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MICROLEARNING AS A STRATEGY FOR ENHANCING DIGITAL COMPETENCY AMONG BS IT PRACTICUM STUDENTS

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Abstract

Despite the growing adoption of digital tools in education, limited research has explored microlearning's effect on practicum readiness, specifically regarding digital competence in IT students. This study examines the effectiveness of microlearning in enhancing digital competence among Bachelor of Science in Information Technology (BSIT) practicum students. Responding to the need for flexible, technology-enhanced teaching methods, the study utilised AI-supported, mobile-accessible microlearning modules during practicum preparation. Using a quasi-experimental, mixed-methods design, 78 students completed pre- and post-intervention self-assessments, complemented by focus group discussions. Results showed a significant improvement in self-perceived digital competence ($M=3.21$ to 4.02, $t(77)=10.56$, $p < .001$). Qualitative insights highlighted microlearning's advantages in accessibility, student engagement, and confidence in using digital tools. The research provides empirical evidence supporting the integration of microlearning into IT education, especially for practicum readiness, and adds to the expanding body of digital pedagogy literature. Microlearning can address digital skills gaps and promote scalable, student-centered learning within information technology program when incorporated into practical courses and supported by AI and mobile technology platforms.

Keywords. AI in Education, Digital Skills, Higher Education, Microlearning, Technology Integration

1. INTRODUCTION

The rapid development of information and communications technology (ICT) has significantly transformed how individuals learn, work, and communicate in the 21st century. As digital technologies continue to progress, higher education institutions face increasing pressure to ensure that graduates possess not only technical expertise but also digital literacy, critical thinking, and adaptability needed to succeed in technology-driven environments (Saltos-Rivas et al., 2021; Zhao et al., 2021; Tondeur et al., 2023). Developing these skills is no longer optional for students in technology-focused programmes such as the Bachelor of Science in Information Technology (BSIT). Instead, it is essential for academic achievement and professional preparedness (Pelaez-Sanchez et al., 2024). This need aligns closely with the United Nations Sustainable Development Goals (SDGs), especially SDG 4, which advocates for inclusive, equitable, and quality education, and SDG 8, which supports inclusive and sustainable economic growth, employment, and decent work.

Within this context, digital competence is increasingly recognised as a multidimensional construct that includes information and data literacy, communication, content creation, safety, and problem-solving in digital environments. This study adopts the European Commission's DigComp 2.2 Framework (Vuorikari et al., 2022) as a guiding reference, offering a standardised lens through which digital competency development can be conceptualised and measured.

This need is especially critical for BSIT students engaged in practicum or internship placements, who are expected to apply theoretical knowledge to authentic workplace situations. However,

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research highlights that many students enter these crucial learning experiences with varying levels of digital competency and self-confidence, often feeling underprepared for the demands of real-world ICT environments (Suzer & Koc, 2024; Tzafilkou et al., 2022). In the Philippine context, the Commission on Higher Education (CHED, 2020) has emphasised the need to enhance digital literacy among tertiary students to improve employability and bridge the digital divide. Addressing these gaps requires more than traditional classroom instruction, which often struggles to meet the diverse, fast-paced, and highly contextual learning needs of students preparing for industry exposure (Zhao et al., 2021).

To address these challenges and promote SDG-aligned educational reform, educators and researchers are increasingly exploring microlearning as a promising, student-centred strategy for improving digital competence (Torres, 2024; Gabrielli et al., 2017; Lykova & Savelyeva, 2025). Microlearning delivers educational content in short, focused, and accessible segments, utilising technology to offer flexible, on-demand learning experiences (Castillo-Sarmiento et al., 2024; Gherman et al., 2022). This approach is supported by cognitive load theory (Sweller, 2011), which suggests that breaking learning into smaller units reduces extraneous cognitive load and enhances information retention. In technical fields such as ICT, where continuous skill development and adaptability are crucial, microlearning enables just-in-time and self-directed learning that meets learners' evolving needs.

Despite increasing global interest in microlearning, its potential to prepare IT students for practicum requirements remains insufficiently explored, particularly in Philippine higher education. This research addresses this gap by examining how AI-supported, bite-sized learning modules can improve digital skills and workplace readiness among BSIT practicum students at a public university in the Philippines.

Specifically, the study aimed to develop and implement microlearning modules focused on essential digital competencies for BSIT practicum students, ensuring alignment with workplace expectations and learner needs. It also sought to assess the impact of microlearning on students' self-perceived digital skills and confidence, recognising the role of digital self-efficacy in enhancing technology readiness. Furthermore, the study examined the effect of microlearning on task performance during practicum preparation to explore its practical relevance to real-world ICT environments. Finally, students' perceptions and experiences regarding the use of microlearning were examined to gain deeper insights into how design, accessibility, and learner attitudes influence learning outcomes.

2. LITERATURE REVIEW

The rapid digitisation of society has increased the importance of graduates having strong digital skills, defined as the ability to use digital technologies effectively, critically, and responsibly in academic, professional, and personal settings (Ala-Mutka et al., 2008). In higher education, particularly in technology-focused courses such as information technology (IT), developing these skills is essential for preparing students for academic success and workplace requirements (Bojórquez-Roque et al., 2024).

International frameworks, such as the European Commission's DigComp 2.2, emphasise digital competence as a vital skill set that includes information literacy, digital communication, problem-solving, and the creative use of digital tools (Suzer & Koc, 2024). Despite these frameworks, studies reveal that many higher education students, including those in IT programmes, feel underprepared to apply digital skills in real-world professional settings, such as internships or practicum placements (Shatte & Teague, 2020; Taylor & Hung, 2022).

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Educators are exploring technology-enhanced learning approaches that foster student engagement and support the development of competencies to address this gap. One such approach gaining traction is microlearning, which involves delivering content in short, focused, and accessible segments, often supported by mobile or AI technologies (Alias & Razak, 2023; Taylor & Hung, 2022). Research suggests that microlearning enhances knowledge retention, motivation, and learner autonomy, making it well-suited for skill-based training and digital literacy development (Shatte & Teague, 2020).

Microlearning's flexible, learner-centred design aligns with the preferences of today's students, who increasingly seek personalised, on-demand learning experiences (Alias & Razak, 2023). However, while the benefits of microlearning are documented in fields such as language learning and corporate training, its role in developing digital competencies among IT students in higher education, particularly in the context of practicum preparation, remains underexplored.

2.1 Theoretical framework

This research draws on two complementary theoretical perspectives—Constructivist Learning Theory and the Technology Acceptance Model (TAM) to highlight how microlearning can support the development of digital competencies among students.

Constructivist Learning Theory underpins the understanding of how learners actively interpret and make sense of new information by engaging with their environment, peers, and learning materials. Rooted in the work of Piaget (1952) and Vygotsky (1978), constructivism suggests that learning is not merely a passive process of absorbing facts but involves actively constructing knowledge through meaningful experiences. In this context, microlearning emerges as a particularly suitable instructional approach. By delivering focused, contextually relevant learning segments, microlearning enables students to engage with content at their own pace, apply knowledge to real-world tasks, and reflect on their learning all essential elements of the constructivist process (Zawacki-Richter & Latchem, 2018). In this way, microlearning shifts learning from a one-way transmission of information to an interactive, student-centred experience.

Complementing this pedagogical perspective is the Technology Acceptance Model (TAM), initially proposed by Davis (1989), which provides insight into the factors affecting learners' willingness to engage with technology-driven interventions. According to TAM, individuals' acceptance and effective use of technology are primarily influenced by two perceptions: perceived usefulness (the extent to which the technology enhances learning or performance) and perceived ease of use (the degree to which the technology is accessible and user-friendly). Recent studies, such as Taylor and Hung (2022), reinforce TAM's importance in educational contexts, emphasising how microlearning's mobile delivery, accessibility, and alignment with real-world tasks foster positive attitudes towards technology. These positive perceptions are crucial in building students' confidence and motivation to work with digital tools, which is a vital element in developing digital competence.

Together, Constructivist Learning Theory and TAM provide a comprehensive perspective for understanding the potential of microlearning as a strategy to develop digital competencies. Constructivism explains how learners acquire knowledge through interactive, contextualised experiences, while TAM highlights the factors influencing learners' willingness to engage with technology. By integrating these frameworks, this study positions microlearning not only as a convenient delivery method but also as a theory-informed approach to supporting both the cognitive and affective dimensions of digital competency development.

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3. OBJECTIVES OF THE STUDY

Specifically, the study aimed to:

1. Design microlearning modules that strengthen BSIT practicum students' core digital skills in line with workplace needs.
2. Measure how microlearning shapes students' digital confidence and self-efficacy.
3. Evaluate its impact on practicum-related task performance in real ICT settings.
4. Capture students' perceptions to understand how design, access, and attitudes affect outcomes

4. METHODOLOGY

4.1 Research Design

This study employed a quasi-experimental, single-group pretest-posttest design combined with a mixed-methods approach. Specifically, a convergent parallel design was used, where quantitative and qualitative data were collected simultaneously and analyzed separately, with findings later triangulated. The microlearning intervention was conducted over an eight-week duration. The quantitative component assessed changes in digital competence, while the qualitative part examined students' perceptions and experiences. This design was selected to offer a comprehensive understanding of the microlearning intervention's effectiveness and relevance.

4.2 Participants

The participants included 78 fourth-year Bachelor of Science in Information Technology (BSIT) students enrolled in the practicum course at a state university in the Philippines during a recent academic term. Total enumeration was used in the quantitative phase to include the entire target population. For the qualitative phase, purposive sampling selected 10 students for a focus group discussion (FGD), ensuring diversity in practicum placements, gender, and digital proficiency levels to broaden the range of insights collected.

4.3 Intervention

The microlearning intervention consisted of a series of concise, targeted modules covering essential digital skills, including productivity tools (e.g., spreadsheets, word processing), basic cybersecurity, digital communication, and online collaboration platforms. The content was designed in accordance with microlearning principles, including chunked delivery, mobile accessibility, and self-paced learning. All modules were delivered through Google Classroom, supported by interactive content (e.g., videos, scenarios, quizzes) that encouraged autonomous engagement and reflective practice.

4.4 Instruments

Three instruments were used to collect data:

Digital Competency Self-Assessment Survey: This validated instrument, adapted from the European DigComp framework, evaluates students' self-perceived digital skills before and after intervention. The tool showed strong internal consistency (Cronbach's alpha = .89) and was pilot-tested for contextual relevance.

Task Performance Rubric: Created in collaboration with the Industrial Link Development Officer (ILDO), this rubric evaluated students' practical application of digital skills during practicum-related activities. Through calibration sessions and standardised criteria, inter-rater reliability was maintained.

Focus Group Discussion Guide: Educational technology experts designed and validated a semi-structured interview guide to gather qualitative insights on students' experiences, engagement, and perceived outcomes from the intervention.

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Data triangulation across these instruments enabled cross-verification of findings and enhanced the overall validity of the study results.

4.5 Ethical Considerations

Participation in the study was entirely voluntary, and informed consent was obtained from all students before data collection. Participants were informed of the study's purpose, procedures, and their right to withdraw at any time without facing any academic or personal consequences. Confidentiality and anonymity were maintained throughout the study by coding responses and securely storing all data. The researcher ensured that all processes adhered to ethical principles in educational research and respected the rights and welfare of the participants.

4.6 Data Analysis

A combination of quantitative and qualitative data analysis techniques was used to systematically explore the impact of microlearning on the development of digital competence among BSIT practicum students. This dual approach ensured that measurable outcomes and contextual student experiences were properly captured and analysed.

4.6.1 Quantitative Analysis

The quantitative data, obtained from the Digital Competency Self-Assessment Survey, were analysed using a paired-samples t-test. This statistical method is suitable for comparing two scores from the same group, specifically before and after an intervention (Field, 2018). The paired design was chosen to account for individual differences among participants and to evaluate changes in perceived digital competency over time.

Before conducting the t-test, the dataset was checked for adherence to key statistical assumptions. Normality was evaluated using skewness and kurtosis values, while data completeness and outliers were examined to ensure reliability. All analyses were carried out using IBM SPSS Statistics, and effect size calculations followed Cohen's (1988) guidelines to interpret the practical significance of any observed changes.

4.6.2 Qualitative Analysis

Qualitative data from focus group discussions and open-ended survey responses were analysed using thematic analysis, following the six-phase framework of Braun and Clarke (2006). These phases included: (1) familiarisation with the data, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) writing up the findings.

The analysis was conducted inductively, allowing patterns and themes to emerge naturally from the participants' responses. Data were first transcribed and reviewed multiple times to ensure accuracy and thoroughness. Codes were developed without a predefined framework and then organised into broader thematic categories reflecting students' shared experiences and insights related to the microlearning intervention. The process emphasised rigour through iterative coding, peer feedback, and alignment with research objectives.

This mixed-methods analytical approach allowed the researcher to establish links between numerical trends and narrative accounts, providing a more nuanced understanding of the educational value of the learning intervention.

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5. RESULTS

This study examined the effectiveness of microlearning in improving the digital skills of Bachelor of Science in Information Technology (BSIT) practicum students. Both quantitative and qualitative data were analysed to give a complete understanding of the intervention's impact.

5.1 Quantitative Results

A paired-samples t-test was conducted to compare students' self-perceived digital competency scores before and after the microlearning intervention. The descriptive statistics (Table 1) show an increase in mean competency scores from pretest ($M = 3.21$, $SD = 0.48$) to posttest ($M = 4.02$, $SD = 0.44$), indicating a positive change following the intervention.

The results of the t-test (Table 2) confirmed that this increase was statistically significant, $t(77) = 10.56$, $p < .001$. The calculated effect size, Cohen's $d = 1.19$, indicates a substantial practical effect, suggesting that the observed improvement is both statistically significant and meaningful in an educational context (Cohen, 1988).

These findings prove that microlearning substantially improved students' self-assessed digital competency.

Table 1 *Descriptive Statistics for Digital Competency Scores (N = 78)*

Measurement	Mean	Standard Deviation	Minimum	Maximum
Pretest	3.21	0.48	2.10	4.10
Posttest	4.02	0.44	3.20	4.90

Table 2 *Paired-Samples t-Test Results for Digital Competency Scores*

Comparison	Mean Difference	t-value	df	p-value	Effect Size (Cohen's d)
Posttest - Pretest	0.81	10.56	77	< .001**	1.19 (Large)

Note: $p < .001$ indicates statistical significance at the 0.05 level.

5.2 Qualitative Results

To supplement the statistical findings, qualitative data were gathered from open-ended survey responses and focus group discussions. A thematic analysis identified three recurring themes that encapsulated students' experiences with the microlearning modules.
Table 3 presents the key themes, brief descriptions and representative participant quotes.

Table 2 *Emergent Themes from Qualitative Analysis*

Theme	**Description**	**Representative Quote**
Accessibility and Flexibility	Students appreciated the ability to access learning content anytime, anywhere, often through mobile devices.	*"I liked that I could review lessons on my phone whenever I had free time."*
Relevance to Real-World Tasks	Students found the modules directly applicable to practicum requirements and future professional tasks.	*"The lessons helped me practice the digital skills I needed during my practicum."*
Increased Confidence and Motivation	The microlearning approach made students feel more confident and motivated to apply digital tools.	*"I feel readier to use digital tools now, and I am not as hesitant as before."*

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These qualitative insights reinforce the quantitative findings by highlighting that the microlearning intervention effectively develops digital competencies and boosts students' confidence, motivation, and perceived preparedness for practicum tasks.

The combined analysis shows that microlearning is an effective teaching strategy for improving digital skills among BSIT practicum students. The notable increase in self-perceived competency, along with positive qualitative feedback on accessibility, relevance, and confidence, endorses the value of microlearning as a scalable and student-centred method for developing competence within information technology education.

5.3 Qualitative Findings

The qualitative analysis of the focus group discussions identified three major themes that reflected students' perceptions and experiences with the microlearning modules.

First, Accessibility and Flexibility emerged as a key theme. Students consistently expressed their appreciation for being able to access the modules at any time and from any location, whether via smartphones, laptops, or other devices. This flexibility enabled them to engage with the content at their own pace, revisit lessons as needed, and integrate learning into their busy schedules. Many students shared that this feature significantly reduced stress, as they no longer felt pressured to absorb information within fixed class hours. The on-demand nature of the modules empowered them to take control of their learning process.

Second, Practical Relevance was recognised as a fundamental strength of the microlearning approach. Students found that the content was directly applicable to the tasks and expectations they encountered during practicum preparation. They appreciated that the lessons were not merely theoretical but focused on real-world digital tools, platforms, and problem-solving scenarios they were likely to face in professional ICT environments. This practical alignment made the learning experience more meaningful and reinforced the link between classroom instruction and workplace readiness.

Finally, motivation and confidence emerged as significant themes. Students explained how the short, focused format of the microlearning modules made complex topics seem more manageable and achievable. The bite-sized content helped them overcome feelings of intimidation often linked with mastering new digital tools. Consequently, many reported increased confidence in engaging with technology, experimenting with digital tasks, and applying their skills in academic and practical contexts. Some even shared that the microlearning experience rekindled their enthusiasm for learning and made them feel more prepared to meet the demands of their upcoming practicum.

Together, these themes demonstrate how microlearning supported students' development of digital skills and addressed key factors such as accessibility, real-world relevance, and learner confidence—elements vital for effective, student-centred ICT education.

6. DISCUSSION

This study investigated the effectiveness of microlearning in enhancing the digital competency of BSIT practicum students. When thoughtfully designed and incorporated into practicum preparation, the findings demonstrate that microlearning can significantly boost students’ self-perceived digital competencies and workplace readiness.

The quantitative results showed a statistically significant increase in digital competency scores following the microlearning intervention, with a large effect size ($d = 1.19$). This outcome aligns

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with previous research highlighting the potential of microlearning to foster digital skills development, especially in higher education contexts where students need flexible, targeted learning opportunities (Taylor & Hung, 2022; Zhang & West, 2020).

The practical significance of the observed improvement makes these findings particularly important. An increase of 0.81 points on a 5-point scale is more than a simple numerical change; it indicates a real shift in how students view their abilities to work with digital tools and tasks, which is crucial for success in academic and professional settings (Redecker, 2017).

The qualitative data further enhances our understanding of these outcomes. Students consistently emphasised the accessibility and flexibility of the microlearning modules, pointing out their ability to engage with content at their own pace, on their own devices, and in line with their individual learning needs. These observations confirm established research on how microlearning's bite-sized, mobile-friendly design suits the preferences of modern learners, who often balance academic, personal, and professional responsibilities (Hung, 2019).

Equally important is the reported relevance of the microlearning content to real-world practicum tasks. Students viewed the modules as directly applicable to the digital tools and skills needed during their practicum experiences. This finding aligns with the constructivist perspective (Piaget, 1972; Vygotsky, 1978), indicating that learning is most effective when it is contextualised, meaningful, and connected to real-world tasks.

Perhaps most encouraging was the rise in confidence and motivation among students. Confidence is a vital yet often overlooked aspect of developing digital competence, as self-efficacy affects students' willingness to engage with technology and apply their skills in unfamiliar situations (European Commission, 2022; Zhang & West, 2020). The qualitative data suggest that microlearning not only transfers knowledge but also fosters positive attitudes toward learning, reduces anxiety, and enhances readiness for real-world application.

From an information technology education angle, these findings have several implications. Firstly, they show that microlearning is more than just a technological trend; it is a viable teaching approach that can effectively support competency development in IT programmes. Secondly, the study underscores the importance of designing microlearning that is carefully curated to align with learning outcomes, industry expectations, and students' real-world tasks.

7. SUMMARY OF FINDINGS

This study examined the effectiveness of microlearning in enhancing digital competence among Bachelor of Science in Information Technology (BSIT) practicum students, employing a combination of quantitative and qualitative methods. Quantitative results showed a statistically significant increase in students' self-rated digital skills after the microlearning intervention. The posttest scores ($M = 4.02$, $SD = 0.44$) were significantly higher than the pretest scores ($M = 3.21$, $SD = 0.48$), with a large effect size (Cohen's $d = 1.19$), indicating a meaningful educational impact.

Qualitative analysis added depth to these findings by identifying three main themes from focus group discussions and open-ended survey responses: (1) Accessibility and Flexibility, (2) Relevance to Real-World Tasks, and (3) Increased Confidence and Motivation. These themes demonstrate how the microlearning modules improved students' digital skills and boosted their motivation, self-efficacy, and preparedness for workplace tasks.

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The results suggest that microlearning is a practical, student-centred method for developing vital digital skills among IT students preparing for practicum placements.

8. CONCLUSION

In an era where digital skills are crucial for academic and professional success, particularly in technology-driven fields, higher education institutions must adopt innovative, flexible methods to prepare students for the demands of the workplace. This study provides empirical evidence that microlearning, supported by AI and delivered in short, accessible segments, effectively enhances digital competence among BSIT practicum students.

The notable gain in students' self-perceived digital skills, along with positive learner experiences related to accessibility, real-world relevance, and increased confidence, positions microlearning as a practical, scalable solution for closing competency gaps in information technology education.

While the study shows promising results, it is essential to recognise its limitations. Although valuable, reliance on self-reported measures may not fully capture objective improvements in digital skills. Future research could include performance-based assessments or long-term tracking to examine the sustained impact of microlearning. Exploring the integration of microlearning across other disciplines and educational contexts would also further deepen our understanding of its potential.

In conclusion, this research affirms that microlearning is not just about shortening content; it is about designing purposeful, student-centred learning experiences that meet learners where they are and equip them with the skills, confidence, and flexibility needed in today's digital landscape.

A paired-samples t-test was conducted to evaluate the effect of microlearning on students' self-perceived digital competence. Descriptive statistics revealed an increase in mean competency scores from the pre-test ($M = 3.21$, $SD = 0.48$) to the post-test ($M = 4.02$, $SD = 0.44$). The results were statistically significant, $t(77) = 10.56$, $p < .001$, with a large effect size ($d = 1.19$), indicating a meaningful improvement in digital competence after the microlearning intervention. These findings align with existing research emphasising the positive impact of microlearning on skill development and learner confidence (Taylor & Hung, 2022; Zhang & West, 2020).

In addition to quantitative data, thematic analysis of qualitative responses from open-ended surveys and focus group discussions identified three recurring themes: (1) Accessibility and Flexibility, (2) Relevance to Real-World Tasks, and (3) Increased Confidence and Motivation. These themes align with prior studies suggesting that microlearning enhances learner autonomy, promotes relevance to authentic tasks, and fosters confidence in applying digital skills (Braun & Clarke, 2006).

9. RECOMMENDATIONS

Based on the findings of this study, several actionable recommendations are proposed to improve digital competency development among BSIT practicum students and guide wider practices within information technology education:

Institutionalise Microlearning in Practicum Preparation. Higher education institutions, especially those offering IT and technology-focused programmes, are encouraged to formally incorporate microlearning modules into practicum and internship preparation. The notable enhancement in students' digital competency observed in this study correlates with international research emphasising the effectiveness of microlearning for skill acquisition and workplace readiness (Taylor & Hung, 2022; Zhang & West, 2020).

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Design Context-Specific, Industry-Relevant Microlearning Content. To maximise impact, microlearning materials should be customised to suit real workplace tasks and up-to-date industry standards. Research highlights that microlearning is most successful when regarded as relevant and applicable to real-world contexts (Braun & Clarke, 2006; Martín-Gutiérrez et al., 2021).

Utilise Mobile and AI Technologies for Delivery. Institutions should capitalise on mobile learning platforms and AI-supported technologies to ensure accessibility and personalisation of microlearning experiences. These tools enhance convenience and foster learner autonomy, a critical factor for effective competency development in technology-driven fields (Bolliger & Martin, 2018; Zhang & Bonk, 2019).

Incorporate Digital Confidence-Building Activities. Given the observed increase in students' confidence and motivation, microlearning interventions should intentionally include elements that promote self-efficacy, such as interactive tasks, immediate feedback, and practice opportunities. Learner confidence has been shown to directly influence the successful application of digital skills (Taylor & Hung, 2022).

Conduct Longitudinal and Objective Competency Assessments. Future research should extend beyond self-reported measures to include objective assessments of digital skills and longitudinal tracking of competency retention. This approach would provide a more comprehensive understanding of the sustained impact of microlearning (Zhang & West, 2020).

10. CONSENT

The author(s) have gathered and kept the participants' written consent following international or university standards.

11. ETHICAL APPROVAL

The author of this article states that the materials and methods used in their work require approval from an ethical committee and/or specific legal permission.

12. DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The author acknowledges the use of generative AI tools to assist with the writing and editing of this manuscript. ChatGPT (GPT-4, via chat.openai.com) helped improve the language and structure of the Introduction and Related Work sections, while Grammarly was employed for grammar, spelling, and plagiarism checks. Quillbot (free version) paraphrased and summarised text for clearer understanding. These tools were solely used to enhance readability and were not involved in creating original content, analysing data, or drawing conclusions. The author carefully reviewed all outputs to ensure accuracy, originality, and ethical compliance.

13. AVAILABILITY OF DATA AND MATERIALS

The datasets utilised and/or analysed during the current study are available from the corresponding author upon reasonable request.

14. COMPETING INTERESTS

The author has declared that no competing interests exist.

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