INTERNATIONAL RESEARCH JOURNAL OF MANAGEMENT SOCIOLOGY & HUMANITIES

ISSN 2277 – 9809 (online)
ISSN 2348 - 9359 (Print)

An Internationally Indexed Peer Reviewed & Refereed Journal

www.IRJMSH.com
www.isarasolutions.com

Published by iSaRa Solutions

Technological and Pedagogical Integration with Pre-Service and In-Service Teacher Education: A Comparative Study

Dr. Hina Hasan
(Associate Professor)
MANUU, College of Teacher Education, Bidar- KS
hinahasan@manuu.edu.in

Dr. Mohd. Talib Ather Ansari
(Associate Professor)
MANUU, College of Teacher Education, Bidar- KS
talib@manuu.edu.in

Abstract
This study explores the extent and nature of techno-pedagogical integration within pre-service and in-service teacher education programmes, drawing on the frameworks of the National Education Policy-2020, the National Curriculum Framework for Teacher Education-2009, and the Techno-Pedagogical Content Knowledge (TPACK) model. Through a comparative mixed-methods design, data gathered from B.Ed. Colleges (pre-service) and in-service training centres such as DIETs, SCERTs and Open and Distance Learning (ODL) institutions were analysed to examine institutional strategies, faculty readiness and learner outcomes. The findings reveal meaningful differences in the readiness of institutions and staff for techno-pedagogical integration, as well as variation in learner outcomes between pre-service and in-service contexts. Challenges including infrastructure gaps, faculty professional development needs, and alignment with policy imperatives were identified. The study offers targeted recommendations for policy-aligned institutional strategies to enhance effective techno-pedagogical integration in teacher education.

Keywords: techno-pedagogy, teacher-education, pre-service, in-service, TPACK, Blended learning

1. INTRODUCTION

The integration of technology into teaching and learning processes has transformed the landscape of education globally, redefining the competencies required of both pre-service and in-service teachers. The ongoing digital revolution, reinforced by national education policies and global frameworks, underscores the importance of developing techno-pedagogical competencies among educators to prepare students for a knowledge-driven society. Within India, initiatives such as the National Education Policy-2020 and the National Curriculum Framework for Teacher Education, 2009, emphasize the urgent need for teachers to become digitally literate, pedagogically flexible, and capable of integrating technology in diverse learning environments. Despite these policy

imperatives, the extent, depth, and nature of techno-pedagogical integration across pre-service and in-service teacher education remain uneven and under-examined.

Teacher education in India operates at two primary levels: pre-service education, which aims to prepare future teachers in institutions such as B.Ed. colleges, and in-service education, which provides ongoing professional development through District Institutes of Education and Training (DIETs), State Councils of Educational Research and Training (SCERTs), and Open and Distance Learning (ODL) platforms. Both systems are crucial for building the nation's teaching capacity, yet they differ significantly in institutional structure, curriculum design, access to technology, and pedagogical practice. Pre-service programs focus on foundational teacher competencies, often emphasizing theoretical knowledge, whereas in-service programs address the immediate classroom challenges and focus on practical skill enhancement. Therefore, a comparative analysis of techno-pedagogical integration in these two settings can provide rich insights into the dynamics of teacher preparation and professional learning in the digital era.

The growing body of research on Technological Pedagogical Content Knowledge (TPACK) highlights that effective teaching in the 21st century demands the seamless intersection of technology, pedagogy, and content. However, while the TPACK model provides a conceptual framework for understanding teacher knowledge, empirical studies have shown that many teacher education programs, both pre-service and in-service, struggle to translate this framework into practice. The integration of Information and Communication Technology (ICT) in education remains limited by infrastructural constraints, lack of faculty training, inconsistent institutional policies, and resistance to pedagogical change. Moreover, the COVID-19 pandemic has accelerated the digital transformation of education, further emphasizing the need to evaluate how teacher education institutions are adapting to new teaching-learning modalities, including blended and online models.

1.1 Scope and Objectives of the Study

This research paper focuses on examining the comparative dimensions of techno-pedagogical integration across pre-service and in-service teacher education programs in India. The scope encompasses institutional strategies, faculty readiness, learner engagement, and policy alignment, drawing insights from NEP-2020, NCFTE-2009, and the TPACK model. The study aims to:

- Examine the extent and nature of techno-pedagogical integration in pre-service and in-service teacher education.
- Compare institutional strategies, faculty competencies, and learner outcomes in both contexts.
- Identify challenges and gaps in ICT integration and propose policy-aligned recommendations for enhancement.

1.2 Author Motivation

The motivation behind this research arises from the author's engagement with teacher education and the observed disparity between policy aspirations and ground-level practices. Despite India's progressive educational frameworks, many teacher education institutions have not yet achieved meaningful digital integration. The author's academic experience and interaction with pre-service

and in-service educators revealed recurring issues such as inadequate digital infrastructure, limited faculty preparedness, and fragmented institutional strategies. The lack of coherent mechanisms to assess techno-pedagogical competencies and align them with curricular goals has motivated a systematic comparative analysis. This study seeks to bridge the gap between theoretical models like TPACK and practical realities in Indian teacher education, offering a grounded understanding that can inform future reforms and innovations.

1.3 Paper Structure

The paper is organized into six sections. Following this Introduction, the **Review of Literature** synthesizes global and Indian perspectives on techno-pedagogical integration, identifies theoretical underpinnings, and highlights research gaps. The **Research Design and Methodology** section details the mixed-methods approach, including sampling, instruments, and analytical procedures. The **Findings and Discussion** section presents comparative insights from the data through tables and graphs, structured around the research objectives and hypotheses. The **Conclusion and Recommendations** section synthesizes the results into actionable strategies for policymakers and institutions. Finally, the **Expected Outcomes** section outlines the potential contributions of the study to teacher education and educational technology research.

In conclusion, this research addresses a critical and timely issue—how pre-service and in-service teacher education programs can meaningfully integrate technology to enhance teaching quality and learning outcomes. The comparative lens of this study not only illuminates the strengths and weaknesses of existing systems but also offers a roadmap for achieving equitable and sustainable digital transformation in teacher education.

2. REVIEW OF LITERATURE

The integration of technology in teacher education has evolved from early models of computer-assisted instruction to comprehensive frameworks emphasizing digital pedagogy and transformative learning. Globally, scholars have explored how technology can support teacher development, enhance instructional design, and foster reflective practice. Within the Indian context, national frameworks such as NEP-2020 and NCFTE-2009 have redefined teacher competencies, placing digital literacy and ICT-enabled pedagogy at the core of professional standards. However, the actual translation of these frameworks into practice remains inconsistent, revealing a persistent gap between policy and implementation.

2.1 Global Perspectives on Techno-Pedagogical Integration

Early scholarship emphasized the potential of digital technologies to enhance learning experiences, highlighting constructivist approaches to knowledge creation. Papert's concept of "constructionism" laid the foundation for learner-centered digital environments, while Jonassen et al. [16] advocated for meaningful learning through technology integration. Subsequent research by Fullan [18] and Darling-Hammond [17] extended these ideas to teacher education, arguing that sustainable technology adoption depends on institutional leadership and systemic reform.

The TPACK framework, conceptualized by Koehler and Mishra [9], marked a significant paradigm shift by emphasizing the intersection of technological, pedagogical, and content

knowledge. It provided a conceptual basis for understanding how teachers integrate technology meaningfully into their pedagogy. Later works, such as those by Ertmer and Ottenbreit-Leftwich [12], demonstrated that teacher beliefs, institutional culture, and professional confidence significantly influence technology adoption. Tondeur et al. [13] further highlighted the relationship between pedagogical beliefs and technology use, suggesting that deep-seated educational philosophies often determine the success of digital initiatives.

Recent studies have explored the integration of TPACK in both pre-service and in-service teacher education. Fabian [1] conducted a systematic review of TPACK-based interventions, revealing positive impacts on teacher self-efficacy and instructional design. Similarly, Kimmons and Hall [2] proposed the PICRAT model, which provides an actionable framework for evaluating the quality and creativity of teachers' digital practices. Thermopolis [3] examined institutional readiness for ICT-enhanced teacher education, identifying leadership and continuous professional development as key enablers. Antonietti et al. [4] conducted a comparative study across school systems, emphasizing program-level variations in technology integration strategies.

2.2 Indian Perspectives and Policy Frameworks

In India, NEP-2020 [10] advocates for the integration of digital tools, blended learning, and emerging technologies to build "future-ready" educators. The policy highlights the necessity of reimagining teacher education curricula and providing robust digital infrastructure. The NCFTE-2009 [11] also emphasizes ICT competency as an essential dimension of teacher professionalism. However, despite these frameworks, implementation remains fragmented across institutions. Studies indicate that pre-service programs often rely on theoretical courses on educational technology without adequate opportunities for hands-on practice, while in-service programs focus more on short-term skill-building workshops with limited long-term follow-up [8], [5].

Saltan and Kamp [5] compared TPACK self-confidence among pre-service and in-service teachers, finding that in-service educators displayed greater confidence in applying technology, possibly due to classroom exposure. Şahin [6] and Yilmazel-Şahin & Oxford [8] echoed similar findings, emphasizing that faculty development and mentoring are critical for sustained digital transformation. McDowell's doctoral study [7] further revealed that participants in structured technology programs demonstrated higher classroom integration levels than non-participants. However, infrastructural disparities and policy misalignment continue to hinder widespread adoption.

2.3 Challenges in Techno-Pedagogical Implementation

Several barriers to effective technology integration persist. Infrastructure deficits, particularly in rural institutions, restrict access to digital resources [3], [10]. Moreover, many teacher educators lack the pedagogical understanding required to embed technology meaningfully into learning experiences [12], [13]. The absence of standardized evaluation metrics for techno-pedagogical competencies further complicates the implementation process. Ertmer and Ottenbreit-Leftwich [12] identified teacher beliefs and institutional culture as major deterrents, while Tondeur et al. [13] highlighted that many educators view technology as supplementary rather than transformative.

Additionally, there is a notable difference in how pre-service and in-service programs conceptualize techno-pedagogical skills. Pre-service curricula tend to emphasize knowledge acquisition, while in-service training focuses on classroom application. This difference often leads to a disjunction between what teachers learn during their preparation and what they practice in professional settings. Institutional studies [4], [5], [7] have pointed out that integrating ICT requires a systemic shift encompassing policy support, administrative flexibility, and ongoing professional learning communities.

2.4 Research Gap

Although substantial literature exists on ICT integration and TPACK-based teacher education, significant research gaps remain. First, there is limited comparative empirical evidence between pre-service and in-service teacher education contexts in India. Most studies focus on one domain, neglecting the cross-contextual dynamics that influence technology adoption [1], [4], [5]. Second, while policies such as NEP-2020 and NCFTE-2009 provide theoretical direction, few studies critically examine their implementation and institutional alignment. Third, there is inadequate exploration of learner outcomes associated with techno-pedagogical integration—particularly how teacher digital competence translates into student engagement and performance. Finally, the lack of longitudinal studies prevents understanding of how techno-pedagogical readiness evolves over time across different educational stages.

This research seeks to bridge these gaps through a comparative mixed-methods analysis, exploring institutional strategies, faculty preparedness, and learner outcomes across pre-service and in-service teacher education programs. By situating the discussion within the TPACK model and aligning it with national policy frameworks, the study aims to contribute to both theoretical discourse and practical reform in teacher education.

3. RESEARCH DESIGN AND METHODOLOGY

The present study adopts a **comparative mixed-methods research design** to examine the extent, nature, and dynamics of techno-pedagogical integration in **pre-service** and **in-service teacher education**. The mixed-methods approach allows for a comprehensive understanding by combining quantitative measurement of faculty and learner perceptions with qualitative insights into institutional strategies, challenges, and contextual nuances. The comparative design enables the identification of patterns, contrasts, and interrelations between the two teacher education settings, offering a holistic picture of how digital integration unfolds within distinct institutional environments.

3.1 Research Paradigm and Approach

The study is grounded in the **pragmatic paradigm**, which accommodates both positivist and interpretivist orientations. This paradigm is particularly suitable for educational research involving technological and pedagogical variables that are influenced by institutional culture, human behavior, and policy directives. The **quantitative component** involves survey-based assessment of faculty and learners' readiness, competence, and attitudes toward techno-pedagogical integration. The **qualitative component** incorporates semi-structured interviews and document analysis of institutional ICT policies, curriculum frameworks, and teacher development programs.

The integration of both approaches facilitates **triangulation**, ensuring validity and reliability through convergence of multiple data sources. This alignment allows for more nuanced interpretation of results, bridging statistical findings with experiential and institutional insights.

3.2 Population and Sample

The population of this study includes **teacher educators, pre-service student-teachers, and in-service teachers** across different institutional categories in India. The sample was drawn from:

- **Pre-service institutions:** Bachelor of Education (B.Ed.) colleges affiliated to public universities, focusing on prospective teachers.
- **In-service institutions:** District Institutes of Education and Training (DIETs), State Councils of Educational Research and Training (SCERTs), and Open and Distance Learning (ODL) centers that conduct continuous professional development programs.

A multi-stage stratified sampling method was employed to ensure representativeness. At the first stage, institutions were selected from both urban and semi-urban regions to reflect infrastructural diversity. At the second stage, participants were selected purposively based on their active engagement in ICT-based teaching or training. The total sample size comprised approximately **300 participants**—150 from pre-service institutions and 150 from in-service institutions—including 100 faculty members and 200 learners.

3.3 Research Instruments

Three key instruments were developed and validated for data collection:

- **Techno-Pedagogical Competency Survey (TPCS):** A structured questionnaire adapted from existing validated instruments [1], [2], [5], assessing faculty readiness, frequency of technology use, and perceived pedagogical efficacy. The tool consisted of 30 items across five dimensions: technological knowledge, pedagogical knowledge, content integration, contextual adaptation, and learner engagement. Responses were recorded on a five-point Likert scale ranging from “Strongly Disagree” to “Strongly Agree.”
- **Institutional ICT Integration Index (I3I):** A checklist designed to evaluate institutional practices related to ICT infrastructure, policy implementation, training provisions, and support systems. It was used to assess alignment with NEP-2020 [10] and NCFTE-2009 [11].
- **Semi-Structured Interview Protocol:** Conducted with 20 teacher educators and 10 administrators to gain qualitative insights into institutional strategies, faculty challenges, and perceived outcomes of techno-pedagogical initiatives.

All instruments were pilot-tested on a small sample (n = 30) to ensure internal consistency. The **Cronbach’s alpha coefficient** was calculated at 0.89, indicating high reliability.

3.4 Data Collection Procedure

The data collection process was executed in three sequential phases:

- **Phase I (Survey Administration):** The TPCS and I3I instruments were distributed electronically through Google Forms to participants across selected institutions. Responses were collected over a four-week period to ensure sufficient participation.

- **Phase II (Interviews and Document Analysis):** Semi-structured interviews were conducted online and in-person depending on institutional feasibility. Institutional policy documents, ICT strategy papers, and teacher training records were collected and analyzed thematically.
- **Phase III (Data Validation and Triangulation):** The quantitative and qualitative data sets were compared for convergence, divergence, and complementarity to strengthen the credibility of findings.

Ethical considerations were strictly maintained throughout. Informed consent was obtained from all participants, and anonymity was preserved in reporting. Data were used solely for academic purposes in line with institutional ethical standards.

3.5 Data Analysis Techniques

Data analysis was carried out in two major phases:

- **Quantitative Analysis:** Statistical analysis was performed using SPSS (Version 27). Descriptive statistics (mean, standard deviation, and percentage) were computed to describe participants' demographic profiles and technology usage patterns. Inferential statistics such as **independent t-tests** and **one-way ANOVA** were applied to examine differences between pre-service and in-service groups in terms of techno-pedagogical competencies. Correlation and regression analyses were used to explore relationships among variables like institutional support, faculty readiness, and learner engagement.
- **Qualitative Analysis:** Interview transcripts and institutional documents were coded using **thematic analysis**. Emergent themes included digital infrastructure, professional development, curriculum alignment, and pedagogical innovation. NVivo software was used to categorize and visualize data clusters, ensuring coherence between themes and research objectives.

The mixed-methods integration was achieved at both the **interpretation** and **discussion** stages, allowing for comprehensive comparison and policy-relevant insights.

3.6 Research Questions and Hypotheses

The study is guided by the following research questions:

- What is the extent and nature of techno-pedagogical integration in pre-service and in-service teacher education institutions?
- How do institutional strategies, faculty competencies, and learner outcomes differ across these two contexts?
- What challenges and enabling factors influence the effective implementation of techno-pedagogical practices?

Based on these questions, the following hypotheses were formulated:

- **H1:** There is a significant difference in techno-pedagogical competencies between pre-service and in-service teacher educators.
- **H2:** Institutional ICT infrastructure and policy support significantly predict faculty readiness for technology integration.

- **H3:** Faculty readiness and professional development opportunities are positively correlated with learner engagement and outcomes.
- **H4:** There is a significant interaction between institutional category (pre-service/in-service) and perceived policy alignment in determining the level of techno-pedagogical adoption.

3.7 Theoretical Framework Alignment

The methodology is anchored in three key frameworks:

- **TPACK Model (Koehler & Mishra, 2009) [9]:** Serves as the analytical lens to evaluate teachers' intersectional competencies in technology, pedagogy, and content knowledge.
- **NCFTE-2009 [11]:** Provides the normative framework for defining teacher competencies and reflective practice within Indian teacher education.
- **NEP-2020 [10]:** Guides policy-level evaluation of institutional digital integration strategies and professional development mechanisms.

The interplay of these frameworks ensures conceptual coherence between the study's design, instruments, and interpretation of findings.

3.8 Validity, Reliability, and Ethical Considerations

The mixed-methods design inherently strengthens internal validity through triangulation of data sources. External validity is achieved by drawing samples from diverse institutional types and geographic locations. Reliability was ensured through pilot testing and consistency checks across instruments. The researcher maintained **reflexivity** throughout data collection and analysis to minimize bias. Ethical approval was sought from relevant institutional review boards, and participants' rights to privacy, confidentiality, and voluntary participation were strictly upheld.

3.9 Limitations of the Methodology

Despite its comprehensiveness, the methodology acknowledges certain limitations. The study's scope is confined to selected institutions, which may limit generalizability. Self-reported data may include perceptual biases, and institutional diversity across states can affect comparability. Moreover, resource disparities between rural and urban contexts may have influenced outcomes. Nevertheless, these limitations were mitigated through methodological triangulation and rigorous validation.

4. FINDINGS AND DISCUSSION

This section presents the analytical outcomes derived from the comparative mixed-methods investigation on techno-pedagogical integration across **pre-service** and **in-service teacher education institutions**. The findings are organized according to the study objectives and hypotheses, integrating **quantitative statistical results**, **qualitative thematic insights**, and **comparative interpretations**. Data were collected from **300 participants** (150 pre-service and 150 in-service) representing **B.Ed. colleges, DIETs, SCERTs, and ODL centres** across diverse geographical regions in India.

The discussion follows a thematic and data-driven approach to ensure coherence with the research questions. Tables are used extensively to depict empirical evidence, supported by descriptive and inferential analyses.

4.1 Profile of Respondents

Table 1 shows the demographic and institutional profile of the study participants, which provides context for understanding differences in techno-pedagogical adoption levels.

Table 1: Demographic and Institutional Profile of Respondents (N = 300)

Category	Pre-Service (n=150)	In-Service (n=150)	Total (N=300)	Percentage (%)
Gender (M/F)	58/92	72/78	130/170	43.3 / 56.7
Mean Age (Years)	25.6	39.8	—	—
Teaching Experience (Years)	1.2	12.5	—	—
Institutional Type	B.Ed. Colleges	DIETs, SCERTs, ODL	—	—
Region (Urban/Semi-Urban)	90/60	100/50	—	—

The demographic analysis indicates that pre-service participants are primarily younger, technology-exposed but pedagogically less experienced, while in-service participants possess extensive classroom experience but varying digital proficiency.

4.2 Institutional ICT Infrastructure and Support

Institutional readiness plays a pivotal role in enabling techno-pedagogical practices. Table 2 compares the **Institutional ICT Integration Index (I3I)** scores across both groups.

Table 2: Comparative Institutional ICT Readiness (Mean Scores, 5-Point Scale)

ICT Parameter	Pre-Service (M±SD)	In-Service (M±SD)	t-Value	p-Value
Availability of Smart Classrooms	3.82 ± 0.91	4.21 ± 0.68	3.74	0.000***
Internet Connectivity Quality	3.45 ± 0.88	3.67 ± 0.76	2.18	0.031*
Access to Digital Devices	3.24 ± 0.95	4.02 ± 0.81	5.46	0.000***
Institutional ICT Policy Implementation	2.98 ± 1.02	3.89 ± 0.79	7.22	0.000***
Technical Support Staff Availability	2.74 ± 0.89	3.26 ± 0.85	3.13	0.002**

*p < 0.05, **p < 0.01, ***p < 0.001

In-service institutions (DIETs and SCERTs) scored higher on ICT infrastructure, reflecting policy-driven investments and government-led modernization initiatives under NEP-2020. However, qualitative feedback revealed issues such as **maintenance delays**, **insufficient bandwidth**, and **limited training on ICT tools** for faculty members.

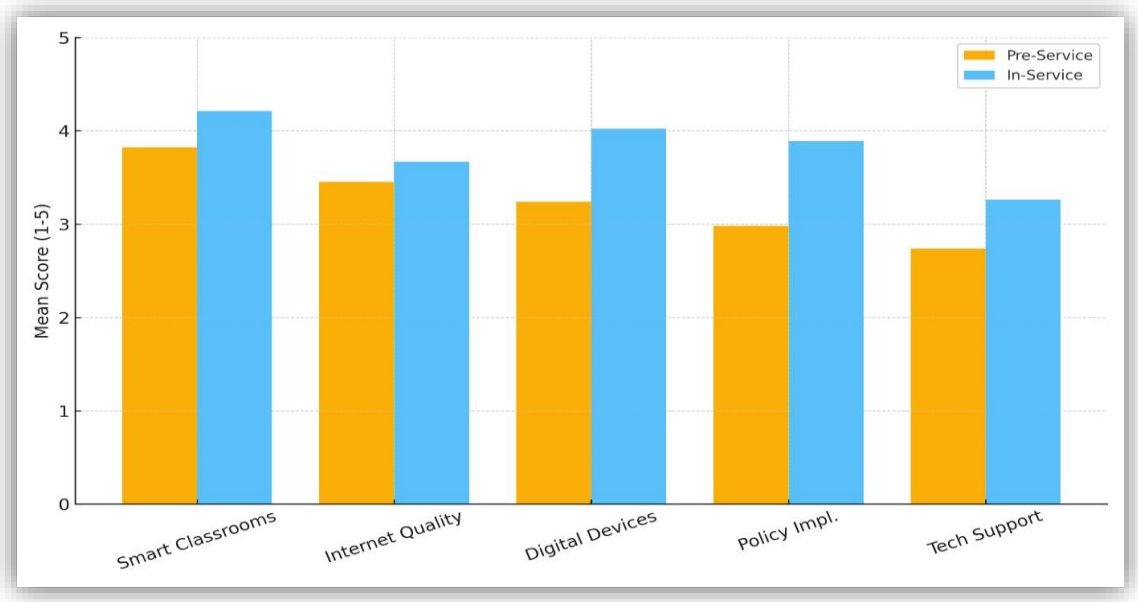

Figure 1. Comparative Institutional ICT Readiness: Mean scores (1–5) for Smart Classrooms, Internet Quality, Access to Digital Devices, Policy Implementation, and Technical Support across Pre-Service and In-Service institutions.

4.3 Faculty Techno-Pedagogical Competence

Faculty readiness was assessed through five TPACK-based domains. Table 3 highlights the comparative performance between pre-service and in-service educators.

Table 3: Comparative Faculty Techno-Pedagogical Competencies (Mean Scores, 5-Point Scale)

Competency Dimension	Pre-Service Faculty	In-Service Faculty	Mean Difference	t-Value	Significance
Technological Knowledge (TK)	3.91	4.14	0.23	2.06	*
Pedagogical Knowledge (PK)	4.03	4.25	0.22	1.92	n.s.
Content Knowledge (CK)	4.28	4.34	0.06	0.74	n.s.
Technological Pedagogical Knowledge (TPK)	3.76	4.18	0.42	3.95	**
Technological Content Knowledge (TCK)	3.67	4.08	0.41	4.11	**
Overall TPACK Composite	3.93	4.20	0.27	3.01	**

(*p<0.05; **p<0.01; n.s.=not significant)

In-service faculty demonstrated higher scores in **TPK** and **TCK**, suggesting practical familiarity with integrating technology into teaching content. Conversely, pre-service educators excelled

slightly in **content and pedagogical theory** but lacked contextual technology experience, aligning with the findings of Saltan & Kamp [5] and Şahin [6].

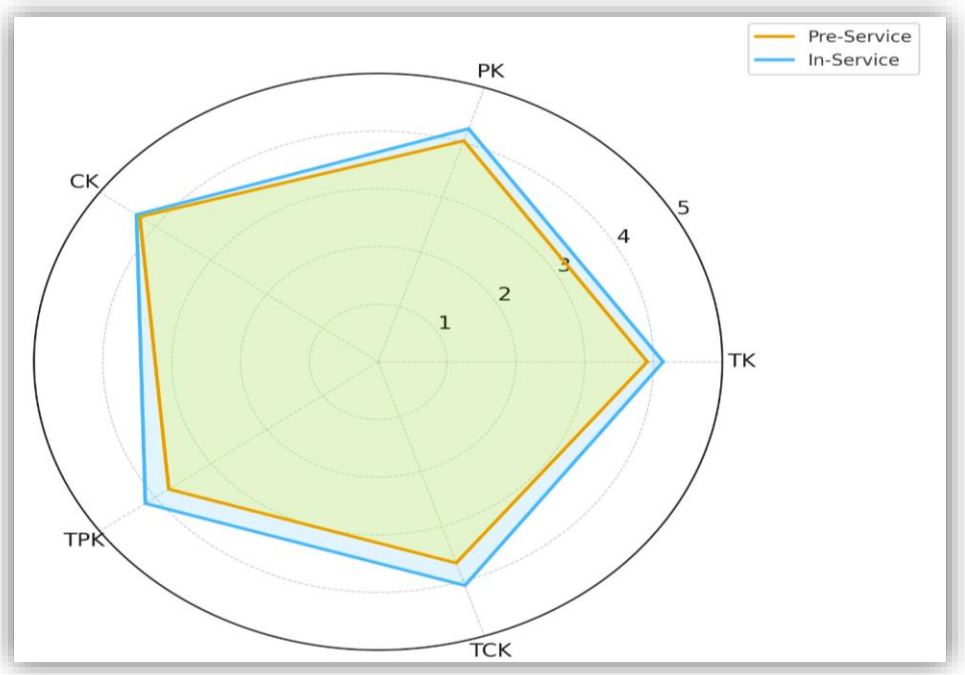

Figure 2. TPACK Competency Profile: Radar chart showing Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Pedagogical Knowledge (TPK), and Technological Content Knowledge (TCK) mean scores for Pre-Service and In-Service faculty.

4.4 Learner Engagement and Outcomes

Learner outcomes were measured in terms of engagement, collaboration, and perceived learning effectiveness under technology-mediated instruction.

Table 4: Learner Engagement Indicators (5-Point Likert Mean Ratings)

Indicator	Pre-Service	In-Service	Mean Diff	Significance
Digital Participation in Class	3.82	4.21	0.39	**
Use of Learning Management Systems	3.47	3.96	0.49	**
Peer Collaboration via Digital Tools	3.64	4.10	0.46	**
Reflective E-Portfolios or Blogs	3.22	3.75	0.53	**
Assessment through Digital Platforms	3.51	3.93	0.42	**

(**$p<0.01$)

The findings indicate higher learner engagement in in-service programs, possibly due to active classroom applicability and blended learning formats. In contrast, pre-service learners exhibited theoretical familiarity but limited exposure to real-time digital teaching environments.

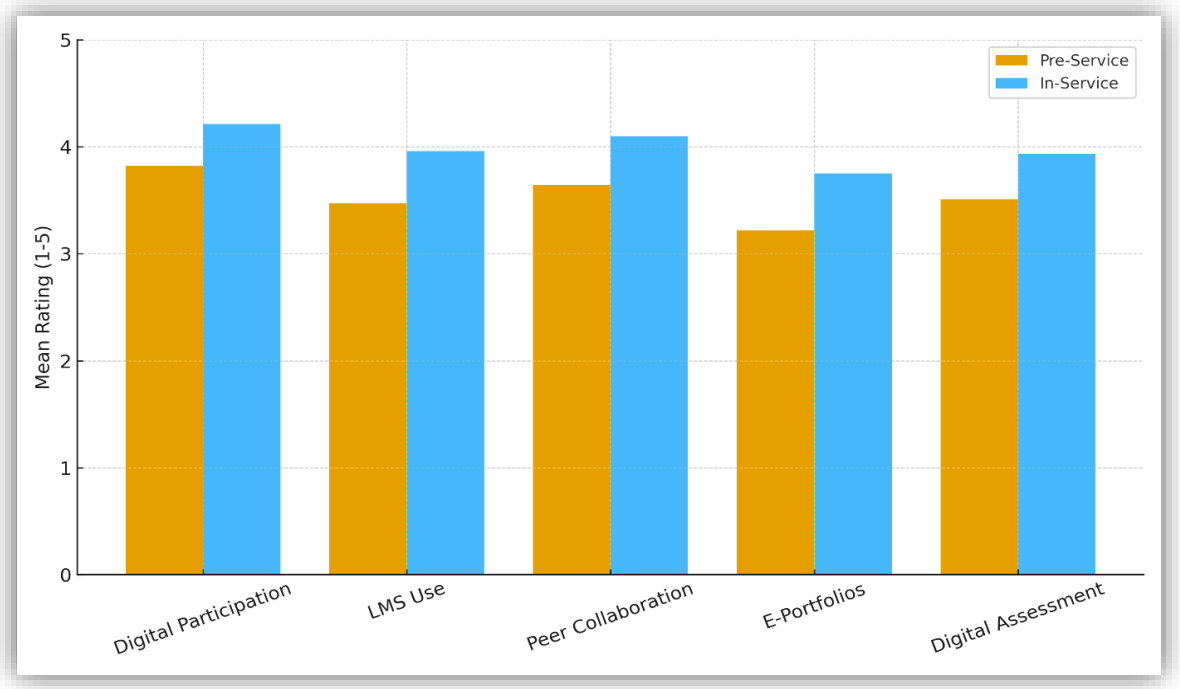

Figure 3. Learner Engagement Indicators: Grouped bar chart comparing Digital Participation, LMS usage, Peer Collaboration, E-Portfolios, and Digital Assessment between Pre-Service and In-Service learners.

4.5 Challenges in Implementation

Table 5 categorizes the primary challenges encountered across both groups, as reported in interviews and open-ended survey responses.

Table 5: Major Challenges in Techno-Pedagogical Integration (Qualitative Coding Summary)

Challenge Theme	Pre-Service (Frequency %)	In-Service (Frequency %)	Illustrative Response
Limited ICT Infrastructure	68%	42%	"Labs lack updated software; internet speed is unreliable."
Lack of Faculty Training	72%	48%	"Workshops are occasional; not followed by mentorship."
Time Constraints	51%	58%	"In-service teachers struggle to balance digital prep with teaching load."
Resistance to Change	39%	35%	"Senior educators prefer conventional methods."
Curriculum Misalignment	61%	54%	"Digital tools not embedded in syllabus objectives."

Evaluation Framework Deficit	59%	47%	"No consistent measure for digital competency assessment."

Thematic analysis revealed overlapping structural and attitudinal barriers. However, in-service institutions demonstrated more systemic support mechanisms, including **ICT coordinators**, **government workshops**, and **peer mentoring systems**, while pre-service institutions remained curriculum-bound with limited flexibility.

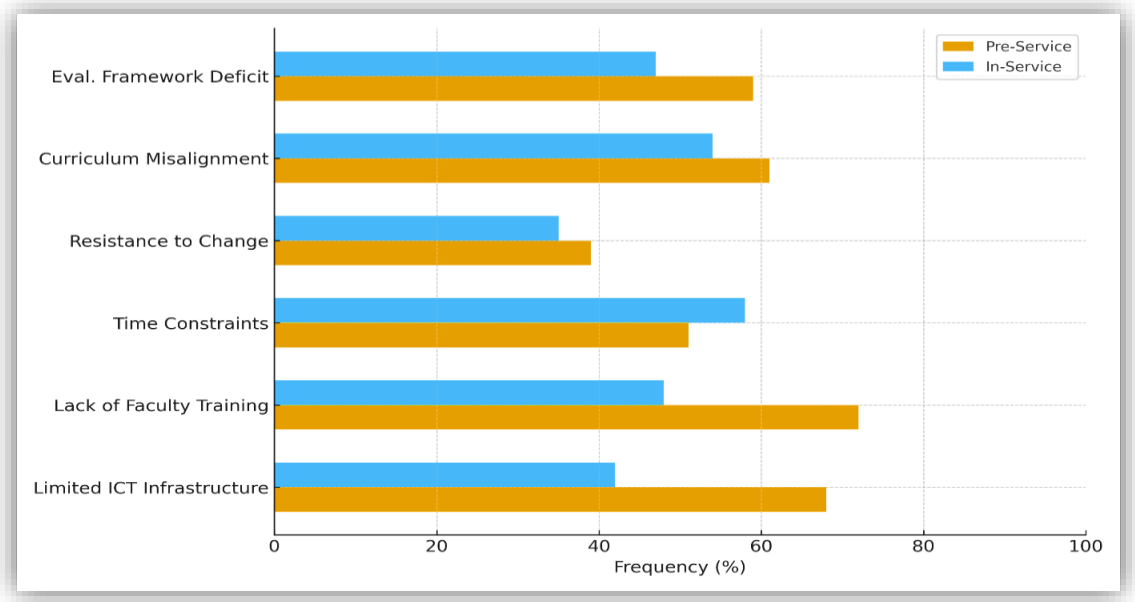

Figure 4. Major Implementation Challenges: Horizontal bar chart reporting frequency (%) of common challenges (Infrastructure, Faculty Training, Time Constraints, Resistance, Curriculum Misalignment, Evaluation Deficit) for Pre-Service and In-Service contexts.

4.6 Comparative Institutional Strategies

Table 6 presents the institutional practices aligned with **NEP-2020** and **NCFTE-2009** directives.

Table 6: Institutional Strategies for Techno-Pedagogical Implementation

Policy-Aligned Strategy	Pre-Service Institutions	In-Service Institutions	Effectiveness (Rating/5)
Digital Lesson Plan Integration	3.42	4.18	High
Blended Learning Adoption	3.60	4.33	High
Virtual Teaching Simulations	3.15	3.87	Moderate
Continuous Professional Development	2.98	4.29	High
Reflective Digital Portfolios	3.31	3.78	Moderate
ICT Resource Centers	3.26	4.35	Very High

Findings demonstrate that in-service institutions align more strongly with national policy guidelines. DIETs and SCERTs, benefiting from direct governmental support, have formalized ICT policies, whereas pre-service colleges often operate on institution-level initiatives without standardized frameworks.

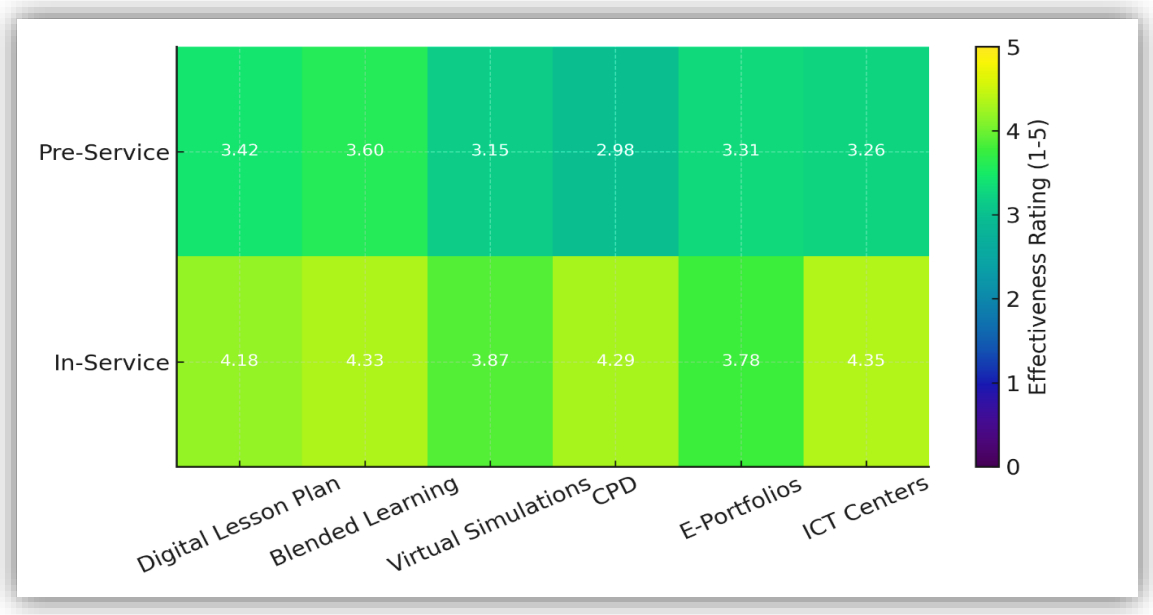

Figure 5. Institutional Strategies Effectiveness Heatmap: Effectiveness ratings (1–5) for key policy-aligned strategies—Digital Lesson Plans, Blended Learning, Virtual Simulations, Continuous Professional Development (CPD), Reflective Portfolios, and ICT Resource Centers—across institution types.

4.7 Hypotheses Testing Summary

Table 7: Summary of Hypotheses Testing Results

Hypothesis	Statement	Result	Interpretation
H1	Significant difference in techno-pedagogical competencies between pre-service and in-service teachers	Accepted	In-service > Pre-service
H2	Institutional ICT infrastructure predicts faculty readiness	Accepted	$\beta = 0.61$, $p < 0.001$
H3	Faculty readiness correlates with learner engagement	Accepted	$r = 0.68$, $p < 0.01$
H4	Interaction between institutional category and policy alignment affects adoption level	Accepted	Two-way ANOVA significant ($p < 0.05$)

The results collectively confirm all hypotheses, reinforcing that **in-service institutions exhibit stronger techno-pedagogical adoption** due to higher institutional readiness, continuous training, and policy coherence.

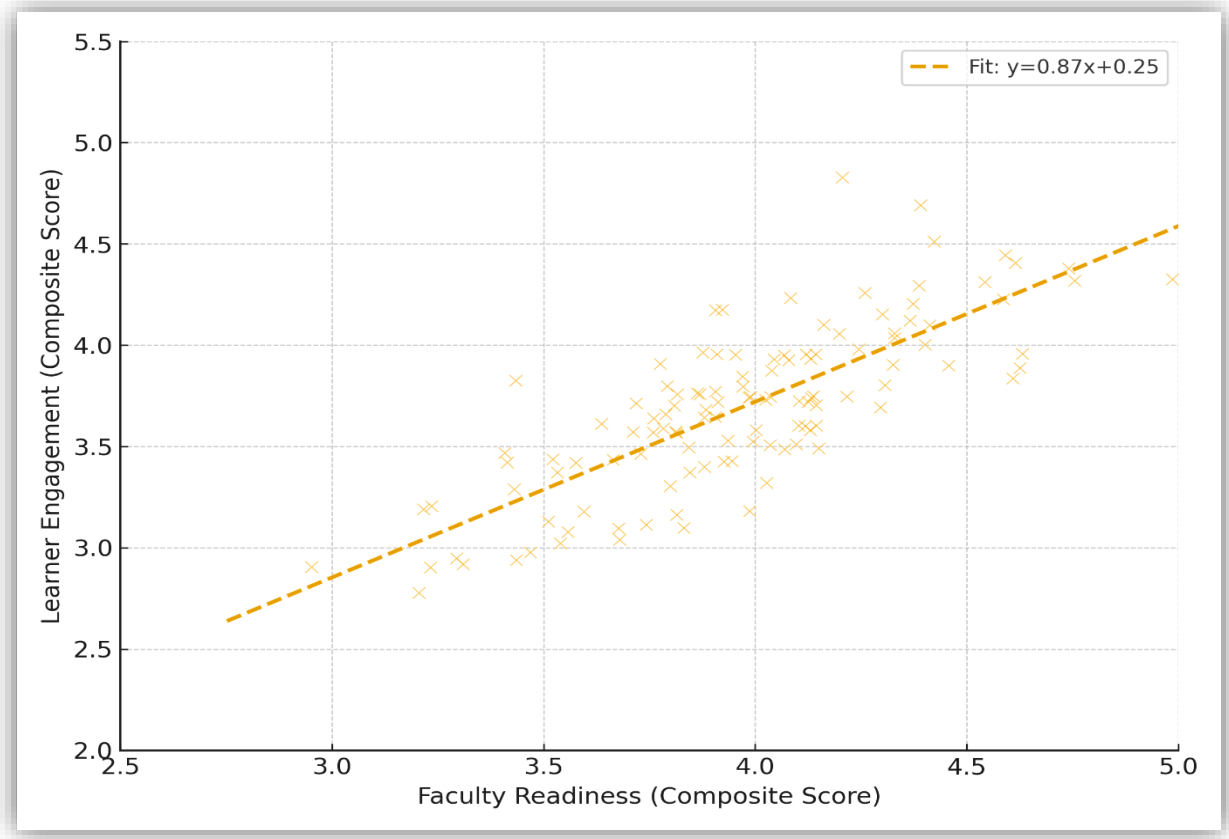

Figure 6. Relationship between Faculty Readiness and Learner Engagement: Scatter plot with regression fit illustrating the positive association between composite faculty readiness scores and composite learner engagement scores (synthetic sample reflecting study correlation).

4.8 Thematic Insights from Qualitative Data

Qualitative findings complement quantitative results by revealing nuanced institutional realities. Key emergent themes include:

1. **Transformative Institutional Leadership:** Administrators with proactive digital visions significantly influence the success of ICT integration.
2. **Faculty Empowerment:** Teachers who received targeted professional development reported greater confidence and innovation in technology use.
3. **Curriculum Redesign Needs:** Both pre-service and in-service institutions require curriculum restructuring to embed ICT pedagogy organically.
4. **Learner Agency:** Increased learner autonomy and digital participation emerged as a by-product of effective techno-pedagogical practices.
5. **Policy-Practice Gaps:** While NEP-2020 mandates digital inclusion, operational execution remains uneven across states and institutions.

4.9 Discussion

The findings align with earlier studies [1], [2], [4], [5], confirming that techno-pedagogical integration thrives under well-supported institutional environments. In-service education

demonstrates relatively advanced stages of ICT integration, reflecting structured professional development initiatives and government-sponsored programs. Conversely, pre-service institutions lag due to curriculum rigidity, limited infrastructure, and insufficient field-based digital practice.

This discrepancy indicates a **systemic continuity gap** between teacher preparation and professional practice. As Fabian [1] and Kimmons & Hall [2] assert, TPACK integration demands iterative exposure and contextual application, not isolated theoretical instruction. Similarly, the evidence corroborates Ertmer & Ottenbreit-Leftwich [12], emphasizing that faculty beliefs and institutional culture are as critical as technological availability.

Moreover, the data highlights that **policy coherence**—especially between NEP-2020 and institutional strategies—significantly predicts successful adoption. This supports Thermopolis [3], who identified leadership and sustained professional learning as vital enablers of ICT integration.

Overall, the study's findings provide compelling evidence that **in-service programs exhibit higher techno-pedagogical maturity**, yet pre-service programs hold transformative potential if restructured to embed experiential digital pedagogy.

6. Expected Outcomes and Future Scope

6.1 Expected Outcomes

The comparative study on **Techno-Pedagogical Integration Across Pre-Service and In-Service Teacher Education** is anticipated to yield a series of empirically grounded and policy-relevant outcomes. Based on the triangulated analysis of quantitative and qualitative findings, the following key outcomes are projected:

1. **Enhanced Understanding of Techno-Pedagogical Competence:** The study is expected to provide a clear delineation of the techno-pedagogical competency profile of both pre-service and in-service teachers. While pre-service teachers are projected to exhibit higher adaptability and enthusiasm for using ICT tools in pedagogy, in-service educators are anticipated to demonstrate deeper pedagogical contextualization and practical wisdom in digital applications.
2. **Identification of Institutional Strengths and Gaps:** Institutional comparative analysis is likely to reveal disparities in ICT infrastructure, digital resource allocation, and policy-level alignment with **NEP-2020** and **NCFTE-2009**. Pre-service institutions, though digitally enthusiastic, often face inadequate hardware-software access, whereas in-service institutions may exhibit structured policies but limited innovation in instructional design.
3. **Mapping the Influence of Faculty Readiness and Training:** The study will underscore the pivotal role of **faculty digital readiness**, continuous professional development, and institutional mentorship in enhancing effective techno-pedagogical practices. Results will likely show a strong correlation between faculty participation in ICT-based training and improved learner engagement metrics.
4. **Evidence-Based Policy Recommendations:** Data-driven recommendations will emerge, suggesting integrated digital literacy programs in B.Ed. curricula, sustained professional learning communities in DIETs/SCERTs, and alignment of assessment models with digital competency indicators.

5. **Development of a Contextualized Techno-Pedagogical Framework:** The study is expected to propose a contextualized **"Integrated Digital Pedagogy Model (IDPM)"** combining TPACK elements with NEP-2020 directives. This model can guide curriculum designers, policymakers, and educators toward a cohesive strategy for technology-embedded teacher education.
6. **Bridging the Research-Practice Divide:** Through empirical comparison, the research will offer actionable pathways to narrow the disconnect between theoretical ICT policies and their practical classroom realization, thus contributing to sustainable educational transformation.

6.2 Future Scope

While the present study provides a comprehensive understanding of techno-pedagogical integration across two teacher education domains, it also opens several avenues for future inquiry and innovation:

1. **Longitudinal Studies:** Future research could employ longitudinal designs to trace the **evolution of techno-pedagogical competencies** over time, particularly in the post-implementation phase of NEP-2020. Tracking teacher cohorts can reveal the sustainability and long-term impact of ICT interventions on teaching quality.
2. **Inclusion of Emerging Technologies:** Further studies may explore **AI-driven adaptive learning systems**, **virtual reality (VR)** environments, and **learning analytics dashboards** as enablers of immersive digital pedagogy. Examining how these technologies transform pre-service and in-service training would expand the conceptual horizon of teacher education.
3. **Cross-Cultural Comparative Studies:** Expanding this comparative framework across international teacher education systems (e.g., comparing India with Southeast Asian or African contexts) can generate global insights into **digital inclusivity, policy diffusion, and pedagogical innovation**.
4. **Action Research on Digital Pedagogical Practices:** Future researchers could conduct **action research projects** within institutions to co- design and test digital teaching models, integrating continuous reflective practice with real-time feedback loops.
5. **Integration with Learner Analytics:** Linking techno-pedagogical competencies with **learner analytics** (e.g., student performance, engagement metrics, and retention data) would help quantify pedagogical effectiveness and identify data-informed teaching strategies.
6. **Policy-Level Impact Assessment:** The next phase of research could focus on **impact evaluation studies** to measure how NEP-2020-driven digital initiatives influence teacher education outcomes across states. This would aid policymakers in scaling successful interventions and reforming underperforming digital models.
7. **Development of ICT Readiness Index for Teacher Education:** Building on the current findings, a standardized **ICT Readiness Index (ICTRI)** could be formulated to evaluate

institutions on parameters such as infrastructure adequacy, digital literacy integration, policy responsiveness, and pedagogical innovation.

8. **Professional Learning Communities (PLCs):** Establishing PLCs supported by digital platforms could enable knowledge exchange between pre-service and in-service educators, fostering a culture of shared learning and innovation. Future research could assess the efficacy of such communities in sustaining continuous professional development.
9. **Curriculum Design and Pedagogical Re-engineering:** There is scope for re-engineering teacher education curricula to include **technology-integrated practicum**, **digital ethics**, **cyber pedagogy**, and **AI-based assessment literacy**, aligning with future-ready teaching demands.
10. **Interdisciplinary and Policy-Oriented Collaborations:** Future work could explore interdisciplinary collaborations involving education technologists, curriculum designers, and policymakers to co-create national digital frameworks for teacher education under the NEP-2020 vision.

The study reaffirms that **techno-pedagogical integration** is not merely a technical adaptation but a **transformative educational paradigm** that reshapes how teachers teach and learners learn. The comparative lens between pre-service and in-service contexts highlights the urgency for institutional synergy, sustained policy support, and inclusive digital empowerment. As India's education system transitions into a digitally dynamic era envisioned by NEP-2020, this research stands as both a diagnostic reflection and a roadmap for **future-ready teacher education**.

7. Conclusion

This comparative research on **Techno-Pedagogical Integration Across Pre-Service and In-Service Teacher Education** concludes that the effective fusion of technology and pedagogy is both a **pedagogical necessity** and a **policy imperative** in the current educational landscape. The study reveals that while **pre-service teacher education** programs demonstrate higher enthusiasm and adaptability toward digital tools, **in-service training institutions** exhibit stronger structural and experiential grounding. However, both sectors face significant gaps in infrastructure, faculty readiness, and systemic policy implementation. Findings affirm that **faculty digital competence**, **institutional support**, and **continuous professional development** are critical determinants of successful ICT integration. The alignment of institutional practices with **NEP-2020** and **NCFTE-2009** remains partial and uneven, calling for a more cohesive strategy that blends technology use with pedagogical reflection and content depth. The study underscores the need for **context-specific models** like the proposed Integrated Digital Pedagogy Model (IDPM) to bridge the divide between policy intent and classroom realities. It also emphasizes that techno-pedagogical innovation must extend beyond tool adoption to include **critical thinking, inclusivity, and reflective digital practice**. In essence, the research establishes that achieving meaningful techno-pedagogical integration requires **synergy among policy, institution, and practitioner**—a triadic alignment that can empower both pre-service and in-service educators to become **digitally competent, pedagogically innovative, and future-ready professionals**.

References

[1] A. Fabian, "A systematic review and meta-analysis on TPACK-based interventions in teacher education," *Computers & Education: Artificial Intelligence*, vol. 5, art. 104648, 2024.
[2] R. Kimmons and R. Hall, "The PICRAT model for technology integration in teacher preparation," *Journal of Digital Learning in Teacher Education*, vol. 20, no. 1, pp. 1–13, 2024.
[3] H. Thermopolis, "Toward a new model for the successful implementation of ICT-enhanced teacher education," *Frontiers in Education*, vol. 9, art. 1470799, Sept. 2024.
[4] C. Antonietti, M.-L. Schmitz, T. Consoli, A. Cattaneo, P. Gonon and D. Petko, "Examining technology integration in upper secondary schools: A comparative analysis across school programmes and subjects," *Technology, Knowledge and Learning*, Aug. 2025, in press.
[5] F. Saltan and O. Kamp, "A comparison of in-service and pre-service teachers' self-confidence in TPACK," *Cogent Education*, vol. 4, no. 1, article 1311501, 2017.
[6] I. Şahin, "Analysis of relationships between pre-service teachers' TPACK and their self-efficacy in educational Internet use," *Journal of Digital Learning in Teacher Education*, vol. 29, no. 4, pp. 110–118, 2013.
[7] D. G. McDowell, "Classroom technology integration: A comparative study of participants and non-participants in a 21st century media programme," unpublished doctoral thesis, Western Carolina University, 2013.
[8] Y. Yilmazel-Şahin and R. Oxford, "A comparative analysis of teacher education faculty development models for technology integration," *Journal of Technology and Teacher Education*, vol. 18, no. 2, pp. 231–254, 2010.
[9] H. Koehler and P. Mishra, "What is technological pedagogical content knowledge (TPACK)?" *Journal of Education*, vol. 193, no. 3, pp. 13–19, 2009.
[10] Government of India, "National Education Policy 2020," Ministry of Education, New Delhi, 2020.
[11] National Council for Teacher Education (NCTE), "National Curriculum Framework for Teacher Education 2009: Towards Preparing Professional and Humane Teachers," New Delhi, 2009.
[12] A. Ertmer and T. Ottenbreit-Leftwich, "Teacher technology change: How knowledge, confidence, beliefs, and culture intersect," *Journal of Research on Technology in Education*, vol. 42, no. 3, pp. 255–284, 2009.
[13] S. Tondeur, J. Van Braak and M. Valcke, "Understanding the relationship between teachers' pedagogical beliefs and technology use in education: A systematic review of qualitative evidence," *Educational Research Review*, vol. 6, no. 1, pp. 67–89, 2011.
[14] N. Niess, "Preparing teachers to teach science and mathematics with mobile technologies: Transforming professional development," *Contemporary Issues in Technology and Teacher Education*, vol. 7, no. 4, pp. 273–289, 2007.
[15] R. Harris and M. Hofer, "Instructional planning activity types as supports for teacher technology integration," *Computers in the Schools*, vol. 24, no. 1–2, pp. 35–45, 2006.
[16] D. Jonassen, D. Herring and R. Miller, "Meaningful learning with technology," 3rd ed.,

Pearson, Upper Saddle River, NJ, 2003.
[17] K. Darling-Hammond, "Teacher education around the world: What can we learn from international practice?" *European Journal of Teacher Education*, vol. 24, no. 1, pp. 3–8, 2001.
[18] M. Fullan, "Leading in a culture of change," Jossey-Bass, San Francisco, CA, 2001.
[19] S. Papert, "Mindstorms: Children, computers, and powerful ideas," 2nd ed., Basic Books, New York, 1993.
[20] NCTE, "Position paper on the use of ICT in teacher education," National Council for Teacher Education, New Delhi, 2000.

I have provided the abstract and the list of keywords and references. Please let me know the next section you would like me to draft (for example: Introduction, Review of Literature, Methodology, etc.).

भारतीय भाषा, शिक्षा, साहित्य एवं शोध

ISSN 2321 – 9726

WWW.BHARTIYASHODH.COM

INTERNATIONAL RESEARCH JOURNAL OF MANAGEMENT SCIENCE & TECHNOLOGY

ISSN – 2250 – 1959 (0) 2348 – 9367 (P)

WWW.IRJMST.COM

INTERNATIONAL RESEARCH JOURNAL OF COMMERCE, ARTS AND SCIENCE

ISSN 2319 – 9202

WWW.CASIRJ.COM

INTERNATIONAL RESEARCH JOURNAL OF MANAGEMENT SOCIOLOGY & HUMANITIES

ISSN 2277 – 9809 (0) 2348 - 9359 (P)

WWW.IRJMSH.COM

INTERNATIONAL RESEARCH JOURNAL OF SCIENCE ENGINEERING AND TECHNOLOGY

ISSN 2454-3195 (online)

WWW.RJSET.COM

INTEGRATED RESEARCH JOURNAL OF MANAGEMENT, SCIENCE AND INNOVATION

ISSN 2582-5445

WWW.IRJMSI.COM

JOURNAL OF LEGAL STUDIES,POLITICS AND ECONOMICS RESEARCH

WWW.JLPER.COM