Interdisciplinary Journal of Education and Humanities
ISSN: 2994-3183| Impact Factor : 6.09
Volume. 12, Number 2; April-June, 2025;
Published By: Scientific and Academic Development Institute (SADI)
8933 Willis Ave Los Angeles, California
https://sadijournals.org/index.php/ijeh |editorial@sadijournals.org

INTEGRATING DIGITAL LITERACY AND ADAPTIVE PEDAGOGIES IN PRE-SERVICE TEACHER EDUCATION: A MIXED-METHODS STUDY OF 21ST-CENTURY TEACHING COMPETENCIES

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Abstract: This mixed-methods study explores the integration of digital literacy and adaptive pedagogies in pre-service teacher education, addressing the gap between teacher preparation and modern classroom demands. Using a quasi-experimental design with 120 pre-service teachers, the study finds that an integrated curriculum significantly improves self-efficacy ($p=0.001$, $d=1.5$), digital literacy skills ($p=0.002$, $d=1.8$), and adaptive pedagogy competency ($p=0.001$, $d=1.6$). Data were gathered through validated Likert-scale questionnaires, competency assessments, semi-structured interviews, and a longitudinal attitude survey (reliability coefficient: 0.81). Analysis using descriptive statistics and ANCOVA reveals that while digital literacy training is included in most teacher education programs (85%), fewer emphasize adaptive pedagogy (70%) and practical classroom integration (65%), despite these being rated as highly effective by educators. The study highlights the need for teacher education programs to systematically incorporate technological and adaptive pedagogical frameworks. It emphasizes experiential learning opportunities as key to preparing future educators for diverse, technology-rich classrooms.

Keywords: Teacher Education, Technology Integration, Adaptive Pedagogies, Pre-service Teachers

Introduction

The educational landscape has transformed significantly due to technological advancements, evolving workforce demands, and shifting student demographics. Köstler and Wolff (2025) emphasize that teachers are central to fostering digital competencies, enabling students to thrive in 21st-century professional settings. Modern classrooms require digitally literate educators who can integrate technology, facilitate personalized learning, and enhance critical thinking and collaboration (Darling-Hammond & Hyler, 2020). To achieve this, teacher education must adopt a holistic approach that combines technological proficiency, social-emotional intelligence, and adaptive learning (Smith et al., 2022). This approach positions pre-service teacher training as a means to enhance self-efficacy, instructional effectiveness, and competency in technology-driven, diverse learning environments.

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Pre-service teacher education programs are expected to equip future educators with essential competencies. However, research indicates a gap between these expectations and actual training outcomes (Odoh & Okeofu, 2020; Chigbu & Azor, 2018). Challenges persist, including inadequate training in digital tools (Okeke, 2025), slow adaptation to evolving educational demands, reliance on traditional teaching methods (Foulger et al., 2017), and inconsistencies in the integration of technology and digital literacy throughout teacher training (Bos et al., 2016; Johnson et al., 2023).

Digital literacy is a fundamental skill in today's world, enabling individuals to access, evaluate, and effectively use digital technologies. It plays a crucial role in shaping students' learning experiences, fostering critical thinking, and preparing them for a technology-driven workforce (Chanda et al., 2024; Haleem et al., 2022; Vrana, 2016). Integrating digital literacy into curricula enhances students' research, communication, and problem-solving skills while promoting responsible technology use (Chanda et al., 2024). Teachers are central to this process, equipping students with the ability to analyze digital content, ensure cybersecurity awareness, and utilize digital resources effectively. Successful digital literacy development relies on strategic technology integration and application.

Technology integration is the continuous and seamless incorporation of digital tools into educational and organizational practices to enhance learning and promote innovative instruction (Chen & Liu, 2023). Mishra and Koehler (2022) emphasized that true integration goes beyond merely using technology; it requires embedding digital tools into instructional strategies to create meaningful learning experiences. In pre-service teacher education, this process equips future educators with the skills and mindset necessary to effectively incorporate digital tools into their adaptive pedagogies.

Adaptive pedagogies are flexible instructional strategies that personalize learning by adjusting to students' needs, technological capabilities, and diverse learning contexts (Rodriguez-Martinez et al., 2022). Plass and Kaplan (2021) highlight that these pedagogies operate at the intersection of cognitive science, educational psychology, and instructional design, creating dynamic learning environments that respond to learners' cognitive abilities, motivation, and prior knowledge. In pre-service teacher education, adaptive pedagogies systematically modify teaching and learning approaches based on assessment data, ensuring measurable and consistent implementation for effective instructional outcomes.

Pre-service teachers are students in professional training programs, developing foundational teaching competencies and reflective practices to meet modern educational demands (Bond et al., 2018; Bahcivan et al., 2019). In the 21st century, they must be equipped to design and manage classrooms using smart technologies and innovative strategies (Maher, 2020; Polat, 2021). Positioned at the intersection of academic preparation and professional practice, they build both content knowledge and pedagogical skills (Grossman et al., 2022). While structured teacher education programs provide coursework, supervised field experiences, and student teaching opportunities (Darling-Hammond et al., 2020), empirical evidence highlights persistent inadequacies in their preparation. Pre-service teacher training in Enugu State, particularly in Nsukka LGA, lacks adequate exposure to digital skills and content necessary for effective 21st-century instructional delivery. Instead, training programs

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emphasize theoretical concepts and extensive literature, often without properly equipped personnel to facilitate digital competency development (Okeke, 2025; Onyebukwa-Nwanoro & Asogwa, 2023; Odoh & Okeofu, 2020; Chigbu & Azor, 2018).

Research shows that pre-service teacher training in Enugu State, particularly in Nsukka LGA, inadequately prepares trainees with essential digital skills for 21st-century instructional delivery. These programs prioritize theoretical discourse and dense literature over practical digital competency (Okeke, 2025; Onyebukwa-Nwanoro & Asogwa, 2023; Onwuzurike & Eze, 2022; Odoh & Okeofu, 2020; Chigbu & Azor, 2018). Even when digital training is included, instructors often lack the expertise to deliver effective instruction (Okeke, 2025; Onyebukwa-Nwanoro & Asogwa, 2023). Many pre-service teachers in Nsukka LGA struggle with basic ICT tools like Microsoft PowerPoint, Canva, and projectors, underscoring the urgent need for integrating digital literacy into teacher education to equip future educators for technology-driven learning environments.

This paper explores how restructuring pre-service teacher education can integrate digital literacy frameworks and adaptive pedagogical approaches to enhance teacher preparedness for 21st-century classrooms. By examining both the process and outcomes of an integrated training model, the study seeks to provide actionable insights for reforming pre-service teacher education and improving the effectiveness of preparation programs.

Statement of the Problem

Teaching in the 21st century extends beyond traditional methods, requiring educators to master digital tools and adaptive teaching strategies. Pre-service teacher education must equip future teachers with the skills to navigate technology-rich classrooms, fostering critical thinking and student-centered learning. Scholars advocate for a comprehensive approach that combines digital proficiency, emotional intelligence, and flexible learning models, enabling educators to integrate technology effectively, personalize instruction, and enhance student engagement. In Enugu State, particularly in Nsukka LGA, pre-service teacher education remains predominantly theoretical, leaving many future educators unprepared to use digital tools like Microsoft PowerPoint, Canva, and projectors. Limited hands-on training, slow adoption of modern teaching methods, and underprepared instructors further hinder digital competency development. This gap creates a disconnect between teacher training and the technological demands of contemporary classrooms.

Closing this gap is crucial, as many teacher training programs still struggle to integrate digital literacy and adaptive teaching effectively. To better equip future educators, pre-service teacher education must incorporate structured digital literacy training, hands-on technology experience, and modern instructional strategies. This study examines how these improvements can enhance teaching effectiveness and prepare new educators for the realities of today's classrooms.

Purpose of the Study

The general purpose of the study was to determine Integrating Digital Literacy and Adaptive Pedagogies in Pre-service Teacher Education: A Mixed-Methods Study of 21st-Century Teaching Competencies. Specifically, the study seeks to:

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Research Questions

The following research questions guided the study:

1. How does participation in an integrated digital literacy and adaptive pedagogy curriculum affect pre-service teachers' self-efficacy and competence in implementing 21st-century teaching approaches?
2. What components of teacher education programs most effectively prepare educators for the demands of technology-rich, diverse classroom environments?
3. How do pre-service teachers' beliefs about technology and pedagogy evolve through structured exposure to integrated teaching approaches?

Hypotheses

The following null hypotheses were tested at 0.05 level of significance:

1. Pre-service teachers who complete the integrated digital literacy and adaptive pedagogy curriculum will demonstrate significantly higher levels of self-efficacy in implementing technology-enhanced instruction compared to those in traditional preparation programs.
2. Pre-service teachers exposed to the integrated curriculum will show measurably improved ability to design learning experiences that foster critical thinking, collaboration, and problem-solving skills.
3. Structured opportunities for technology-pedagogy integration coupled with guided reflection will lead to more sophisticated beliefs about technology's role in education.

Methodology

The study employed a quasi-experimental design, comparing pre-service teachers in an integrated curriculum (experimental group: n = 60) with those in traditional programs (control group: n = 60). Both groups completed pre- and post-assessments on technological pedagogical content knowledge, self-efficacy, and beliefs about teaching with technology. The experimental group received training through a curriculum incorporating digital literacy frameworks and adaptive pedagogical approaches in coursework and field experiences. This design provided in-depth insights into the effectiveness of integrated teacher preparation methods.

The study population comprised 120 pre-service teachers from elementary and secondary education programs across three schools in Nsukka LGA, Enugu State. Participants, in their junior and senior years, were selected to assess their development through methods courses and student teaching. Stratified random sampling ensured balanced representation across subject areas (mathematics, science, language arts, and social studies) and grade levels (elementary, middle, and secondary). Within each school, participants were randomly assigned to control or experimental groups, ensuring demographic balance in age, gender, and prior technology experience.

The study utilized multiple data collection instruments, including a Likert-scale questionnaire measuring pre-service teachers' self-efficacy, digital literacy skills, and confidence in adaptive pedagogy. Pre- and post-training competency assessments evaluated their knowledge and skills before and after the integrated curriculum. Semi-structured interviews captured their experiences and perceived improvements in teaching competencies. Additionally, content analysis of teacher training curricula (CATTC) examined the inclusion of digital literacy

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and adaptive pedagogy. A survey for education administrators provided insights into curriculum effectiveness and areas for improvement.

A longitudinal attitude survey (LAS) was administered at multiple stages of training to track shifts in beliefs about technology and pedagogy. Sample items included statements such as "Technology enhances student engagement and should be central to modern teaching" and "I feel confident integrating technology into my lesson plans to support diverse learning needs." The questionnaire underwent face validation to ensure item appropriateness, and its reliability was confirmed using the Cronbach alpha method, yielding a reliability coefficient of 0.81. The researcher, assisted by two research assistants, administered and retrieved the questionnaires. Data analysis involved mean, standard deviation, and percentage calculations for research questions, while analysis of covariance (ANCOVA) was used to compare post-test scores between the experimental and control groups, adjusting for pre-test differences.

Result

Table 1: Impact of Integrated Digital Literacy and Adaptive Pedagogy on Self-Efficacy and Competency

Variable	Pre-Test Mean (SD)	Post-Test Mean (SD)	p-Value	Effect Size (Cohen's d)
Self-Efficacy	3.2 (0.8)	4.5 (0.6)	0.001	1.5
Digital Literacy	2.9 (0.7)	4.3 (0.5)	0.002	1.8
Adaptive Pedagogy	3.1 (0.9)	4.6 (0.4)	0.001	1.6

Table 1 analysis showed notable improvements across key competencies. Self-efficacy increased from a pre-test mean score of 3.2 (SD = 0.8) to a post-test mean of 4.5 (SD = 0.6). Digital literacy improved from 2.9 (SD = 0.7) to 4.3 (SD = 0.5), while adaptive pedagogy rose from 3.1 (SD = 0.9) to 4.6 (SD = 0.4). The results indicate a statistically significant enhancement ($p < 0.05$) in self-efficacy, digital literacy skills, and adaptive pedagogy competencies after training. These findings align with Smith et al. (2022), reinforcing the effectiveness of integrated pedagogical approaches in improving teacher preparedness.

Table 2: Key Components of Effective Teacher Education Programs

Component	% of Programs Including It	Effectiveness Rating (1-5)
Digital Literacy Training	85%	4.6
Adaptive Pedagogy	70%	4.4
Practical Classroom Integration	65%	4.8

The analysis reveals that while digital literacy training is widely included in teacher education programs (85% inclusion, 4.6 effectiveness rating), adaptive pedagogy (70%, 4.4 rating) and practical classroom integration (65%, 4.8 rating) receive comparatively less emphasis. These findings align with Cameron and Murphy (2023), underscoring the need for more experiential learning opportunities to enhance teacher preparedness.

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Table 3: Evolution of Pre-Service Teachers' Beliefs on Technology and Pedagogy

Time Point	Mean Attitude Score (SD)	% Agreement with Technology Enhances Learning
Pre-Training	3.1 (0.9)	58%
Mid-Training	3.9 (0.7)	78%
Post-Training	4.5 (0.5)	92%

The results demonstrate a positive shift in attitudes toward technology integration in teaching. Pre-training, the mean attitude score was 3.1, with 58% of participants acknowledging that technology enhances learning (SD = 0.9). By mid-training, this increased to a 3.9 mean score, with 78% support (SD = 0.7). Post-training, the mean attitude score rose to 4.5, with 92% recognizing the value of technology in education (SD = 0.5).

Discussion of the Findings

The results show a statistically significant improvement ($p < 0.05$) in self-efficacy, digital literacy skills, and adaptive pedagogy competence among pre-service teachers after training. Polt (2021) emphasized that while pre-service teachers are familiar with digital tools for personal use, this does not automatically translate into effective pedagogical application. This highlights the need for structured training to bridge the gap between personal technology use and instructional proficiency. Scholars have consistently argued that pedagogical digital competence requires explicit, structured learning beyond informal technology exposure (Okeke, 2025; Drossel et al., 2019; Tondeur et al., 2017). The findings further confirm that integrating digital literacy and adaptive pedagogies in teacher education enhances self-efficacy, competence, and teaching effectiveness, aligning with previous research advocating for technology-rich curricula (Tharp & Keller, 2023).

The data in Table 2 highlights key components of effective teacher education programs, revealing that while digital literacy training is commonly included, adaptive pedagogy and practical classroom integration receive less emphasis. This aligns with Cameron & Murphy (2023), who stress the need for experiential learning in teacher education. Schuster (2019) further notes that standalone digital skills courses often lack domain-specific application, limiting their impact on teaching effectiveness. Integrative approaches, which embed digital skills within subject-specific pedagogical frameworks, enhance both relevance and practical application. Additionally, programs that prioritize hands-on classroom integration yield better outcomes, underscoring the importance of practice-based learning.

The results in Table 3 reveal a progressive shift in pre-service teachers' beliefs about technology and pedagogy, indicating an increasing acceptance of technology integration in teaching. This aligns with Williams & Thompson (2021), who found that structured exposure to digital tools enhances teachers' perceptions of technology's educational value. Additionally, the findings suggest that prolonged, structured engagement with technology

positively influences pedagogical beliefs. This supports Khan et al. (2022), who emphasize the role of iterative learning experiences in shaping teaching philosophies and reinforcing the importance of technology in modern education.

Conclusion

This study underscores the critical need to integrate digital literacy and adaptive teaching strategies into pre-service teacher education. A curriculum that combines these elements enhances future educators' confidence, digital proficiency, and adaptability in the classroom. The findings reveal that hands-on experience with digital tools and teaching strategies shifts teachers' perspectives, fostering a more effective approach to technology integration in education.

Despite increased efforts to incorporate digital literacy in teacher training, gaps remain in practical application and adaptive pedagogy. Addressing these challenges requires structured, experiential learning opportunities that connect technology with real classroom scenarios.

To fully prepare future educators, training programs must extend beyond basic digital skills, encouraging meaningful application within subject areas and fostering teaching philosophies over time. By doing so, new teachers will enter the workforce equipped to navigate and succeed in today's technology-driven, diverse classrooms.

Recommendations

1. Teacher education institutions should revise curricula to incorporate digital literacy and adaptive pedagogical strategies.
2. Pre-service teachers should engage in more hands-on training, including simulations and real-world teaching scenarios.
3. Continuous learning opportunities should be provided for in-service teachers to reinforce and expand their competencies.

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