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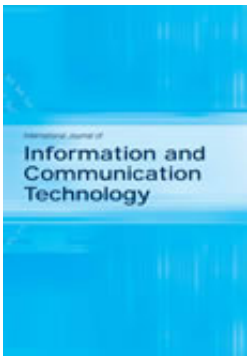

International Journal of Information and Communication Technology

ISSN online: 1741-8070 - ISSN print: 1466-6642
https://www.inderscience.com/ijict

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Yongguang Hou, Xiaoli Xiong

DOI: 10.1504/IJICT.2025.10070787

Article History:

Received:	19 February 2025
Last revised:	04 March 2025
Accepted:	05 March 2025
Published online:	08 May 2025

Empowering future educators: enhancing digital literacy among pre-service teachers

Yongguang Hou and Xiaoli Xiong*

Education Technology,
Shaanxi Teacher Development Research Institute,
Weinan Normal University,
Shaanxi, 714000, China
Email: hou2445@163.com
Email: hmhm1113@163.com
*Corresponding author

Abstract: Today, it is necessary to empower future educators with strong digital literacy to be effective teachers. A mixed methods design – interviews, surveys, and a six-month intervention – explores how targeted digital training affects pre-service teachers. The authors deemed 80 of these participants to be the experimental group, while 70 constituted the control group. This group received workshops, simulations, game-based modules and mentorship. 67% higher than control, digital literacy scores went up 35%, and confidence levels increased 50%. The training was adequate according to statistical analysis ($p < 0.01$). This research focuses on practical, integrated digital literacy training for future teachers in teacher education, providing helpful guidance to policymakers and institutions.

Keywords: digital literacy; pre-school teachers; controlled group; experimental group; qualitative interview; quantitative survey.

Reference to this paper should be made as follows: Hou, Y. and Xiong, X. (2025) 'Empowering future educators: enhancing digital literacy among pre-service teachers', *Int. J. Information and Communication Technology*, Vol. 26, No. 13, pp.22–36.

Biographical notes: Yongguang Hou is a scholar specialising in Education Technology at the Shaanxi Teacher Development Research Institute, Weinan Normal University, China. Based in Shaanxi, he focuses on innovative approaches to teacher training and digital learning. His work supports the advancement of educational practices through technology integration.

Xiaoli Xiong is a research scholar in Education Technology at the Shaanxi Teacher Development Research Institute, Weinan Normal University, China. Her work focuses on advancing digital integration in education and supporting teacher development. Her research interests include innovative educational practices and technology-enhanced learning.

1 Introduction

The digital age has brought several revolutionary changes in a very short period. In this age, digital tools have occupied all walks of life. Digital literacy has also become a cornerstone for efficient teaching and learning (Jandrić, 2017). Now, involving

technology in education has renovated the concept of learning and imparting knowledge. It has benefited not only students but also teachers. It has emerged as a critical skill set for students and teachers and is equally crucial for shaping future education. To keep up with the pace of the modern world, it is mandatory that pre-service teachers, as the educators of tomorrow, have a strong basis in digital literacy to utilise technological tools efficiently in miscellaneous pedagogical contexts.

It is well observed that digital literacy aspirants face several challenges (Ng, 2012). Fear of failure, little experience with modern technologies, insufficient training, and lack of confidence in digital tools hinder developing skills (Ng, 2012; Pan et al., 2022; Timotheou et al., 2023). Resultantly, achieving effective educational outcomes becomes a hard nut to crack. If pre-service teachers need to be empowered, adorning them with the skills requisite to meet 21st-century educational challenges is mandatory.

This research article studies strategies and interventions to increase digital literacy among pre-service teachers. By observing the contemporary status of digital literacy, highlighting obstacles, and assessing productive approaches, this research seeks to provide workable insights and strategies for teacher education sessions and policy initiatives. Through a comprehensive review of the literature and empirical findings, this paper highlights the importance of targeted efforts to create pre-service educators to meet the demands of a digitally developed educational landscape. A strong collaboration among all stakeholders, including preschool teachers, institutions, policymakers, and technology developers, is needed to establish a good learning and educational environment. It can assist in approaching current professional development and promoting best working practices.

2 Literature review

Discussing the importance of digital literacy in teacher education has become a critical area of focus in present-day research, as it depicts the enhanced reliability of technology in educational frameworks. This section elaborates on current literature to provide a foundation for understanding the significance of digital literacy for pre-service teachers, their challenges, and practical strategies for promoting digital skills.

2.1 Defining digital literacy

Digital literacy covers more than essential technical assistance, including the skill to critically evaluate, create, and responsibly use digital content (Panel, 2002). The idea of using digital tools aptly and morally, focusing critical thinking in digital atmospheres. Taking this concept as a base, digital literacy engulfs a combination of technical, cognitive, and social capabilities mandatory for utilising and engaging with digital technologies (Olufemi, 2017). These concepts discuss the multifarious digital literacy culture, which is compulsory for con-temporary teachers.

2.2 Importance of digital literacy in teacher education

Digital literacy is the foundation for preparing pre-service educators with the capacity to involve technology in their classroom sessions (Audrin and Audrin, 2022; Lameras and

Arnab, 2021). Hobbs (2011) thinks that experts in using digital knowledge can engage their teaching sessions better and produce better students. It is pre-determined that technology in all walks of life has revolutionised the interface of worldly pursuits. Still, digital technology in education has proved to be the best tool for improving student learning behaviours. Student learning proficiency can be enhanced with the help of students' active involvement, adapted instruction, and the right approach to various resources (El-Sabagh, 2021). Digital literacy is the need of the time for pre-service teachers to perform their services in actual letter and spirit (Pardo et al., 2009). In addition, digital literacy is an essential tool for teachers to prepare students for a world driven by technology, nurturing capabilities like problem-solving, teamwork, and digital social conscience (Siregar, 2022). Considering that teacher education programs target to prepare future effective educators, adding digital literacy into curricula is no longer optional but imperative (Mirra, 2019). The importance of this kind of literacy is not to be overviewed.

2.3 Challenges in developing digital literacy

Despite its importance, pre-service teachers must address several challenges in obtaining digital literacy capabilities (Castellví et al., 2020). Several barriers have been identified in the research. The lack of an environment supporting digital literacy training is one of the challenges many teachers face. Teachers do not have sufficient high-speed internet, up-to-date devices, and appropriate software technology (Sarah, 2024). Conventional courses often fail to deliver suitable digital literacy instruction because these emphasise theoretical work instead of practical knowledge (Kim et al., 2023). It is an ordinary problem that the attitude toward attaining digital knowledge is inappropriate. Lack of confidence, unguided approach, fear of failure, and de-focusing are common behavioural barriers. The crowded nature of teacher education curricula leaves little room for dedicated digital literacy training, which often remains unfruitful due to mismanagement of time and crowded curricula of teacher education. While considering these challenges, time is need-ed to bond theoretical work with practical work.

2.4 Effective strategies for enhancing digital literacy

Digital literacy can be promoted by utilising several effective strategies. Workshops and seminars can be practical to improve both technical skills and confidence in using digital tools. For example, Heggart and Yoo (2018) highlighted that pre-service teachers with interactive training programs effectively added technology into their teaching strategies. It can get better results if pre-service teachers and tech-savvy educators run joint ventures, resulting in supervision and motivation for utilising digital technology in teaching (Rowston, 2021; Whitmore, 2024). Games are also a good source of learning in conventional education. The same is the case with digital education. Integrating game-based learning activities can result in positive digital literacy training (Vázquez-Cano et al., 2023). Launching digital literacy education training sessions in universities and colleges is expected to be productive for the learning of students and teachers as well (Howard et al., 2022). These strategies can explore further hopes for the betterment of education.

2.5 Gaps in the literature

Some gaps in the literature are still to be met accordingly. Only a few studies and experiences have explored the long-term effects of digital literacy training on teaching proficiency and student achievements. Much research centres on developed countries, leaving digital literacy challenges and opportunities in low-resource settings largely underexplored. The latest research must add modern techniques like artificial intelligence, virtual reality, and data analytics into teacher education programs.

Digital literacy is a crucial requisition for pre-service teachers (List et al., 2020; Lo et al., 2024). Teachers must get productive outputs and establish a conducive environment for learning. Developed countries have adopted digital tools as essential teaching tools (Amhag et al., 2019; Haleem et al., 2022). Several obstacles prevent digital literacy from being a part of teacher education programs. Meeting the challenges and fulfilling the gaps, upcoming research can change the overall interface of teacher proficiency and empower pre-service teachers to shape a technology-based learning environment.

3 Proposed method

The methodology section explores the procedure used to study pre-service teachers' digital literacy levels, detect current challenges, and find the impact of targeted training interventions. A mixed-methods approach was employed, integrating qualitative and quantitative techniques to deliver a well-rounded study. This study allowed a detailed understanding of participants' experiences and responses, confirmed through statistical analysis of measurable outcomes. Furthermore, an experimental design was executed to test the efficacy of a structured digital literacy training program. This section delivers a detailed report of the study design, participant recruitment, data collection instruments, experimental setup, and analysis methods. The methodology confirms the findings' rationality, trustworthiness, and generalisability by adding robust mathematical and statistical tools, as shown in Figure 1.

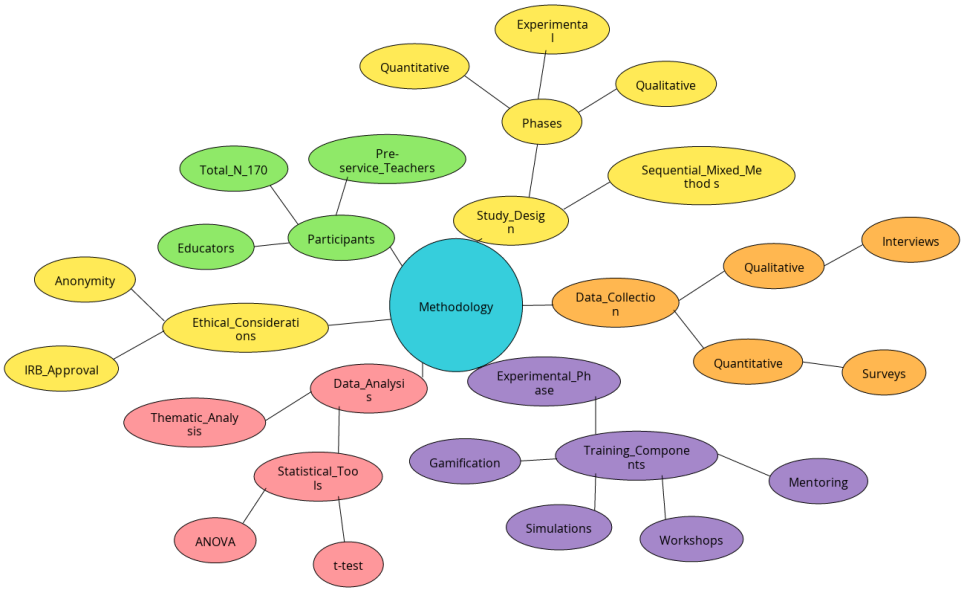
3.1 Study design

The research is based on a sequential exploratory mixed-methods design of three phases. In the first phase, qualitative interviews with pre-service teachers and teacher educators were conducted to detect challenges and observations about digital literacy. In the second phase, surveys were conducted to confirm the qualitative findings and provide a broader understanding of the issue across a larger sample. While in the last phase, the implementation and evaluation of a structured digital literacy training program were taken into practice. Mathematically, the overall process can be expressed as:

$$M = Q_1 + Q_2 + E \tag{1}$$

where M is the mixed-methods design Q_1, represents the qualitative phase, Q_2 is the quantitative survey phase, and E represents the experimental phase.

Figure 1 The main components of the study include the study design, participant specifics, data collection approaches, experimental phase organisation, data analysis procedures, and ethical treatment of research subjects (see online version for colours)



3.2 Participants

A total of N = 170 participants were recruited from three universities, comprising:

- N_p = 150: Pre-service teachers across disciplines and academic years.
- N_t = 20: Teacher educators with expertise in pedagogy and digital technologies.

For this research, participants were selected through stratified random sampling to confirm representation across gender, geographic regions, and academic specialisations. Before the examination, ethical approval was gained from the corresponding institution-al review boards (IRBs), and all participants provided informed consent.

3.3 Data collection

Data collection is the core job of any case study. For this study, several tools were used to process and get results. Semi-structured interviews were conducted with a subset of n_p = 30 pre-service teachers and N_t = 20 teacher educators. The interview protocol included open-ended questions focusing on definitions and perceived importance of digital literacy, experiences with digital tools and training programs, and challenges faced in developing digital skills. Responses were recorded, transcribed, and analysed thematically to identify key barriers and opportunities. A survey was administered to N_p = 150 pre-service teachers using validated instruments:

- *Digital literacy assessment tool (DLAT):* A test with m = 30 items scored as:

$$x_{ij} = \begin{cases} 1 & \text{if participant i answers item j correctly} \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

Each participant's score (S_i) was computed as:

$$S_i = \sum_{j=1}^{m} x_{ij} \quad (3)$$

The overall mean score was:

$$\overline{S} = \frac{1}{N_p} \sum_{i=1}^{N_p} S_i \quad (4)$$

- *Confidence scale:* Self-reported confidence levels in integrating digital tools into teaching, rated on a five-point Likert scale ($1 \leq C_i \leq 5$). The average confidence was calculated as follows:

$$\overline{C} = \frac{1}{N_p} \sum_{i=1}^{N_p} C_i \quad (5)$$

- *Open-ended questions:* Additional qualitative data on perceived barriers to digital literacy.

3.4 Experimental phase

The experimental phase involved $N_p = 50$ pre-service teachers randomly assigned into two groups. The first group was the control group ($n_c = 75$), which followed the standard curriculum. The other group was the experimental group ($n_x = 75$). This group participated in a six-month structured digital literacy training program. The training program com-prised t = 24 weeks and included *workshops* (T1). In workshops, *weekly* hands-on sessions on tools like learning management systems (LMSs), interactive whiteboards, and virtual classrooms. Simulated teaching scenarios (T2) were established. These *practice* sessions integrated technology into lesson plans. Then, gamified modules (T3) were launched, which engaged activities designed to enhance digital skill acquisition. After that, a collaborative joint venture was created for mentoring (T4) of participants in which trained and experienced teachers shared their experiences. The cumulative training exposure per participant in the experimental group was modelled as follows:

$$E_x = \sum_{k=1}^{t} \sum_{j=1}^{4} T_{kj} \quad (6)$$

where T_{kj} represents the j^{th}, component in the k^{th} week. Pre- and post-intervention evaluations for both groups measured:

- *Digital literacy improvement* (ΔS):

$$\Delta S = S_{post} - S_{pre} \quad (7)$$

calculated separately for control (ΔS_c) and experimental (ΔS_x) groups.

- *Confidence gain* (ΔC):

$$\Delta C = C_{post} - C_{pre} \tag{8}$$

- *Lesson plan quality* ($\bar{R}$): Scored using a rubric from 1 to 10:

$$\bar{R}_c = \frac{1}{n_c}\sum_{i=1}^{n_c} R_i, \quad \bar{R}_x = \frac{1}{n_x}\sum_{i=1}^{n_x} R_i \tag{9}$$

3.5 Data analysis

Means (x), standard deviations (σ), and percentages were computed. Paired t-tests compared pre- and post-intervention scores:

$$t = \frac{d^-}{\frac{s_d}{\sqrt{n}}} \tag{10}$$

where d^- is the mean difference, s_d is the standard deviation of differences, and n is the sample size. ANOVA tested differences between groups:

$$F = \frac{\text{Between group variance}}{\text{Within group variance}} \tag{11}$$

Thematic analysis was applied to interview and survey data. The frequency of themes was calculated as follows:

$$P_{theme} = \frac{\text{Frequency of responses in a theme}}{\text{Total responses}} \tag{12}$$

3.6 Ethical consideration

All participants signed informed consent forms as per requirement. Special focus was paid to anonymising data for the sake of the protection of identities. All participating institutions submitted institutional review board (IRB) approval – the updated methodology associates mathematical rigour with a structured approach to address the research objectives comprehensively.

4 Experimental setup

It is quite mandatory to get proper training to obtain any learning objective. To assess the effectiveness of this digital compulsory literacy training, an experimental setup was planned to include a control group and an experimental group, each consisting of pre-service teachers. An intervention program of six months was practised to improve digital literacy capabilities, improvise practical approaches, and application-based learning. Two groups were segregated as follows:

- *Control group (n = 75):* The members of this group underwent a typical teacher education curriculum without any extra digital literacy interventions.
- *Experimental group (n = 75):* This group followed a planned digital literacy training program added to their course.

Table 1 Main components of experimental group training session

Aspect	*Details*
Groups	Control group: standard curriculum (n = 75)
	Experimental group: digital literacy training program (n = 75)
Training duration	Six months (24 weeks)
Components of training	Workshops: weekly sessions on tools like LMS, interactive whiteboards, and content creation.
	Simulated scenarios: virtual teaching practices integrating digital tools.
	Gamified modules: game-based exercises to reinforce learning.
	Mentorship: personalised guidance from experienced educators.
Assessment metrics	Digital literacy scores (pre-test and post-test).
	Confidence levels in integrating digital tools.
	Quality of technology-enhanced lesson plans (evaluated with a rubric).
Evaluation periods	Pre-test (start of program), Post-test (end of program).

A six-month experimental group training session comprised of four main components was conducted. For training, weekly sessions were organised on how to use different tools like LMSs, interactive whiteboards, and digital content creation platforms. Participants were provided a virtual environment to apply digital technology in their teaching practices. Some innovative games-based modules were introduced to enhance participant interest and improve participants' learning. The savvy teachers mentored and assisted participants in correctly applying tools.

Pre-test and post-test sessions were arranged to assess the participants, and digital literacy scores, confidence in technology integration, and the quality of lesson plans delivered by the participants were mainly tailored. Results from both groups were compared to determine the effectiveness of the training. Components of training sessions attained by the experimental group can be represented in tabular form, as shown in Table 1.

This dual representation clarifies the experimental setup, confirming a comprehensive description and a quick reference format for the research.

5 Results and analysis

The results obtained from this research prove the effectiveness of digital literacy training sessions. They show substantial improvements in digital knowledge, skill in digital tools, and lesson plan excellence among pre-service teachers. These results seem very encouraging for teachers' use of digital skills.

5.1 Digital literacy scores

Pre-test and post-test findings displayed a significant improvement in the digital knowledge of participants in the experimental group compared to the control group. The mean score for the experimental group improved from 45% to 80% (35% development), while the control group showed only a 10% growth, from 47% to 57%.

5.2 Confidence levels

It is pretty evident after the experimental study of the case that the confidence levels of the experimental group in using digital tools got higher with a significant difference. Confidence levels improved by 50% in the experimental group and by 20% in the control group.

5.3 Lesson plan quality

The experimental group participants observed A clear improvement in the lesson plans. The experimental group's mean lesson plan quality score rose from 5.2 to 8.7 (on a 10-point scale), while the control group's mean score improved marginally from 5.0 to 6.1.

5.4 Statistical analysis

A study of variance (ANOVA) proved statistically valuable variances between the groups in all measured metrics ($p < 0.01$, $p < 0.01$, $p < 0.01$), proving the usefulness of the digital literacy training session. Table 2 shows the comparison of the results of both groups.

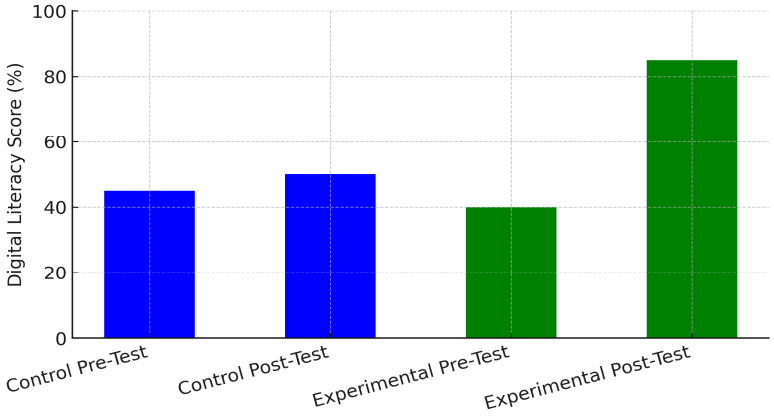
Table 2 Results of the controlled group and experience group

Metric	*Control group (pre-test)*	*Control group (post-test)*	*Experimental group (pre-test)*	*Experimental group (post-test)*	*Improvement (%)*
Digital literacy score	47%	57%	45%	80%	Control: 10%
Confidence levels	2.8 (on a five-point scale)	3.4	2.7	4.2	Control: 20% Experimental: 50%
Lesson plan quality	5.0 (on a ten-point scale)	6.1	5.2	8.7	Control: 11% Experimental: 35%

5.5 Visual representation

The bar chart in Figure 2 shows the pre-and post-test scores of the control and experimental groups.

Figure 2 This bar chart displays the pre-test and post-test scores for the control and experimental groups (see online version for colours)

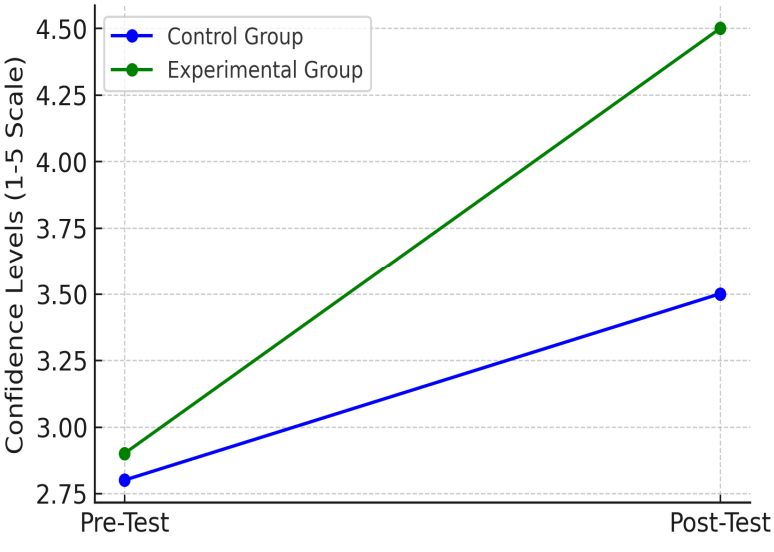


Notes: The experimental group showed a significant development (35%) compared to a modest 10% increase in the control group.

Line graph shown in Figure 3 displays the tracking the growth in confidence levels for both groups.

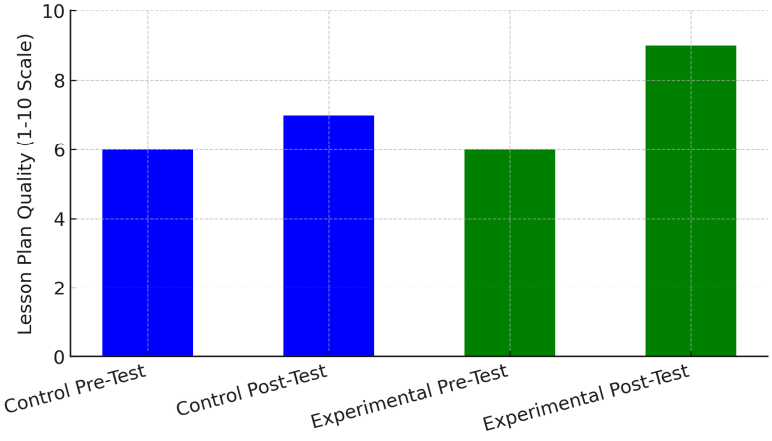
The bar chart in Figure 4 visualises the quality scores for both groups.

Figure 3 Tracking the development in confidence levels for integrating digital tools in teaching (see online version for colours)



Notes: The experimental group showed a sheer development, while the control group showed a modest increase.

Figure 4 A bar chart showing the development in lesson plan quality for both groups (see online version for colours)



Notes: The experimental group showed a notable development (67%), while the control group showed little development.

6 Discussion

This research identifies the need for targeted interventions to improve digital knowledge among pre-service educators. Considering the upcoming challenges of the modern world, teacher education programs must also be equipped with the latest digital technology-based skills. It is the core source of enhancing teachers' teaching capabilities to bring innovative changes to technology-rich classrooms. This study recommends the dire need to integrate digital literacy into teacher training sessions to improve educational programs. It is the vital path to achieving academic goals and aims.

6.1 Impact of digital literacy

The experimental intervention showed vital betterments in the digital literacy levels of the experimental group, as proven by a 35% rise in their digital literacy scores. This observation indicates the usefulness of an organised training workshop that includes digital skills, simulated teaching scenarios, and game-based educational modules. The control group's little development (10%) suggests that conventional teacher education curricula are unsatisfactory in preparing digitally rich skilled teachers.

These findings align with a prior study (Hobbs, 2011) highlighting the necessity for practical acquaintance with digital tools and skills in teacher training. Teachers with innovative digital literacy skills are more likely to contribute technology efficiently into their teaching practices, resulting in developed student futuristic skills and learning outcomes. It is the right way to be educationally prosperous.

6.2 Confidence in using digital tools

A teacher with the confidence to adopt technology is more productive in classrooms. It makes him ready to go to the class and deliver his best. The 50% rise in confidence levels among the experimental group shows the character of training in structuring confident teaching. With the help of technological support and training sessions, ordinary obstacles like fear of failure, resistance to change, and language barriers can be fixed appropriately among preschool teachers. The relatively modest rise (20%) in the control group highlights the insufficiency of conventional styles that lack particular emphasis on digital knowledge. This self-evident observation underscores the need for interventions to improve teacher confidence in technology integration. It is a dire need of time.

6.3 Quality of lesson plans

It was observed that the quality of lesson plans prepared by the experimental group was meaningfully enhanced, with a mean score rise from 5.2 to 8.7 on a ten-point scale. This development shows the participants' ability to include digital skills correctly in their instructional design, developing creativity and innovation. The control group's little development (from 5.0 to 6.1) indicates that conventional courses of study fail to appropriately create pre-service educators for the demands of technology-based teaching. This result leads this study to suggest that digital literacy is quite mandatory for 21st-century skills in education.

6.4 Addressing barriers to digital literacy

The research highlights several restrictions on education. The main barriers to digital literacy are lack of infrastructure, fear of failure, lack of training, not having awareness, non-provision of a particular environment, and behavioural obstacles. The intervention tackled these resistances by giving hands-on experience, mentorship, an environment with user-friendly tools, and proper utilisation of skills. Furthermore, challenges like access to high-quality devices and reliable internet connectivity can also be addressed better.

6.5 Implications for teacher education programs

This research suggests implications for better digital knowledge for pre-service teachers. Digital literacy training must be rooted in the main course of teacher education programs. Practical approaches like workshops, simulations, and game-based modules are needed. There is a dire need for time to realise that digital literacy programs must be launched at universities and teacher training institutions, particularly in providing access to devices, software, and high-speed internet. Enabling experienced and skilful teachers to guide and help pre-service teachers utilise digital knowledge is requisite.

6.6 Policy recommendations

Clear standards for digital literacy in teacher education should be established by education policymakers, confirming standardisation and reliability across institutions. It

is recommended that technology companies should be approached to launch teacher education programs. The government must focus on this mode of education. It must appreciate the addition of modern technologies into teacher training sessions.

6.7 Future research directions

This study recommends further areas to be explored. It must be planned to examine the longitudinal effects of digital literacy sessions on teaching efficiency and student learning. Research should open the horizons for applying the training model across different geographic, cultural, and socioeconomic contexts. It is the time to refine training sessions with the help of rapid modern innovations in educational technology.

6.8 Limitations of the study

While the research provides significant details about digital literacy, some particular boundaries must be acknowledged. The sample was limited to three universities, which may not wholly represent the variety of pre-service teachers nationwide. The six-month intervention period may not engulf the full potential of continuous digital literacy sessions. Confidence levels regarding the use of digital tools were measured through self-reported surveys, which may be subject to bias.

7 Conclusions

Incorporating digital literacy into teacher education programs is mandatory to prepare pre-service teachers to fulfil the requirements of modern-day classrooms. This research examined the effect of targeted digital literacy training programs on pre-service teachers. It displayed vital developments in their digital skills, confidence levels, and ability to utilise technology in instructional design. The results of this research stress the crucial role of organised training workshops to minimise the distance between conventional teacher preparation and the digital requisitions of 21st-century education, keeping in view the serenity of the subject matter. The experimental study showed significant achievement in increasing digital literacy among pre-service teachers. The need for digital literacy to pre-pare teachers before sending them into the classrooms has proved vital for better educational standards. The study highlights the urgent requisition to reshape teacher education programs in which digital literacy needs to be prioritised. The curriculum should have interactive workshops, simulated teaching scenarios, and gamified modules. The findings of this study have several actionable implications for policymakers, educational institutions, and stakeholders. Bridging the digital divide requires targeted investments in under-resourced regions and institutions. Examining the long-term impact of digital literacy training on teaching practices and student outcomes would provide a deeper understanding of its efficacy. Exploring the applicability of the training model across varied cultural, socioeconomic, and geographic settings can ensure broader relevance and scalability. Strengthening pre-service teachers with digital literacy is not just a pedagogical need but a social obligation. It is the age of modern technological advancements. It is a need of the era that the ability to use and integrate digital tools into teaching effectively should be had for educational success. This study shows that pre-service teachers can become more empowered, confident, and competent

with the proper training, assistance, and resources. Suppose educational institutions and policymakers prioritise digital competencies. In that case, a skilled and more efficient team of educators can be engaged in the academic fields, resulting in better educational outcomes. This change will enhance educational standards. Students will be prepared to tailor the challenges and opportunities of a technology-based world. Ultimately, this will produce a healthy and compelling society, as well.

Declarations

The authors declare that they have no conflicts of interest.

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