It is crucial to remember that e-assessment is more than just converting traditional evaluation techniques to digital form, claim Baneres et al. (2019). Additionally, formative e-assessment actively engages students by pushing them to interact and complete tasks rather than just listening passively in class, as noted by Tsakiridis et al. (2022). Multiple-choice online formative assessment activities can significantly improve students' learning experiences, particularly when they are accessible, reproducible, and provide precise, instant feedback (Ylmas et al., 2020).

Much of the current literature on e-assessment either ignores the unique difficulties involved in teaching mathematics or does not concentrate on the undergraduate level. Bakker et al. (2021) highlighted the importance of this issue for scholars in mathematics education. Their international survey of math educators identified "assessing online" as one of the eight key challenges facing mathematics education research over the next decade. Despite acknowledging the "significant advantages" of e-assessment over traditional methods, the authors caution that "assessing what we value is considerably harder to do well than just evaluating what is comparatively simple to evaluate in an online setting." Additionally, Prendes et al. (2022) reported that most teachers utilize formative e- assessment in online postgraduate programs. Based on this, they concluded that formative e- assessment is an effective strategy for enhancing the learning process across all educational levels.

A closer examination of existing gaps in the literature could provide valuable insights that support the development and effective use of formative e-assessment in graduate-level mathematics education, an area with significant potential benefits for the field. While much of the research on formative e-assessment focuses on undergraduate or K-12 settings, its application and effectiveness in graduate-level mathematics courses remain less explored. In these advanced courses, summative evaluation continues to be the main focus, while formative evaluation, despite its crucial role in promoting learning, receives limited attention.

To address this gap, the researcher gathered the perspectives of mathematics teachers on the usefulness of formative e- assessment. It is believed that integrating formative e-assessment at the graduate-level can enhance both current and future educators' competencies by strengthening their assessment literacy. Understanding these perspectives is essential for informing professional development, guiding policy decisions, and ensuring the successful implementation of digital assessment practices in mathematics education.

Problem statement

To explore the perceptions of mathematics master's students, regarding the contribution and efficacy of formative e-assessment in supporting teaching and learning, based on their experiences as both learners and practitioners in creating and answering e-

assessments within the course Analysis 1. Specifically, this sought answers to the following questions: What are mathematics teachers' perspectives on contribution and efficacy of formative e-assessment conducted through Google classroom in mathematics education in terms of the instructional and learning value, technological efficiency, and student engagement outcomes? How often do respondents use formative e-assessment tools and how comfortable are they using them? Does the respondents' perception of the contribution and efficacy of formative e-assessment significantly correlate with: a. frequency of use of formative e-assessment tool; and b. level of comfort in using formative e-assessment tool?

4. What are the respondents' views on the following: a. use of formative e-assessment with multiple-choice questions in graduate –level courses such as Analysis 1; b. advantages for graduate school students when using a formative e-assessment tool (multiple-choice type) in the subject Analysis 1;
c. challenges or limitations encountered when creating the formative e-assessment instrument (multiple-choice type); d. functionalities they consider essential in an e-assessment tool for effective formative assessment in teaching math; and e. how does formative e-assessment influence teaching practices?

Methods

Research design

To successfully answer the research objectives, this study used a *mixed-method research design* that combined quantitative and qualitative techniques (Creswell et al., 2021; Dawadi et al., 2021). This design was suitable since it made it possible to comprehend the study in every aspect. In particular, the first section of the study tool, which collected graduate students' overall perceptions regarding formative e- assessment, and their frequency of use and comfort levels in using formative e-assessment tools provided quantitative data. Furthermore, the instrument's second section, which comprised of five open- ended questions that allowed participants to comment on their opinions about formative e-assessment, was used to gather qualitative data. Throughout the qualitative investigation, thematic analysis of the responses was conducted through the use of inductive coding.

phases and proceedings

The study was carried out in Analysis 1 course, a core subject taught by the researcher in graduate mathematics curriculum. Analysis 1 was intentionally selected because it covers the fundamental concepts in both Differential and Integral Calculus, which are essential for advanced mathematics understanding. After each topic was discussed in class, the researcher administered formative assessments composed of 10 to 15 questions, delivered electronically through Google Classroom. These formative e-assessments served to reinforce understanding and provide timely feedback to students. Additionally, one of the course requirements was the development of instructional materials that included e-assessments for both the pretests and

posttests, allowing students to actively engage with and experience the assessment process. This dual role, participating in assessments and designing them, allowed students to experience formative e- assessment both as learners and as prospective educators.

This study is limited to the use of Google Classroom due to its widespread use in the Philippines, particularly in basic and higher education institutions. Other learning management systems such as Moodle, Edmodo, or Microsoft Teams were excluded to maintain consistency in platforms features and user experience. As such, it also limits the generalizability of the findings to other LMSs with different structures and functionalities.

Data collection was conducted, beginning in December 2023 and continuing through August 2024.

Participants

A purposive sampling strategy was employed, deliberately selecting the graduate students from the Master of Arts in Teaching program, majoring in Mathematics, who were enrolled in Analysis 1 course during the during the 2023-2024 academic year (First Semester, Second Semester, and Summer), and the Second Semester of the 2022-2023 academic year. This non-random approach ensured the selection of information-rich cases most relevant to the research questions (Campbell et al., 2020). Of the 124 students enrolled in the *Analysis 1* course taught by the researcher during these periods, 62 voluntarily participated in the study. Purposive sampling was suitable for the purpose of this study, the strategy used made sure that answers came from those who could offer hands-on insights.

participants characteristics

Of the 62 participants, 38 (61.29 %) are female and 24 (38.71 %) are male. Regarding their workplace, 33 (53.23 %) working in private institution, 27 (43.55 %) in public institution , and 2 (3.23 %) in non-profit organization. In terms of work experience, 44 (70.97 %) have between 1 and 5 years, 15 (24.19 %) have 6 to10 years, and 3 (4.84 %) have 11 to 15 years of experience. Employment status shows that 42 (67.74%) are teachers, all of whom are permanent employees. Additionally, 3 (4.84 %) are Instructors, 1 or 1.61% is an Assistant Principal, 6 or 9.68 % are holding non- teaching positions, and 2 or (3.22 %) are self-employed.

Their perspectives on this study are likely shaped by both their current classroom experiences and their exposure to formative e-assessment and to new pedagogical approaches through the graduate –level coursework. Their limited years of teaching experience suggest they may be more open to adopting innovative methods such as formative e-assessment , especially as they are still developing their teaching philosophical and classroom practices. Working predominantly in private institutions, where there may be more flexibility or emphasis on technology integration and student-centered approaches. Thus, their profile implies a readiness and potential enthusiasm for integrating formative e-assessment tools to

enhance learning outcomes, it also suggests they are in a key position to benefit from professional development focused on adaptive learning, as they are still forming habits and strategies that will shape their long –term teaching practices.

Research instruments

The first section of the questionnaire, consisting of 15 items, focused on graduate students' general opinions regarding formative e- assessment. This section utilized a questionnaire adapted from Peculea (2020). To ensure the reliability of the instrument in the current context, Cronbach's alpha was computed and yielded a value of **0.93**, indicating high internal consistency.

Five open- ended questions created by the researcher were added in the second section, allowing participants to provide more details about how they view formative e-assessment, particularly in relation to questions in the multiple-choice format. To guarantee their accuracy, the questions were validated by experts including mathematics teachers and English language specialists, who assessed their relevance, clarity, and congruence with the goals of the study.

Data analysis

Descriptive statistics were used by the researcher to examine the data gathered from respondents. Frequency counts were used to evaluate the frequency and comfort level of respondents' usage of these tools based on their experience in a graduate course as students and as math teachers. To calculate the frequency of use, participants were asked to score on a 5-point Likert scale, where 1 indicated "rarely or never," 2 "occasionally," 3 "sometimes," 4 "often," and 5 "always."

Likewise, another 5-point Likert scale was used to determine the *level of comfort* in using these tools: 1 meant "very uncomfortable," 2 meant "uncomfortable," 3 meant "neutral," 4 meant "comfortable," and 5 meant "very comfortable."

The researcher calculated *means* and *standard deviations* to summarize and interpret the results, highlighting the variations in perceptions about the contribution and efficacy of formative e-assessment in mathematics. IBM SPSS Statistics for Windows, Version 22 was used to conduct the statistical analysis.

Pearson's correlation coefficient (r) was computed in order to investigate the correlations between variables. The analysis specifically examined the association between respondents' perceptions about utilizing formative e-assessment and (1) how frequently they use formative e- assessment tools, and (2) how comfortable are they using them. The significance of each correlation was evaluated using the associated p-value, with results considered statistically significant at $p < 0.05$.

Ethical consideration

Participation in the study was voluntary, with informed consent obtained through a

Google Form questionnaire, where participants indicated their willingness to participate. They were fully informed of their rights, including the right to withdraw at any time without penalty. All collected data was anonymized to protect participant privacy and confidentiality, and it was securely stored on a password-protected computer accessible only to the researcher. The raw data was scheduled for deletion after the publication of this study. This study underwent review and approval by the research Ethics Committee of Marikina Polytechnic College to ensure compliance with ethical standards. The research adhered to institutional guidelines and best practices for protecting the rights and well-being of participants throughout the study.

Results and discussion

This section presents the results and discussion centered around the research objectives. The multi-phase process, ranging from course participation and assessment engagement to reflective evaluation ensured that the data collection was aligned with the research objectives and grounded in authentic learning experiences. The integration of instructional design and student response within a real academic context added depth and relevance to the findings.

- Perceptions of mathematics teachers regarding the contribution and efficacy of formative e-assessment conducted through Google classroom in mathematics education in terms of instructional and learning value, technological efficiency, and student engagement outcomes.

Table 1 displays the summarized results of the survey, with relevant statistical measures.

Table 1

Perceptions of mathematics teachers regarding the contribution and efficacy of formative e-assessment in mathematics

Variables	Mean	SD	Level
1. Formative e-assessment is an essential component of the teaching-learning process.	4.08	0.79	High
2. Formative e-assessment (multiple-choice type questions) is appropriate for mathematics subjects.	3.69	1.03	High
3. Using formative e-assessment (multiple-choice type questions) can add value to my learning.	3.97	0.88	High
4. Formative e-assessment (multiple-choice type questions) helps me to identify the meanings of difficult concepts that I am struggling to understand.	3.82	1.04	High

5. Formative e-assessment (multiple-choice type questions) helps me to identify the skills that I acquired with difficulty.	3.90	0.93	High
6. Formative e-assessment (multiple-choice type questions) provides the necessary information to adjust teaching and learning while it happens.	3.81	0.92	High
7. Formative e-assessment (multiple-choice type questions) guides teachers and students in decision-making on how to advance in achieving their goals.	3.90	0.86	High
8. Formative e-assessment (multiple-choice type questions) may not be feasible due to technological issues.	3.76	0.88	High
9. Formative e-assessment (multiple-choice type questions) should employ dependable technologies.	4.03	0.76	High
10. Formative e-assessment (multiple-choice type questions) is more affordable than paper-based assessment.	3.90	1.08	High
11. Marking is more accurate, because computers don't suffer from human error.	3.69	1.00	High
12. Feedback given is fast.	4.40	0.89	Very High
13. Formative e-assessment benefit more students than from paper-based assessment.	3.44	0.91	High
14. Formative e-assessment goes hand in hand with e-learning (e.g. using Google classroom).	3.97	0.84	High
15. Formative e-assessment improves student engagement and participation.	3.81	0.93	High
Overall Mean	**3.88**	**0.92**	**High**

Note: 4.21-5.00 Very High, 3.41-4.20 High, 2.61-3.40 Moderate, 1.81- 2.60 Low, 1.00-1.80 Very Low

The analysis based on observed scores for each item showed a high level of opinion for formative e-assessment. The descriptive statistics results showed that the mathematics teachers perceive the *instructional and learning value, technological efficiency, and student engagement outcomes* of formative e-assessment conducted through Google classroom in mathematics education at a *high level* of contribution and effectiveness as shown in the sample mean score (M=3.88, SD=0.92). The *very high level* of mean was found in the item: *Feedback given is fast* (M=4.40, SD=0.89). This implies that in terms of technological efficiency mathematics teachers value the benefits of the online formative assessments, particularly the immediate feedback they provide. This appreciation was evident when they were given series of short quizzes through an online platform provided by the researcher. Being able to verify students' current level of knowledge and receive feedback as soon as the quiz was finished were

the features that they valued the most. These findings reinforce the claims of several authors. They consistently show that both teachers and students hold positive perceptions of formative e-assessment due to its ability to: improving motivation and engagement, give prompt and personalized feedback, and provide adaptable learning opprtunities (Astiandanni et al.,2021; Peculea, 2020; Tsakiridis et al., 2022).

Among the items assessed, the statement "*formative e-assessment benefit more students than from paper-based assessment "received the lowest mean score* (M= 3.44, SD= 0.91). Despite this, the mean still falls within the range interpreted as high level of contribution and effectiveness. This indicates that the mathematics teachers somewhat doubtful about the benefits of formative e-assessment in mathematics compared to paper-based assessments. The benefits that f*ormative e-assessment (multiple-choice type questions)* might not be seen as outweighing the established benefits of paper-based methods, especially if teachers feel that it might not fully measure all the necessary skills in mathematics like in working on problem solving step-by-step.

The results further show the varying perceptions among mathematics teachers regarding different aspects on the use of formative e-assessment in mathematics subjects. These are as follows: formative e-assessment is an essential component of the teaching-learning process (M=4.08, SD=0.79).

Formative e-assessment (multiple-choice type questions) should employ dependable technologies (M=4.08, SD=0.79), using formative e-assessment (multiple-choice type questions) can add value to my learning (M= 3.97, SD=0.88), formative e-assessment goes hand in hand with e-learning (e.g. using Google classroom) (M= 3.97, SD=0.84), formative e-assessment (multiple-choice type questions) helps me to identify the skills that I acquired with difficulty (M= 3.90, SD=0.93), Formative e-assessment (multiple-choice type questions) guides teachers and students in decision-making on how to advance in achieving their goals (M= 3.90, SD= 0.86, formative e-assessment (multiple-choice type questions) is more affordable than paper-based assessment (M= 3.90, SD= 1.08), formative e-assessment (multiple-choice type questions) helps me to identify the meanings of difficult concepts that I am struggling to understand (M= 3.82, SD= 1.04), formative e-assessment (multiple-choice type questions) provides the necessary information to adjust teaching and learning while it happens (M= 3.81, SD= 0.92), formative e-assessment improves student engagement and participation (M= 3.81, SD= 0.93), formative e-assessment benefit more students than from paper-based assessment (M= 3.81, SD= 0.93), formative e-assessment (multiple-choice type questions) may not be feasible due to technological issues (M= 3.76, SD= 0.88), Formative e-assessment (multiple-choice type questions) is appropriate for mathematics subjects (M=3.69, SD=1.03) and marking is more accurate, because computers don't suffer from human error (M=3.69, SD=1.00).

- Respondents' frequency of use and comfort levels in using formative e-assessment tools.

Table 2 provides a summary of respondents' frequency of use and comfort levels in using formative e-assessment tools, based on the respondents' experiences as mathematics teacher and as learners in a graduate course.

Table 2

Frequency of use and comfort level in using formative e-assessment tool

How frequently do you currently use formative e-assessment in your math class?		
Description	*frequency*	*Percent*
1-Rarely or never	4	6.45
2-Occasionally	9	14.52
3-Sometimes	21	33.87
4-Often	14	22.58
5-Always	14	22.58
How comfortable are you in using technology-based formative assessment tools?		
Description	*frequency*	*Percent*
1- Very Uncomfortable	4	6.45
2-Uncomfortable	1	1.61
3-Neutral	15	24.19
4- Comfortable	14	22.58
5- Very comfortable	18	29.03

The data shows that the use of formative e-assessment in math classes varies among respondents, with the majority using it at least sometimes. Specifically, about 33.87% of respondents reported using formative e-assessment "Sometimes", while 22.58% use it "Often," and another 22.58% use it "Always." Meanwhile, 14.52% use it "Occasionally," and a smaller group, 6.45%, rarely or never use these assessments. This suggests a generally positive adoption trend, but with room to increase more frequent usage.

Regarding comfort levels with technology-based formative assessment tools, the majority appear comfortable or very comfortable. About 51.61% of respondents indicated they are either "Comfortable" (22.58 %) or "Very comfortable" (29.03 %) using these tools. A notable 24.19 % remain neutral, while only a small percentage feel uncomfortable (1.61 %) or very uncomfortable (6.45 %). This indicates that most users have a reasonable degree of confidence with the technology, which could support further integration of e-assessment in their teaching practices.

- Correlation analysis between respondents' perceptions of the contribution and efficacy of formative e-assessment in mathematics and their reported frequency of use and level of comfort with formative e-assessment tools.

Table 3 displays the correlation analysis between respondents' perceptions of the contribution and efficacy of formative e-assessment in mathematics and their reported frequency of use and level of comfort with formative e-assessment tools.

Table 3

Correlation of respondents' perception on the contribution and efficacy of formative e-assessment correlation with frequency of use of formative e-assessment tool

Variable	Mean	Std. Deviation	r-value	Description	p-value	Interpretation
1. Perception on the contribution and efficacy of formative e-assessment in mathematics subjects	3.88	0.920	.049	Very weak correlation	.708	Not Significant
2.Frequency of use of formative e-assessment tool	3.40	1.180				
3. Level of comfort in using formative e-assessment tool	3.82	1.08	.154	Weak correlation	.233	Not Significant

The mean frequency on the use of formative e-assessment tool was 3.40 (SD=1.18), while the mean comfort level on the use of formative e-assessment tool was 3.82 (SD=1.08). The variety of frequency of use is slightly higher than that of comfort level. This indicates that there are greater differences in respondents' reported usage habits of formative e-assessment than in their level of familiarity with it. Their usage frequency varies somewhat more, indicating variations in practice.

A Pearson correlation was conducted to examine the relationships. Results indicated that the correlation between respondents' perception on the contribution and efficacy of formative e-assessment in mathematics subjects using formative e-assessment correlation with frequency of use of formative e-assessment tool was not statistically significant, $r(60) = .049, p = .708$, suggesting a very weak correlation. The very weak correlation suggests that the frequency of usage of formative e-assessment tools is not significantly correlated with respondents' favourable opinions of its instructional and learning value, technological

efficiency, and student engagement outcomes. This suggests that even though educators may recognise the advantages of formative e-assessment, additional difficulties might be impeding regular or consistent use. Similarly, the correlation between respondents' perception correlation with level of comfort in using formative e-assessment tool was not statistically significant, $r(60) = .154, p = .233$, suggesting a weak correlation or no positive correlation.The findings provide insight into teachers' experiences with e-assessment tools in the multiple-choice type of questions.

Although no significant relationship was found between respondents' perception on using formative e-assessment correlation with frequency of use of formative e-assessment tool and between respondents' perception on using formative e-assessment correlation with level of comfort in using formative e-assessment tool, this suggests that teachers' perception on using formative e-assessment may not directly influence how confidently they use such tools. This may indicate that other factors, such as prior experience, training , or technical suppport , play a more substantial role in shapings users' comfort levels.

Increasing opportunities for usage may improve comfort levels, even among those with neutral or varied perceptions. Future studies should explore additional factors such as training, institutional support, or user motivation to better understand what drives positive perceptions and effective implementation. These results align with previous research. For instance, Valdez and Maderal (2021) examined students' perception of online assessments and its relation towards mathematics learning and found high levels of motivation and generally positive attitudes toward online assessments.

Perceptions variations were attributed to four key factors: ease of use and functionality, personal preference, technical considerations, and complementation with other methods. Similarly, Afacan et al. (2020) concluded that computer literacy enhances students' knowledge base and positively influences their perception of online exams. Valdez and Maderal (2021) also reported that students demonstrated strong motivation to learn and viewed online assessments favorably, reinforcing the notion that technical familiarity and user- centered design play a crucial role in shaping assessment perceptions. Furthermore, Janer and Ricafort (2022) emphasized that students exhibit a positive attitude toward e- learning, largely due to their prior knowledge and experience with online platforms. In the study of Al Beiki et al. (2023), the results showed that teachers significantly increased their use of formative e-assessment strategies after participating in the online professional learning community program.

- Respondents' views on the following:

a. use of formative e-assessment with multiple-choice questions in the graduate –level courses such as Mathematical Analysis;

Use of formative e-assessment with multiple-choice questions in the graduate –level courses such as Mathematical Analysis is positive because of the following reasons:

Theme 1. Promotion of active and self –directed learning

Participants noted that *formative e-assessment with multiple-choice questions* stimulates students' active and self-managed learning.

Theme 2. Flexibility and accessibility

It was reported to be better for graduate students since some are employed and can take the test whenever it is convenient before it is due; saving them time ; it is an excellent tool for quickly identifying the specific areas that need to be remedied and it reduces the amount of time that needs to be spent in monitoring and checking.

Theme 3. Efficiency in assessment and feedback

Participants pointed out several shortcomings in the application of formative e-assessments, such as prone to guessing and cheating, and limited feedback.

Theme 4. Diagnostic and remedial function

It was also highlighted that formative e-assessment cannot measure other areas in problem solving.

These limitations suggest a need for better assessment design, enhanced feedback mechanisms, and a wider variety of assessment formats. Al-Hattami (2020) reported that using various technological applications for formative evaluation helps teachers in providing direct feedback and student learning by optimizing their success and achievement. However, challenges such as online cheating, plagiarism, and technical difficulties, especially on platforms like Quizziz, remain significant concerns in e-assessment, with studies highlighting issues like students outsourcing tests or cheating at rates similar to traditional settings (Doğan,2020;Elsani et al., 2024; Divjak et al.,2024).

b. advantages for graduate school students when using formative e-assessment tool (multiple-choice type) in the subject Mathematical Analysis

Theme 1. Benefits

The respondents gave the following advantages, first in terms of benefits: easy, flexible, consistent and fair grading, efficient use of study time, less error in solving because there is correct option in the alternative so you will keep on trying to solve the problem, increased performance tracking, and has ability to identify and address knowledge gaps quickly since the feedback is real time.

Theme 2. Methods

While in terms of methods: less paper-based work for teachers, for students it allows them to solve without feeling in a hurry, and assist students with the gradual acquisition of difficult topics.

According to the responses, the use of formative e-assessment in mathematics greatly improves the quality of teaching and learning. Specifically, it fosters a more efficient, encouraging, and successful learning environment. The results align with the findings of

several studies. Studies highlight that the key advantages of e-assessment over traditional assesments include instant feedback, online/ remote interaction, fast grading, and providing tailored feedback. These features enhance efficiency and learner engagement. However, it also has drawbacks, especially when it comes to maintaining academic integrity and providing tailored feedback (Alamr et al.,2023; Dogan et al., 2020; Orsi & Juliano, 2021).

c. challenges or limitations encountered when creating the formative e-assessment instrument (multiple-choice type) through Google classroom;

Theme 1. Difficulty in designing higher-order thinking (HOTS) questions

Participants noted several difficulties in developing formative e-assessment tools, especially multiple choice, with regard to assessment design and pedagogical considerations. These included the challenge of crating questions that evaluate higher-order thinking skills(HOTS), like analysis, synthesis, and evaluations; distributing the difficulty of questions evenly; and the fact that rearranging the questions in the Google Classroom can unintentionally deviate from the assessment's logical flow or structure.

Theme 2. Technological limitations of e-assessment platform

Participants also mentioned a number of technological limitations, including limited availability of mathematical symbols and notations in platforms like Google Classroom, the challenge of accurately typing complex mathematical, symbols, equations, and formulas.

Theme 3. Dependence on internet connectivity

The requirement for steady internet connectivity to guarantee easy setup and delivery was reported by the participants.

These difficulties imply that developing successful formative e- assessments needs for more than just subject-matter expertise; it also needs for platform-specific content knowledge, technological proficiency, and alignment with educational goals. To address these issues, institutions must enhance their support systems, including providing clear instructional design guidelines and improving the tool capabilities of e-learning platforms. The findings are consistent with existing literatures.

While online assessment offers efficiency and immediate feedback, they often fall short in measuring collaborative skills and critical thinking. Teachers face challenges in designing effective assessment that will enable learners to show their knowledge without any obstacles and difficulties. These difficulties highlight the need for careful planning and meaningful feedback, which is often lacking due to emphasis on grades and content volume (Anwar et al.,2022; Babo, 2021; Petrova et al., 2020; Prendes et al., 2022).

d. functionalities they consider essential in an e-assessment tool for effective formative assessment in teaching math;

Several functionalities were identified as essential for effective formative e-assessment:

Theme 1. Essential technical features

Technical features were reported by participants as essential for effective e-assessment: real-time feedback, accessibility, user friendly interfaces, automated grading, and scoring systems. It highlights the need for investment in tools that support these features. It was also mentioned that a steady internet connection is also necessary for the efficient usage of e-assessments

Theme 2. Assessment design and integrity

Participants suggested using time limitations, randomising the sequence of the questions, and limiting the use of generic downloaded questions that students may simply seek online in order are features that are necessary to maintain intellectual honesty and question security.

Theme 3. Feedback and learning support

Other participants pointed out that providing immediate feedback, and actionable feedback including corrections are essential. This suggests deep learning and reasoning, an area e-assessments were seen as limited.

Theme 4. Diverse questions format

Participants suggest that rather than depending only on multiple-choice formats, teachers can add fill-in the-blank and identification-type questions. This suggests that institutions need to make sure the e-assessment platforms they select complement the instructional design and work well with the Learning Management System (LMS).

Findings support previous studies. Formative e- assessments face several challenges, including inadequate facilities, poor internet connectivity, and the extra time needed to create and give tests. Technical problems, in particular limited internet bandwidth, glitches, and sudden logouts further complicate their use. To address these barriers, it is essential to provide students with clear instructions, enabling user adaptability, and providing timely academic and technical support throughout the process (Almuhanna, 2023; Astiandani et al.,2021; Binova et al., 2024).

e. how formative e- assessment influence teaching practices?

According to participants' answers to this question, formative e-assessment has a big impact on instructional strategies in terms of the following:

Theme 1 . Individualized Learning, and innovation in teaching practice

By making it possible to design individualised learning pathways that modify pace and emphasis in response to each student's demands, it improves adaptive learning. The application of more innovative and significant teaching strategies, especially in disciplines like mathematics was also noted.

Theme 2. Immediate Feedback and Correction

In order to promptly resolve misconceptions and guide future lesson planning, it also enables teachers to identify areas in which students need reinforcement and to guide prompt

feedback. Additionally, students who struggle with particular concepts can benefit from prompt treatments supported by formative e-assessment.

Theme 3. Data driven, student-centered teaching

Teaching consequently become more data-driven, student-centered, and responsive. All students will eventually benefit from better learning experiences and results as a result of this practice, which not only supports self-directed learning habits

These results imply that a move towards more adaptable, customized, and reflective education is supported by the use of formative e-assessment. Teachers are better able to make wise decisions, raise to student engagement, and consistently improve learning results when they customise instruction to each learners's specific requirements. The results supports earlier studies. Online instruction can successfully incorporate e-assessment. Improving teachers' proficiency with e- assessments can improve student's interest and enthusiasm for learning activities. Additionally, e-assessment improves student learning, reduces instructional time, and creates a more engaging and joyful learning environment (Al-Hattami, 2020; Azharini et al., 2023; Peculea, 2020).

Conlusions

The study concludes by pointing out that mathematics teachers acknowledge and appreciate the instant feedback and diagnostic value that formative e-assessments offer, especially when it comes to quick quizzes that let them quickly check students' comprehension. These features are especially valued for their efficiency in tracking student progress in real time. However, there remain uncertainties about whether formative e-assessments especially those relying on multiple –choice formats offer greater benefits than traditional paper-based assessments in effectively measuring comprehensive mathematical skills, such as step-by- step problem solving.

Although the mathematics teachers acknowledge the benefits of formative e-assessments, especially when it comes to providing instant feedback, there is a crucial disconnect between belief and practice because there is no significant correlation between their perception on the contribution and efficacy of formative e-assessment and actual use or comfort levels. To address the disconnect between teachers' belief in the value of formative e-assessment and their actual usage or comfort levels, the Institution may invest in sustained professional development. Providing training modules that focus on practical applications, such as using LMS tools effectively, creating excellent online tests (such HOTS questions), and analysing assessment results to inform instructional decisions. Additionally, peer mentoring and follow-up support can reinforce these skills and promote long-term adoption. To this end, the following suggestions are put forth proposed to direct the successful and long-term implementation of formative e-assessment in higher education environments. Teachers ought to get specialised training to improve their pedagogical and technical proficiency so they can

successfully use formative e-assessment. Such training ought to be ongoing, cooperative, and in line with learning goals, as per the established TPACK structure. Training should examine new developments like gamification and artificial intelligence while also addressing the needs of diverse learners, increasing student engagement, and enhancing the efficacy of education. Teachers should be encouraged to exchange best practices and work together to improve assessment techniques as part of their continuous professional development.

Institutions may consider introducing a Learning Management System (LMS) at the graduate school level, ensuring that it includes sufficient math notation support, such as equation editors or LaTeX compatibility, to facilitate clear and accurate communication of mathematical ideas. Lastly, formative e-assessment procedures may be regularly reviewed in order to track teachers' effectiveness and make sure that these tools are accurately gauging the learning outcomes and advancement of students.

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