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Article

CAPACITY BUILDING FOR TEACHERS IN DEVELOPING COUNTRIES: A SYSTEMATIC REVIEW OF SUSTAINABLE ICT TRAINING FRAMEWORKS WITH A FOCUS ON BANGLADESH

Niger Sultana[1]; Sharmin Afroje[2]; Mohammad Shoriful Hossan Shohel[3];

[1] *MSC in Management Information System, Lamar University , TX, USA.*
MSC Educational leadership, University of Malaya, Kuala Lumpur, Malaysia.
Email: niger19nov@gmail.com

[2] *PGD in ICT*
Email: sharminafroje10@gmail.com

[3] *MSC in Industrial Engineering, College of Enginering, Lamat University, Beaumont, TX, USA*
Email: shoriful.hossan@gmail.com

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ABSTRACT

This study systematically reviewed sustainable frameworks for Information and Communication Technology (ICT) teacher training in developing countries, with a specific focus on Bangladesh and comparative international contexts. Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, a total of 133 articles published between 2005 and 2023 were identified, screened, and synthesized. The review aimed to critically examine the core components, implementation challenges, and sustainability strategies of ICT capacity-building initiatives for teachers. Significant findings highlight that pedagogically aligned curriculum design, experiential blended learning methodologies, continuous peer mentoring, and hands-on practice are central to effective and sustainable ICT integration in education. However, persistent infrastructural and connectivity gaps, particularly in rural and low-income areas, pose substantial barriers to program effectiveness. The analysis further emphasizes the importance of institutional leadership, policy alignment, and multi-stakeholder collaboration, involving Ministries of Education, donor agencies, and NGOs, in promoting program sustainability. Sustainability indicators such as ICT usage rates, teaching innovation, and student engagement were found to be critical for evaluating long-term impacts, while longitudinal evaluations and integration into local Education Management Information Systems (EMIS) were identified as underdeveloped yet essential mechanisms for continuous monitoring. The study also uncovered critical gaps in existing literature, including the underrepresentation of rural school contexts and the limited use of teacher-led, participatory model designs. The findings collectively suggest that sustainable ICT teacher capacity building requires a holistic approach that bridges technical skills development, pedagogical integration, institutional support structures, and ongoing evaluation within a context-sensitive framework.

KEYWORDS

ICT Training; Teacher Capacity Building; Sustainable Education; Developing Countriest; Educational Technology

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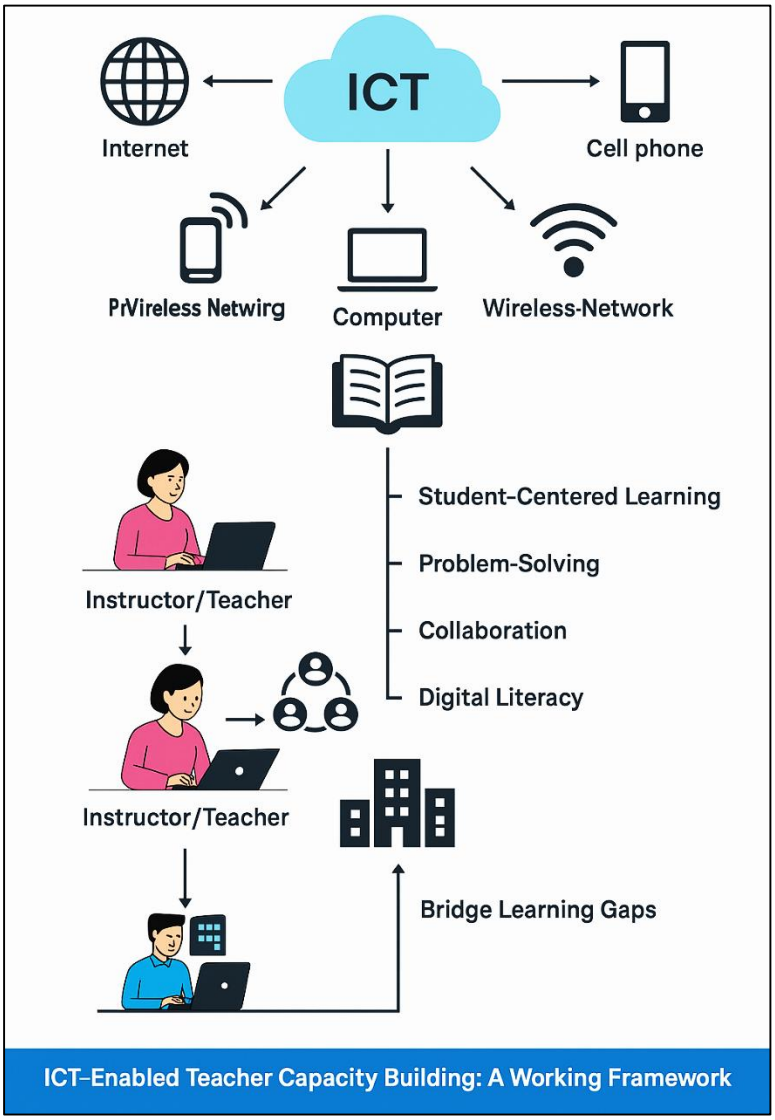
INTRODUCTION

Information and Communication Technology (ICT) broadly refers to technologies that provide access to information through telecommunications, encompassing the internet, wireless networks, cell phones, computers, and other communication mediums (Luu & Freeman, 2011). In the context of education, ICT includes a range of digital tools and resources used to communicate, create, disseminate, store, and manage information, thereby reshaping the way teachers and students interact with content and each other (Demetriadis et al., 2003). ICT integration in education supports student-centered learning and fosters critical skills such as problem-solving, collaboration, and digital literacy. The World Bank emphasizes that ICT-enhanced education can bridge gaps in learning opportunities, particularly in remote or underserved areas. Furthermore, Gao et al. (2009) argues that ICT can democratize access to knowledge and foster inclusive educational environments. These definitions set the foundation for understanding the critical role of ICT in teacher capacity building, particularly in developing countries where education systems often face challenges such as under-resourced schools, outdated teaching methods, and lack of professional development opportunities.

Figure 1: ICT–Enabled Teacher Capacity Building: A Working Framework for Inclusive and Digital Pedagogy



The international significance of ICT capacity building for teachers is increasingly evident through numerous global initiatives aimed at integrating technology into education systems. The United Nations' Sustainable Development Goal 4 (SDG 4) underscores the importance of inclusive and equitable quality education and lifelong learning opportunities for all, with ICT considered a key enabler. The World Economic Forum notes that digital skills are essential for 21st-century employment, positioning ICT education as critical for national development. Similarly, the Global Education Monitoring Report highlights that teacher training in ICT is a prerequisite for effective technology integration into classrooms. Hsu (2010) argue that without adequately trained teachers, investments in educational technologies yield limited returns. Numerous countries, such as Singapore, South Korea, and Estonia, have demonstrated that systematic teacher ICT training can lead to significant improvements in educational quality and digital economy readiness. These examples emphasize the importance of designing sustainable ICT training frameworks that go beyond one-off workshops to promote ongoing professional development, adaptability, and digital pedagogical skills (Buabeng-Andoh, 2012).

In developing countries, however, the adoption of sustainable ICT training frameworks for teachers faces a variety of challenges rooted in infrastructural limitations, policy fragmentation, and socio-economic disparities. According to Zhang (2003), many African, South Asian, and Latin American countries struggle with inadequate digital infrastructure, which hampers large-scale teacher training

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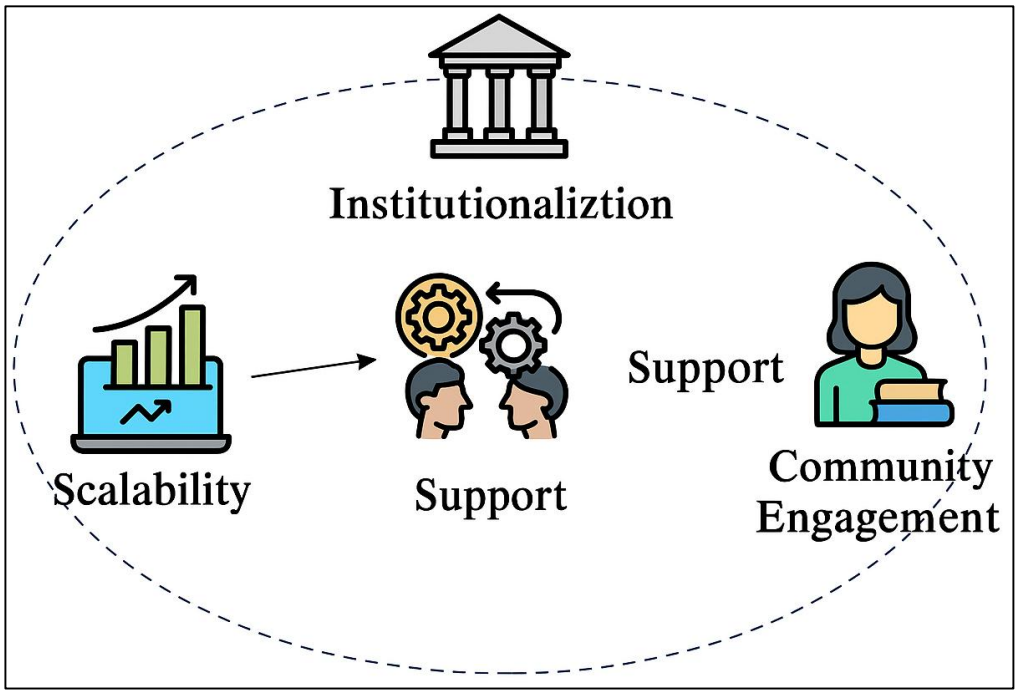
initiatives. In Bangladesh, issues such as unreliable electricity, poor internet connectivity, and limited access to digital devices compound these challenges (Talebian et al., 2014). Mehran and Nahid (2010) emphasizes that successful ICT training programs must be context-sensitive, taking into account local needs, available resources, and cultural factors. Research by Kozma and Wagner (2005) illustrates that one-size-fits-all models often fail in developing countries because they do not align with ground realities. Furthermore, Chai et al. (2011) argue that teacher attitudes toward ICT and prior experiences with technology critically influence the success of training programs. These challenges underline the necessity for sustainable frameworks that incorporate long-term support, practical skill-building, localized content, and continuous assessment mechanisms (Tondeur et al., 2008).

Figure 2: Sustainable ICT Teacher Training: A Scalable, Supportive, and Institutionalized Community Framework



The concept of sustainability in ICT teacher training frameworks encompasses various dimensions, including institutionalization, scalability, resource efficiency, and community ownership (Angeli & Valanides, 2005). According to Luu and Freeman (2011), sustainable training programs are those embedded within national educational strategies, supported by consistent funding, and adaptable to evolving technological landscapes. Furthermore, Demetriadis et al. (2003)suggest that sustainability requires the active involvement of local educators in program design and implementation to ensure relevance and ownership. Additionally, Gao et al. (2009) propose that sustainable ICT training must include mentoring systems, peer support networks, and communities of practice. Hsu (2010) further emphasizes the role of leadership development in sustaining ICT integration at the school level. Studies from India (Buabeng-Andoh, 2012), Zhang (2003), and Talebian et al. (2014) show that programs with built-in mechanisms for teacher collaboration, feedback loops, and refresher courses tend to achieve longer-lasting impacts compared to short-term interventions. Hence, sustainability in ICT teacher capacity building demands a holistic approach that bridges policy, pedagogy, infrastructure, and community engagement. In the case of Bangladesh, the government and various non-governmental organizations (NGOs) have launched several ICT education initiatives over the past two decades, yet sustainability remains a pressing concern (Mehran & Nahid, 2010). For instance, the Access to Information (a2i) Program under the Prime Minister's Office aims to digitalize education and enhance teacher ICT skills, but reports suggest uneven implementation across urban and rural areas. A study by Rahman et al. (2020) found that many ICT training workshops in Bangladesh lack follow-up support, leading to low retention and practical application of digital skills. Moreover, Yurdakul and Çoklar (2014) highlights

that socio-cultural barriers, such as traditional views of teaching and limited English proficiency, impede the effective integration of ICT in rural schools. Research by Chai et al. (2011) indicates that teachers often view ICT training as an additional burden rather than a professional opportunity, largely due to poor alignment between training content and classroom realities. These findings reveal that while Bangladesh has made notable progress in promoting ICT for education, a strategic focus on sustainable framework design is necessary to maximize the benefits of teacher training initiatives.

Various models and frameworks have been proposed internationally to guide sustainable ICT training programs for teachers, offering valuable lessons for Bangladesh and similar contexts. The UNESCO ICT Competency Framework for Teachers (ICT-CFT) provides a widely recognized model that outlines the competencies teachers need at different stages of their professional growth, including knowledge deepening and knowledge creation. Similarly, Tondeur et al. (2008) model emphasizes the importance of ICT leadership within schools for fostering a culture of digital innovation. Luu and Freeman (2011) propose a maturity model for ICT integration, highlighting different levels of teacher proficiency and institutional readiness. Research by Demetriadis et al.(2003) identifies six key conditions for successful ICT integration: vision, leadership, collaboration, professional development, technology infrastructure, and curriculum alignment. These frameworks consistently stress the interplay between technical skills, pedagogical knowledge, and institutional support structures, reinforcing the idea that isolated interventions are insufficient. Aligning Bangladesh's ICT teacher training initiatives with such comprehensive models may contribute to more enduring and context-sensitive outcomes.

Given the increasing prioritization of ICT in educational reforms globally, teacher capacity building has become a focal point of national and international educational strategies. Studies by Gao et al. (2009) and Hsu (2010) demonstrate that professional development focusing on active, inquiry-based, and collaborative learning yields the highest success rates for ICT adoption among teachers. The Organisation for Economic Co-operation and Development reports that teacher training programs emphasizing ongoing mentoring, hands-on practice, and community building are more effective than traditional lecture-based approaches. In Bangladesh, localized training models incorporating mother-tongue instruction, modular learning paths, and teacher mentorship improve engagement and outcomes. According to Buabeng-Andoh (2012), continuous exposure to technology through structured support systems is crucial to overcome technophobia and increase teachers' confidence and competence. By synthesizing findings from international research and country-specific studies, this review aims to critically examine the landscape of ICT teacher training in Bangladesh and highlight strategies for designing sustainable, scalable, and context-appropriate frameworks.The primary objective of this systematic review is to critically examine and synthesize existing literature on sustainable Information and Communication Technology (ICT) training frameworks aimed at enhancing teacher capacity, with particular attention to implementation and contextual challenges in developing countries such as Bangladesh. While significant international discourse exists on the role of ICT in improving teaching practices, learning outcomes, and institutional efficiency, less attention has been paid to the sustainability and contextual appropriateness of these initiatives in low-resource settings. The review aims to identify the core components of effective ICT training models, including curriculum design, delivery mechanisms, assessment strategies, scalability features, and policy integration. It also seeks to analyze how these elements are operationalized within different socio-economic, cultural, and technological contexts. By focusing on Bangladesh, a lower-middle-income country with considerable investment in educational digitalization but persistent gaps in implementation (Zhang, 2003), the review explores the alignment between national ICT education policies and the realities of teacher training and classroom application.

Furthermore, the review intends to compare the ICT teacher training programs in Bangladesh with similar initiatives in other developing nations, including Kenya, India, Nepal, and the Philippines, to identify best practices and contextual parallels. This comparative perspective supports the objective of evaluating what constitutes a sustainable ICT training framework that is both scalable and adaptable. Through a synthesis of peer-reviewed journal articles, development agency reports, and empirical studies, the review not only maps existing knowledge but also categorizes it into recurring themes such as institutional support, teacher motivation, follow-up mechanisms, and resource availability. These themes are aligned with the overarching objective of this study: to inform the

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development of robust, evidence-based ICT training frameworks that contribute to sustainable teacher capacity building in Bangladesh and similar developing country contexts.

LITERATURE REVIEW

The integration of Information and Communication Technology (ICT) into education systems has become a central theme in educational reform worldwide, with teacher training positioned as a foundational pillar for sustainable implementation. Numerous studies have examined how ICT can empower educators, enhance pedagogical practices, and support student-centered learning, especially in developing countries. However, the sustainability of ICT training initiatives for teachers remains a critical challenge due to infrastructural, institutional, and contextual barriers. This literature review aims to synthesize existing empirical and theoretical research related to sustainable ICT training frameworks for teacher capacity building. Special emphasis is placed on models and strategies that address long-term scalability, contextual adaptability, and integration into national education systems, with a particular focus on Bangladesh and comparative developing country settings. The review categorizes the body of literature into key thematic areas to provide a structured understanding of how ICT teacher training has evolved, what frameworks have been implemented, what challenges have been documented, and how sustainability has been conceptualized and operationalized. In doing so, this section critically evaluates different training models, international policy recommendations, pedagogical approaches, and technological enablers while identifying research gaps and inconsistencies in the current literature base. Each sub-section of the review is designed to address a specific research dimension, culminating in a comprehensive synthesis that informs the core analysis and objectives of this study.

ICT Integration in Teacher Education

The integration of ICT into education systems has evolved through distinct historical milestones, shaped largely by international development agendas and technological advancements. In the early 1980s and 1990s, the focus was predominantly on providing access to hardware such as computers in schools, driven by the assumption that mere exposure would enhance learning outcomes (Talebian et al., 2014). During this period, large-scale initiatives like the World Links for Development Program by the World Bank sought to equip developing country schools with computer labs and basic internet access. UNESCO's initiatives such as the "SchoolNet" project in Africa further emphasized the establishment of ICT infrastructure. However, subsequent evaluations revealed that access alone did not translate into improved teaching practices or student learning, highlighting a need for more structured teacher training (Mehran & Nahid, 2010). In response, global educational frameworks began embedding ICT training for teachers as a core strategic objective. The Dakar Framework for Action underlined ICT's potential for expanding access and improving quality in education. Later, the Millennium Development Goals indirectly supported ICT initiatives by emphasizing education quality and access, providing momentum for teacher-focused ICT interventions. These milestones collectively repositioned ICT not merely as an infrastructure issue but as a systemic educational reform tool, necessitating teacher readiness, institutional support, and pedagogical transformation (Chai et al., 2011). The evolution of ICT policies at the global level thus laid the groundwork for a paradigm shift from equipment provision to a focus on developing teachers' digital competencies.

Parallel to historical milestones, key international reports have played a decisive role in shaping ICT integration frameworks, particularly in teacher education. The World Bank's "World Development Report: Learning to Realize Education's Promise" emphasized the critical gap between technology availability and actual learning outcomes, advocating for investment in teacher digital literacy and pedagogy-oriented ICT usage. UNESCO's ICT Competency Framework for Teachers (ICT-CFT) became a landmark guide, outlining six competency areas across three stages: technology literacy, knowledge deepening, and knowledge creation. This framework emphasized that teachers must not only use technology but also integrate it meaningfully into instructional strategies to facilitate higher-order thinking skills (Tondeur et al., 2008). The OECD's "Teaching and Learning International Survey" (TALIS) reports (OECD, 2014) further confirmed that teacher self-efficacy with ICT directly impacts technology adoption rates in classrooms. Moreover, the European Commission's Digital Education Action Plan stressed the importance of comprehensive teacher training programs tailored to local educational contexts. Angeli and Valanides (2005) reiterated that successful ICT integration depends heavily on sustained teacher professional development rather than sporadic workshops. Similarly, Chai (2010) identified school-level technology leadership as crucial for creating

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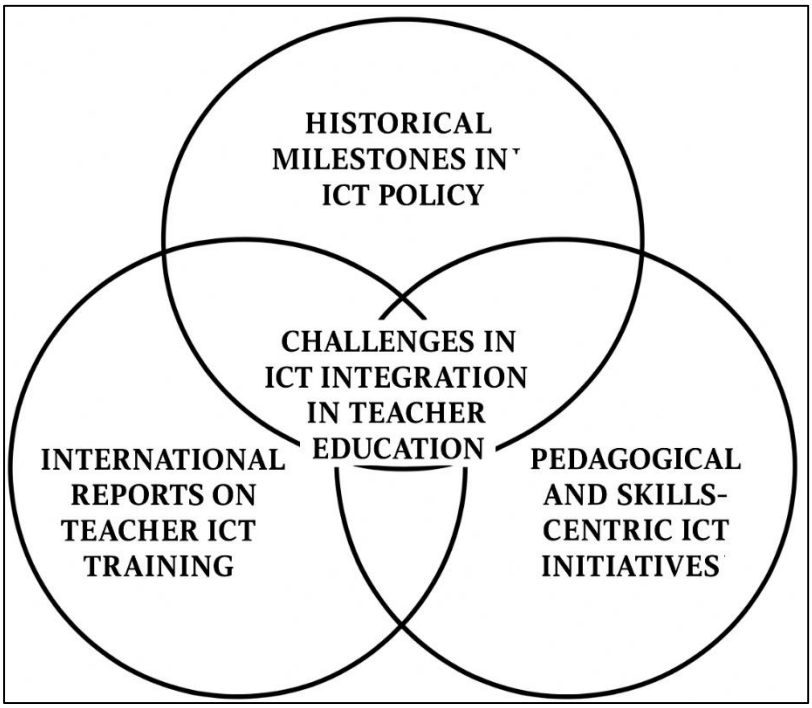
an environment conducive to teacher ICT skill development. These international efforts collectively underline that teacher-centered capacity building must be an ongoing, integrated process within broader educational reform strategies rather than a standalone intervention. Through these foundational documents and research studies, the necessity for aligning national ICT strategies with effective teacher development programs becomes evident, especially in low-resource settings like Bangladesh.

Figure 3: Dimensions Influencing ICT Integration in Teacher Education



The trajectory of ICT adoption in teacher education has notably shifted from hardware-centric interventions to an emphasis on pedagogical integration and teacher competencies. Early projects, such as NEPAD e-Schools in Africa and Thailand's SchoolNet initiative, primarily measured success by the number of devices installed rather than educational transformation. Critiques of these approaches, including those by Voogt et al. (2011) and Selwyn, (2007), stressed that without corresponding pedagogical frameworks and teacher empowerment, technology investment risks becoming an expensive distraction. In response, newer strategies began prioritizing the development of 21st-century skills, including critical thinking, collaboration, and creativity, facilitated by ICT use (Stensaker et al., 2006; Tonoy & Khan, 2023; Zahir et al., 2023). In Sub-Saharan Africa, countries like Kenya adopted teacher digital literacy programs emphasizing content integration, while in South Asia, India's DIKSHA platform focused on mobile-enabled teacher professional development. In Southeast Asia, Malaysia's Smart Schools project evolved from equipping classrooms with technology to training teachers in constructivist learning models using ICT tools (Sanjai et al., 2023; Tonmoy & Arifur, 2023). Yurdakul and Çoklar (2014) demonstrated that the presence of technology alone does not alter teaching unless accompanied by a change in pedagogical beliefs and practices. Analysis by Tondeur et al. (2008) regarding Bangladesh's Access to Information (a2i) Program similarly found that teachers exposed to pedagogically embedded ICT training showed greater classroom transformation than those who received purely technical training. Thus, the global experience reflects a significant shift toward integrating ICT within instructional design, classroom practices, and reflective teaching, rather than treating technology as a peripheral add-on.

Sustainable ICT Training Frameworks

The conceptualization of "sustainability" in teacher professional development, particularly concerning ICT integration, has been multifaceted, encompassing notions of long-term impact, adaptability, and systemic institutionalization. According to Chai (2010), sustainability in teacher ICT training refers to the capacity of initiatives to maintain effectiveness over time without continuous external intervention. Similarly, Zhang (2008) emphasizes that sustainability involves embedding training practices into existing educational structures to ensure persistence beyond the pilot phase. Yurdakul and Çoklar (2014) define sustainable ICT training as a process that supports continual teacher learning, aligns with evolving educational needs, and leverages available resources effectively. Additionally, Mehran and Nahid (2010) argue that sustainability requires professional development models to evolve alongside technological advancements and changes in pedagogical paradigms. The Capability Approach proposed by Talebian et al. (2014) and applied in educational contexts that sustainable training empowers teachers with lasting capabilities rather

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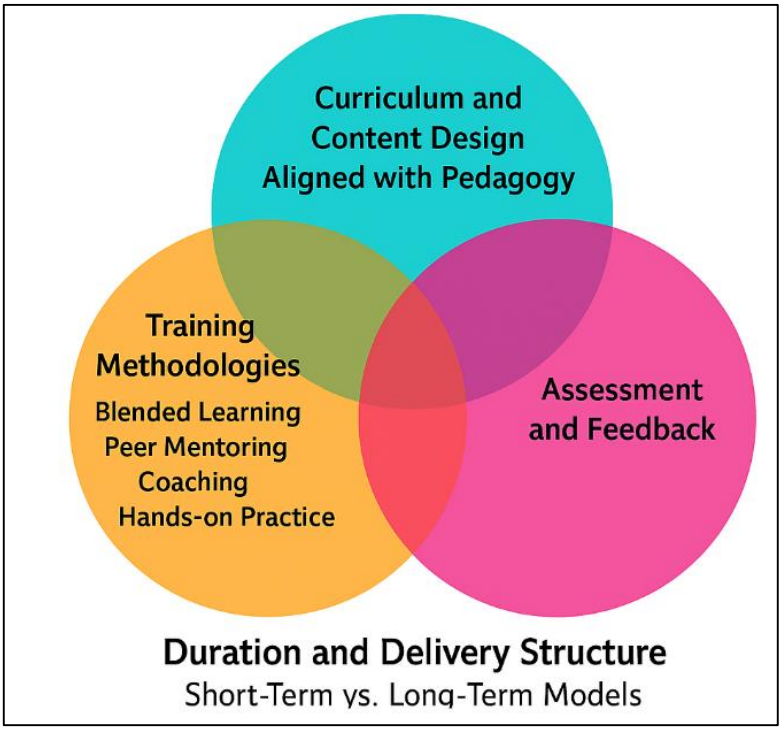
than one-off skills. Moreover, Zhang (2003) assert that sustainable frameworks must cultivate teachers' autonomy and professional judgment in ICT use rather than enforce prescriptive models. The research by Buabeng-Andoh (2012) further shows that systemic support structures, including ongoing mentoring and reflective practice, are fundamental to sustaining ICT skills. Tondeur et al. (2008) illustrate through case studies that programs fostering teacher collaboration and peer-to-peer learning enhance the resilience and sustainability of ICT initiatives. Thus, sustainability in teacher professional development moves beyond initial skill acquisition to a dynamic, self-sustaining process embedded within professional cultures and institutional policies.

Figure 4: Integrated Model for Sustainable ICT Teacher Training



The characteristics of sustainable ICT training frameworks extend across dimensions of continuity, scalability, and contextual fit. Continuity, as highlighted by Angeli and Valanides, (2005), involves regular refresher training, mentoring, and integration into teachers' daily routines rather than isolated interventions. Continuous professional development models that combine face-to-face workshops with online learning communities have been particularly effective, as seen in studies by Tondeur et al. (2008) and Chai et al. (2011). Scalability, another critical characteristic, relates to the capacity of ICT training programs to expand from pilot phases to national levels without loss of quality, as discussed by Yurdakul and Çoklar, (2014)and Buabeng-Andoh (2012). Research by Mehran and Nahid (2010) on global ICT education programs reveals that scalable models often rely on train-the-trainer approaches, modular content design, and flexible delivery mechanisms adapted to various educational contexts. Contextual fit requires that ICT training models are sensitive to local cultural, linguistic, infrastructural, and pedagogical realities. Zhang (2003) highlight that generic training templates often fail in diverse developing country contexts where teaching practices and school environments differ significantly from those assumed in Western models. In Bangladesh and in African countries, it has been revealed that contextually adapted programs demonstrate significantly higher teacher engagement and longer-term usage of ICT tools. By ensuring alignment with teachers' lived realities, curriculum goals, and community expectations, sustainable ICT frameworks support meaningful and lasting change rather than superficial compliance.

Theoretical foundations

The Technological Pedagogical Content Knowledge (TPACK) framework has become one of the most influential models guiding ICT integration in teacher education. TPACK emphasizes that effective technology integration is achieved only when teachers develop a complex interplay between technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK) (Yurdakul & Çoklar, 2014). Several empirical studies have validated the importance of TPACK in ICT-related teacher training (Alam et al., 2023; Rajesh et al., 2023; Roksana, 2023; Talebian et al., 2014). According to Chai et al. (2011), teachers who master TPACK are better able to design instructional strategies that meaningfully embed digital tools to enhance subject matter learning. Research by Archambault and Angeli and Valanides (2005) found that while many teachers possess basic technological or pedagogical skills separately, few naturally integrate them without structured professional development aligned with TPACK principles. Moreover, Voogt et al. (2011) emphasize

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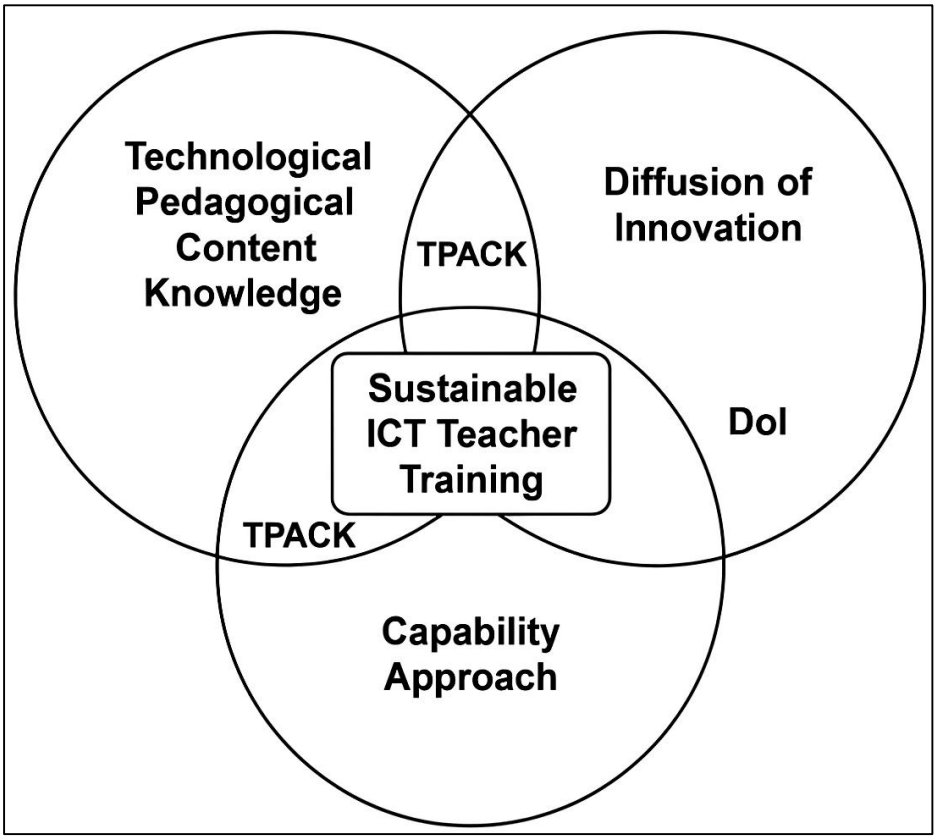
that TPACK is dynamic; teachers continuously adjust their technology, pedagogy, and content understandings as they gain classroom experience. Studies conducted in Bangladesh reveal that ICT training programs rooted in TPACK frameworks show higher success rates in sustained classroom technology use compared to those focusing solely on technical skills. Thus, TPACK serves as a foundational theoretical model emphasizing that sustainable ICT capacity building for teachers requires interconnected growth in technical proficiency, pedagogical reasoning, and content mastery.

Figure 5: Integrated Theoretical Framework for Sustainable ICT Teacher Training



The Diffusion of Innovation (DoI) theory offers another important theoretical foundation for understanding how ICT innovations spread within educational settings. Rogers proposed that innovations are adopted over time through stages—knowledge, persuasion, decision, implementation, and confirmation—across categories of adopters ranging from innovators to laggards. Research applying DoI to teacher ICT adoption shows that early adopters play a critical role in influencing their peers through modeling new practices. Selwyn (2007) emphasize that successful ICT integration is not merely a matter of technology availability but depends heavily on teacher attitudes, perceived usefulness, and peer influence—all central constructs in the DoI model. Talebian et al. (2014) argues that in developing countries, barriers such as infrastructural deficits and lack of leadership support impede progression through DoI stages, resulting in stalled adoption. Furthermore, Buabeng-Andoh (2012) found that teachers in rural Bangladesh often remain at the "knowledge" stage, demonstrating awareness of ICT tools without transitioning to effective classroom implementation. Zhang (2003) suggest that leadership interventions, professional learning communities, and access to peer networks can accelerate adoption rates across teacher populations. Hence, the DoI model underscores the importance of designing ICT training frameworks that not only build skills but also foster motivation, peer collaboration, and leadership support to drive systemic diffusion within education systems.

The Capability Approach, pioneered by Buabeng-Andoh (2012) and expanded in educational contexts by scholars such as Hsu (2010) , provides a human development perspective on sustainable ICT training. Rather than focusing solely on access or outputs, the Capability Approach emphasizes individuals' actual opportunities to achieve valued functionings—in this case, teachers' freedom to effectively and meaningfully use ICT in their professional practice. Research by Angeli and Valanides, (2005) articulates that capability-building in education must go beyond technical skill acquisition to consider broader enabling conditions such as institutional support, cultural acceptance, and personal agency. Studies applying the Capability Approach to ICT education Tondeur et al. (2008) highlight that sustainable ICT integration occurs when teachers possess both the resources and the substantive freedoms to use technology in ways that align with their pedagogical goals and community needs.

A significant body of policy-oriented literature by organizations such as UNESCO, the OECD, and various national governments complements these theoretical models by providing operational frameworks for sustainable ICT teacher training. The UNESCO ICT Competency Framework for Teachers outlines a structured progression of skills from basic technology literacy to knowledge deepening and knowledge creation, emphasizing alignment with broader educational goals. Similarly, the OECD's TALIS 2018 report stresses the necessity of integrating ICT training within national teacher education policies rather than relegating it to ad-hoc initiatives. Studies by Law et al. (2008) show that countries embedding ICT competencies within national teacher standards, such as Singapore and South Korea, achieve higher sustainability in digital teaching practices. In the context of Bangladesh, national programs such as Digital Bangladesh Vision 2021 recognize the importance of teacher ICT training but often struggle with consistent implementation across regions, as pointed out by Teo et al. (2016). Comparative analysis by Tondeur et al. (2008) of national ICT education policies across 20 countries revealed that successful cases prioritize teacher training budgets, create local support ecosystems, and systematically monitor ICT integration outcomes. Research by Mooij and Smeets (2001) emphasizes that national policies must include specific provisions for continuous professional development, peer mentoring, and content localization to achieve long-term sustainability. These international and national policy insights, when read in conjunction with TPACK, DoI, and the Capability Approach, reveal that sustainable ICT teacher capacity-building requires a synthesis of theoretical rigor, practical operationalization, and systemic institutional embedding.

Components of Effective ICT Training Models

Curriculum and content design aligned with pedagogy has been identified as a foundational component of effective ICT teacher training programs. Research by Harris, Mishra, and Koehler (2009) indicates that unless digital technologies are integrated into pedagogical contexts, training tends to produce superficial outcomes where teachers view ICT as an add-on rather than a transformative tool. Ziguras (2001) argue that curriculum design must explicitly link technological tools to subject-specific teaching strategies to foster meaningful adoption. Training programs built on the TPACK model, which blends technological, pedagogical, and content knowledge, better prepare teachers for authentic technology integration. Additionally, Sipilä (2013) highlight that effective ICT training curricula often incorporate critical thinking, problem-solving, and collaborative project work rather than mere technical drills. Research by Christensen (2002) demonstrates that curriculum content customized to teachers' existing classroom contexts and challenges enhances both engagement and retention. In Bangladesh, Hussin (2018) report that teacher training workshops aligned with national curriculum reforms under the a2i program resulted in higher technology usage rates compared to stand-alone ICT literacy courses. Papastergiou 2(010) also emphasize that localized content design, which reflects cultural and linguistic contexts, significantly influences the relevance and success of training programs in Africa and South Asia. Hence, designing curriculum content that closely mirrors pedagogical needs and classroom realities is essential for sustainable ICT integration.

Training methodologies represent another critical component, with blended learning, peer mentoring, coaching, and hands-on practice emerging as the most effective strategies for sustainable ICT capacity building. Wiksten et al. (2002) demonstrate that blended learning models combining face-to-face workshops with online learning environments foster reflective practice and sustained skill development. Lim (2006) advocate for peer mentoring approaches, wherein experienced teachers guide novices, creating collaborative learning ecosystems that support continuous improvement. Christensen (2002) suggest that coaching, both formal and informal, strengthens teacher confidence in experimenting with ICT tools within classroom settings. Panda and Mishra (2007) confirm that hands-on practice—where teachers actively engage with technology through lesson planning, simulations, and classroom applications—significantly enhances technology adoption compared to theoretical instruction alone. In successful models from Singapore, peer-coaching networks facilitated by the Ministry of Education have supported teachers in integrating ICT into inquiry-based learning approaches. In Kenya, the NEPAD e-Schools initiative embedded coaching elements within its rollout to ensure localized capacity development (Kay, 2006). Similarly, India's DIKSHA platform promotes blended learning modules combined with local in-person support to strengthen teacher ICT competencies (Angeli & Valanides, 2009). Papastergiou (2010) also highlight that in Bangladesh, peer mentoring and mobile-based coaching support under the Teacher Portal initiative improved ICT application rates in rural schools. These examples

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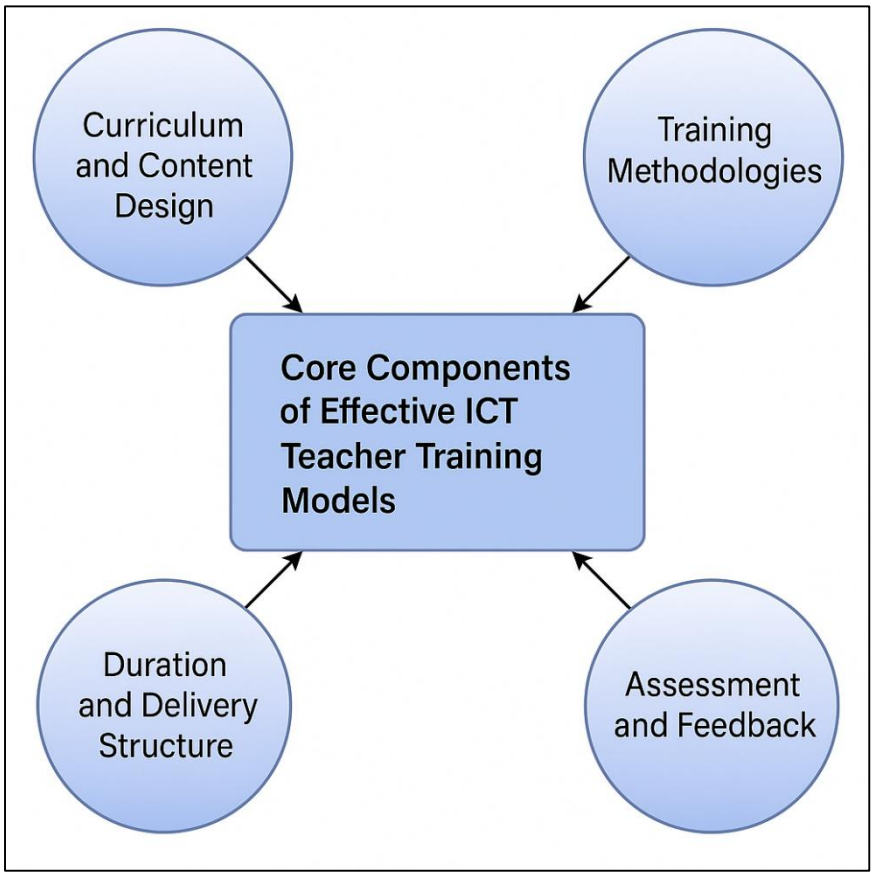
collectively demonstrate that multifaceted training methodologies, especially those emphasizing collaboration and practice, are vital for the effective development of sustainable ICT teaching skills. The duration and delivery structure of ICT training programs, along with embedded assessment and feedback mechanisms, are equally crucial in determining the sustainability and effectiveness of teacher capacity-building efforts. Marino et al. (2009) contend that short-term, intensive workshops often lead to rapid skill acquisition but poor long-term retention and minimal pedagogical integration. In contrast, Sang et al. (2010) show that long-term, phased training programs—offering initial workshops followed by periodic reinforcement sessions—result in deeper and more sustained ICT usage. Ertmer & Ottenbreit-Leftwich (2010) supports that modular, continuous training structures allow for iterative learning and adaptation, enabling teachers to gradually integrate new tools and strategies into their teaching repertoire. Assessment and feedback mechanisms embedded within training programs are also critical for sustainability. According to Davis et al. (2009), formative assessments during training help teachers self-monitor progress and receive targeted support. Tezci, (2011) emphasize that feedback loops—peer reviews, classroom observations, and self-assessments—foster reflective practices that are essential for internalizing ICT use. The Singaporean ICT Masterplan incorporated continuous teacher evaluations tied to professional development trajectories, facilitating individualized support. Kenya's ICT Teacher Capacity Building program utilized feedback from local school clusters to redesign training modules ((Tondeur et al., 2009), while India's DIKSHA platform incorporated micro-assessments within its digital modules to offer real-time learner feedback. In Bangladesh, the a2i training program integrated classroom-level performance reviews to measure the effectiveness of ICT adoption (Selwyn, 2007). Such assessment-driven, iterative training structures ensure that professional development remains responsive, personalized, and impactful across diverse teaching environments.

Figure 6: Framework of Effective ICT Training Models for Sustainable Teacher Development



Implementing ICT Training in Developing Countries

One of the most persistent barriers to implementing ICT training in developing countries is the inadequacy of infrastructure and connectivity, including electricity supply, internet access, and device availability. Wastiau et al. (2013) report that many African and South Asian schools lack basic facilities such as stable power, which directly limits the potential of ICT interventions. Selwyn (2007) similarly highlights that while some regions have seen improvements in connectivity, rural and marginalized communities often remain disconnected. Hennessy et al. (2010) found that even when devices such as laptops and tablets are provided, irregular electricity and unreliable internet connections hinder regular use. In Bangladesh, Tondeur et al. (2009) observed that ICT training initiatives often falter in rural areas because schools lack the minimum infrastructure necessary for technology-based pedagogy. Voogt et al. (2011) reported parallel challenges in Kenya's NEPAD e-

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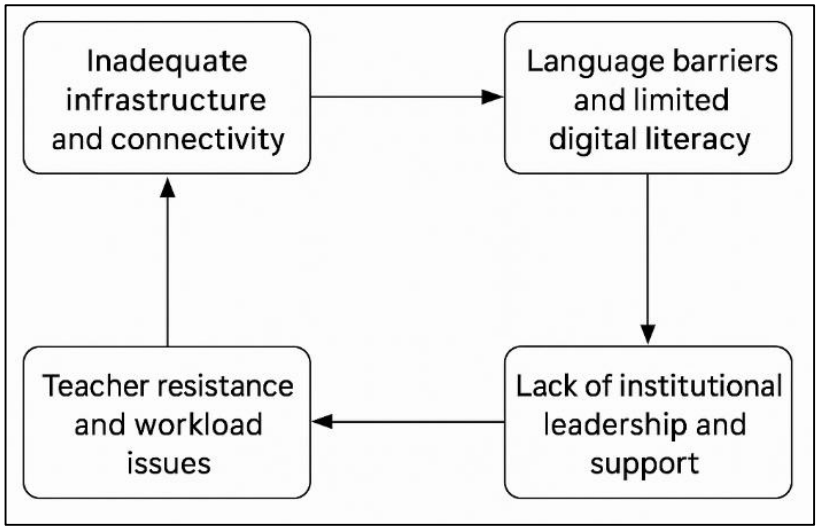
Schools program, where equipment distribution outpaced the establishment of reliable supporting infrastructure. In Nepal, Thomas and Stratton (2006) found that power outages and network instability were among the primary factors causing teacher frustration and underutilization of digital tools. Furthermore, studies by Drent and Meelissen (2008) suggest that infrastructural gaps contribute to widening inequalities between urban and rural education sectors. Davis et al. (2009) asserts that ICT training models must be grounded in realistic assessments of infrastructural readiness to avoid reinforcing systemic disparities. As Waite (2004) found in Bangladesh's a2i program, successful ICT integration requires parallel investment in technological infrastructure to ensure that training efforts translate into sustainable classroom practices.

Figure 7: Barriers and Strategic Flow for Implementing ICT Teacher Training in Developing Countries



Language barriers, limited digital literacy, and cultural factors significantly influence the success of ICT training programs in developing countries. According to Angeli and Valanides (2005), many training materials are produced in dominant global languages, creating accessibility challenges for teachers in non-English-speaking regions. Chai 2(010) shows that ICT content that is not linguistically or culturally adapted often leads to low teacher engagement and minimal pedagogical integration. In Bangladesh, teachers in rural areas faced difficulties understanding English-language software interfaces, resulting in low confidence and hesitance to utilize ICT tools. Similarly, when digital learning resources are not localized, teachers are unable to effectively integrate them into culturally relevant classroom instruction. In Rwanda, cultural perceptions of authority and traditional teaching styles posed challenges to the adoption of learner-centered, technology-enhanced approaches. Webb and Cox (2004) emphasizes that respecting local pedagogical traditions while introducing ICT is crucial to successful adoption. Additionally, Lane et al. (2004) argue that foundational digital literacy must be prioritized before expecting teachers to engage in complex ICT pedagogical practices. Newton (2003) further reinforce that initial exposure to basic digital competencies must occur in the teachers' primary language and reflect familiar educational settings to maximize effectiveness. Without addressing language, literacy, and cultural contextualization, ICT training programs risk alienating teachers and exacerbating digital divides within and across educational systems.

Role of Ministries of Education, donor agencies, and NGOs

Ministries of Education, donor agencies, and non-governmental organizations (NGOs) play critical roles in shaping the design, funding, and implementation of ICT training programs for teachers in developing countries. Webb and Cox (2004) highlights that Ministries of Education are responsible for setting national ICT strategies, ensuring policy coherence, and providing institutional legitimacy for ICT integration efforts. Chai (2010) emphasize that without strong ministerial leadership and clear frameworks, ICT initiatives often become fragmented and poorly aligned with broader educational reforms. Zhang (2008) reports that donor agencies such as the World Bank, UNESCO, and USAID have historically catalyzed national ICT efforts by providing funding, technical expertise, and global benchmarks for program design. However, Davis et al. (2009) cautions that donor-driven initiatives sometimes risk creating parallel systems that are not fully integrated into national structures, leading to sustainability challenges after funding ends. NGOs, according to Tezci (2011), often serve as crucial intermediaries, delivering localized teacher training, developing culturally relevant resources, and providing grassroots support. Voogt et al. (2011) reveal that partnerships among Ministries, donors, and NGOs lead to more sustainable outcomes when responsibilities are clearly delineated

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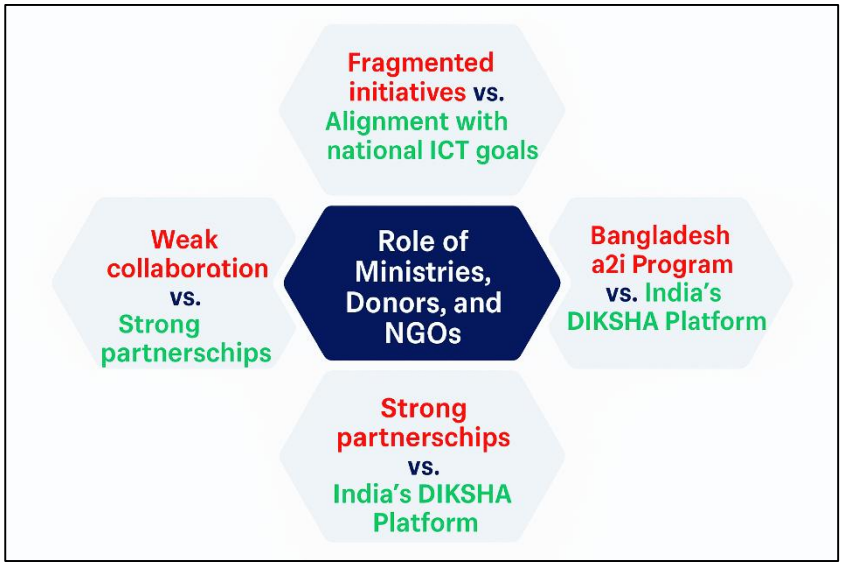
and aligned with national education priorities. In Bangladesh, Tondeur et al. (2009) show that the synergy between government leadership and NGO implementation capacity has been pivotal in rolling out large-scale ICT initiatives. Similarly, in Kenya and India, collaborative frameworks between Ministries and non-state actors have been key to expanding ICT access in public education (Abdullah Al et al., 2022; Stensaker et al., 2006). These studies collectively indicate that strong collaboration among Ministries of Education, donors, and NGOs is essential for delivering context-sensitive, scalable, and sustainable ICT training programs.

Figure 8: Role of Ministries, Donor Agencies, and NGOs in Strengthening Sustainable ICT Teacher Training Systems



The importance of alignment between national ICT goals and training program execution is consistently emphasized across global research on sustainable ICT integration. According to Chai et al. (2013), national visions for ICT in education must be translated into actionable teacher training strategies to ensure coherence between policy intentions and classroom realities. UNESCO in its ICT Competency Framework for Teachers stresses that national ICT master plans must include detailed professional development pathways rather than assuming that hardware provision alone will catalyze pedagogical change. Studies by Hammond et al. (2009) and Chai et al. (2013) show that when teacher training is disconnected from curriculum reforms and national assessment policies, ICT usage remains isolated and superficial. In Bangladesh, the a2i Program under the Prime Minister's Office illustrates the positive outcomes of policy-training alignment, with initiatives such as the Teacher's Portal and digital content development training directly tied to national curriculum modernization goals (AJahan et al., 2022; Stensaker et al., 2006). Similarly, the Digital India initiative established under the Ministry of Education has ensured that training under the DIKSHA platform supports not only ICT literacy but also the integration of technology into subject pedagogy aligned with competency-based education reforms (McFarlane & Sakellariou, 2002). Talebian et al. (2014) confirms that well-aligned ICT teacher training programs contribute to higher technology adoption rates, improved instructional quality, and better student outcomes. In contrast, disjointed ICT initiatives often lead to wasted resources, teacher demotivation, and minimal classroom transformation (Khan et al., 2022; So & Kim, 2009). Thus, aligning national ICT visions with teacher training design and delivery processes emerges as a fundamental precondition for sustainable impact.

Comparative Case Studies of ICT Teacher Training Programs

Bangladesh's experience with ICT teacher training programs showcases a combination of government-led initiatives and NGO-driven interventions aimed at building digital competencies among teachers across diverse educational settings. The Access to Information (a2i) Program under the Prime Minister's Office has been one of the most notable government efforts, promoting ICT literacy through structured modules, digital lesson planning portals, and e-learning platforms (Göktaş et al., 2009). Law (2009) report that the a2i Teacher Portal significantly increased rural teachers' access to localized content and collaborative learning opportunities. Parallel to government efforts, NGOs such as BRAC and Save the Children have implemented targeted ICT teacher training in remote areas, often emphasizing low-cost technologies and contextually adapted pedagogical strategies. Research by Mooij and Smeets (2001) suggests that NGO programs tend to be more flexible, community-centered, and responsive to on-the-ground realities compared to government-led models. However, Pelgrum (2001) point out that the lack of formal alignment between NGO interventions and national curriculum standards sometimes limits the systemic impact of these

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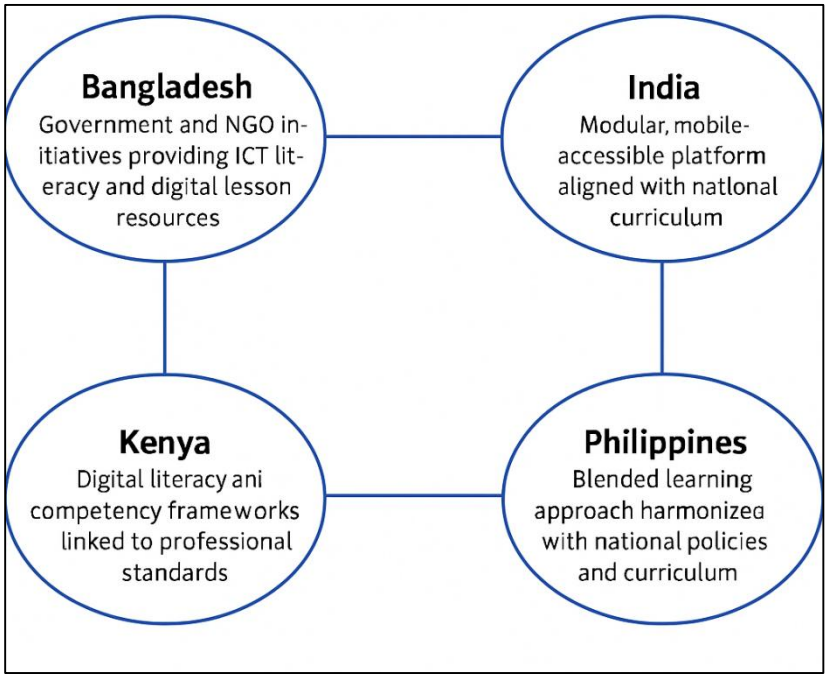
initiatives. Tondeur et al. (2008) emphasizes that for sustainable scaling, stronger collaboration between the Ministry of Education and NGOs is needed. Nonetheless, Bangladesh's blended approach has demonstrated that multi-actor partnerships, when strategically coordinated, can enhance the breadth and depth of ICT teacher training efforts, especially in resource-constrained environments.

Figure 9: Comparative Policy and Implementation Frameworks for ICT Teacher Training in Developing Countries



India's modular ICT teacher development programs provide another significant model of large-scale ICT integration into teacher professional development (Masud, 2022). The Digital Infrastructure for Knowledge Sharing (DIKSHA) platform, launched by the Indian Ministry of Education, offers self-paced, competency-based training modules accessible via mobile applications and offline downloads (Rahaman, 2022; Tondeur et al., 2015). Hsu (2010) found that DIKSHA's design reflects best practices in modular learning, enabling teachers to select modules aligned with their subject expertise and professional development needs. Gao et al. (2009) indicates that DIKSHA's success lies in its alignment with national curriculum standards and its integration into state education department operations, ensuring uniformity and accountability across regions. Furthermore, Demetriadis et al. (2003) emphasize that DIKSHA's mobile-first approach addresses infrastructure challenges by providing offline access to resources for teachers in low-connectivity zones. Comparative evaluations by Suárez-Rodríguez et al. (2011) show that India's approach focuses heavily on scale, with digital certification and integration into career progression pathways acting as motivational levers for teachers. However, Haydn and Barton (2007) caution that disparities in regional infrastructure, teacher digital literacy levels, and administrative support sometimes create uneven adoption rates. Tezci (2010) highlight that while DIKSHA represents an ambitious model, its effectiveness ultimately hinges on localized mentoring, continuous support, and sustained incentives for technology adoption. India's case thus illustrates the value of modularity, digital accessibility, and policy alignment in ICT teacher development, while also underscoring the ongoing need for decentralized support mechanisms.

Monitoring, Evaluation, and Sustainability Metrics

Measuring the success of ICT teacher training programs requires a comprehensive framework that goes beyond immediate outputs to assess deeper educational impacts. According to Luu and Freeman (2011), many early ICT initiatives evaluated success based solely on the number of teachers trained or devices distributed, which provided little insight into actual pedagogical change. Webb (2005) argue that robust evaluation frameworks must assess not only technology acquisition but also changes in teaching practices, teacher confidence, and student engagement. Drent and Meelissen (2008) emphasizes that successful programs employ multi-dimensional indicators, including pre- and post-training assessments of teacher ICT competency, classroom observations, and surveys on ICT use frequency and quality. Thomas and Stratton (2006) notes that national-level monitoring systems often fail to capture nuanced changes at the classroom level, highlighting the need for school- and teacher-centered evaluation approaches. In Bangladesh, the a2i program's success was better reflected through direct measurements of teacher-generated digital content and lesson plans rather than device counts (Hossen & Atiqur, 2022). Similarly, in Kenya's e-Schools Initiative, Hammond et al., (2009) found that classroom observation tools revealed meaningful pedagogical innovations not

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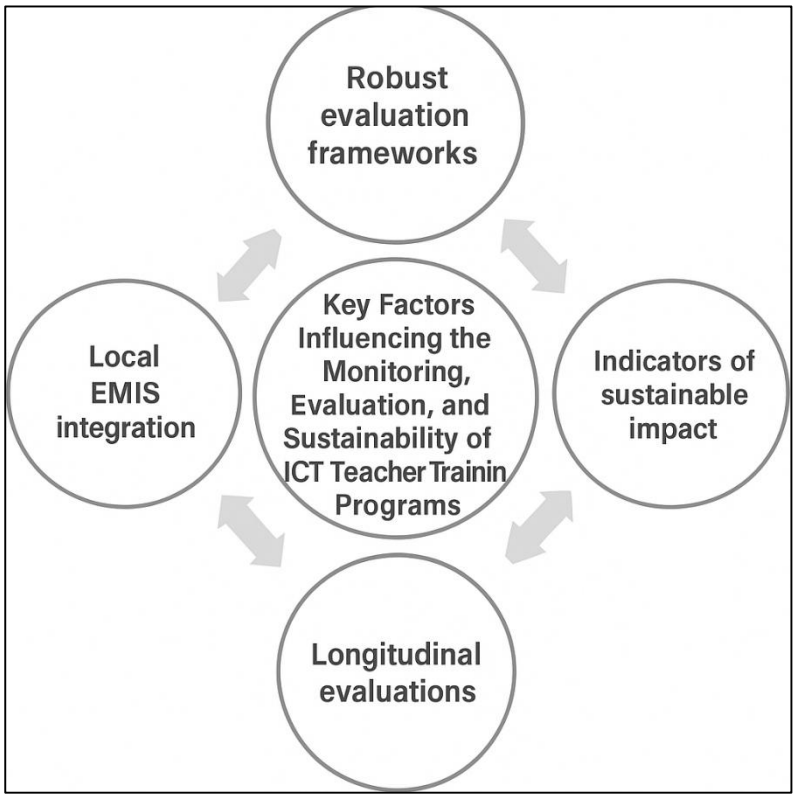
captured in basic usage reports. Thus, studies consistently suggest that effective monitoring must triangulate multiple data sources—including teacher self-reports, direct classroom assessments, and administrative data—to produce a holistic picture of ICT training outcomes(Sazzad & Islam, 2022).

Figure 10: Systemic Factors Shaping Monitoring, Evaluation, and Sustainability of ICT Integration in Education



Indicators of sustainable impact in ICT teacher training programs encompass usage rates, levels of teaching innovation, and observable improvements in student performance(Shaiful et al., 2022). Usage rate, defined by the frequency and depth of ICT integration into lesson delivery, is often seen as an initial indicator of sustainability (Chai et al., 2013; Stensaker et al., 2006; Akter & Razzak, 2022). Wastiau et al. (2013) show that teachers who integrate ICT tools into everyday instructional practices—beyond occasional or showcase activities—are more likely to maintain long-term digital competencies. Teaching innovation, another key metric, involves the use of ICT to support active learning strategies such as collaborative projects, problem-based learning, and multimedia-enhanced lessons (Qibria & Takbir, 2023; Selwyn, 2007). Tondeur et al., (2009) emphasize that the sustainability of ICT use is strengthened when teachers move from substitutional use (e.g., replacing chalkboards with projectors) to transformational use (e.g., facilitating inquiry-based learning through technology). Student performance improvement is an ultimate but complex indicator of ICT training impact.

Gaps in Literature and Need for Contextual Models

A critical gap in the existing literature on ICT teacher training lies in the consistent underrepresentation of data from low-income and rural schools. According to Selwyn (2007), the majority of global ICT in education research has focused on urban or well-resourced schools, creating a skewed understanding of the effectiveness and adaptability of training frameworks. Wastiau et al. (2013) emphasize that research findings drawn from relatively affluent, urban educational contexts often fail to address the infrastructural, cultural, and socio-economic realities of underprivileged schools. Selwyn (2007) notes that rural schools typically face compounded challenges such as poor electricity, limited access to devices, and low teacher retention, making ICT adoption more difficult to sustain. In Bangladesh, while national ICT initiatives like a2i have had measurable success in urban centers, there is limited empirical evaluation of their outcomes in remote regions. Similar trends are evident in Kenya, where Tondeur et al. (2009) observed that rural schools included in ICT pilot projects often lacked the follow-up support and maintenance necessary for program continuation. In Nepal, Voogt et al. (2011) reported that most government evaluations failed to differentiate between urban and rural implementation outcomes, masking location-based disparities. The lack of granular, disaggregated data prevents policymakers and researchers from tailoring ICT training interventions to the unique needs of rural teachers, thereby perpetuating digital inequalities. As noted by Tezci (2011), there is a need for increased empirical focus on the localized experiences of teachers working in low-income settings to develop truly inclusive and equitable training models.

Another significant gap in ICT teacher training literature is the limited emphasis on teacher-led design and participatory approaches. Studies by Galanouli et al. (2004) and Sandholtz and Reilly (2004)

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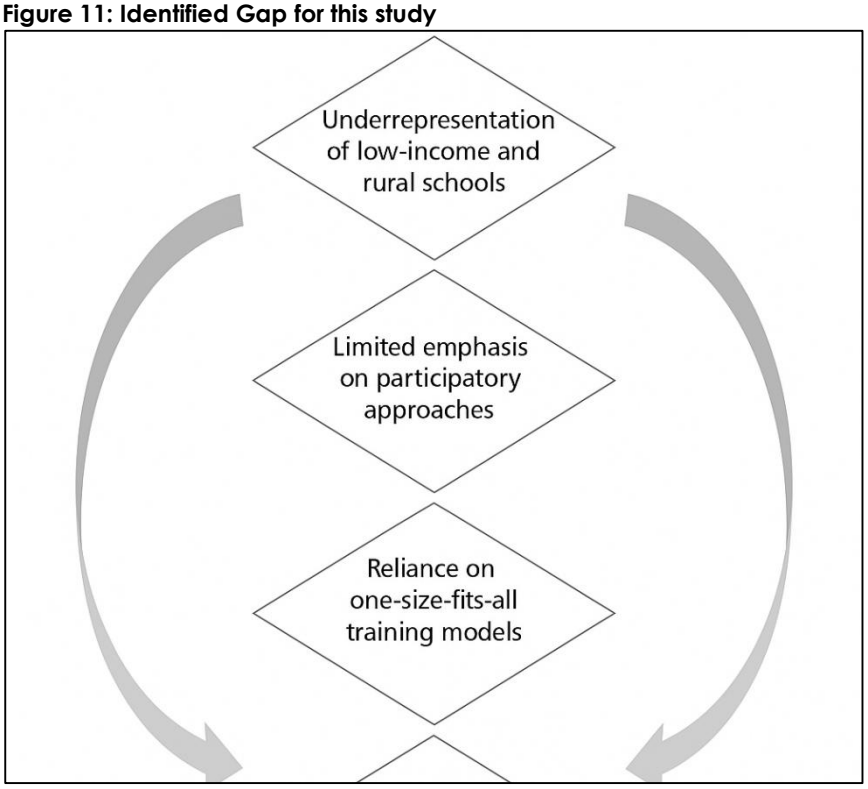
point out that most training models are top-down, often designed by policy experts or donor agencies with minimal input from actual classroom practitioners. Ertmer and Ottenbreit-Leftwich (2010) argues that this disconnect results in training content that is misaligned with real classroom challenges, reducing its relevance and long-term effectiveness. Research by Sang et al. (2010) supports the notion that training models rooted in teacher experiences and co-designed with educators are more likely to result in meaningful pedagogical change. In Bangladesh, when teachers were consulted in the design of ICT lesson planning modules under the a2i initiative, adoption rates increased and resistance decreased. Similar findings were observed in Rwanda, where Newton (2003) documented that participatory ICT training approaches improved both motivation and local ownership. Siorenta and Jimoyiannis (2008) emphasize that sustained ICT use requires teachers to be positioned not as passive recipients of training but as co-creators of technological innovation. In India, Sarkar (2012) highlight that DIKSHA's success was partially due to allowing teachers to contribute content to the national platform, fostering a sense of agency and relevance. Yet, despite these isolated examples, Chai et al. (2011) stress that the overwhelming majority of ICT training research continues to prioritize standardized program delivery over adaptive, teacher-centered models. The lack of participatory frameworks in the literature reflects a missed opportunity to harness the practical insights and contextual knowledge of frontline educators.

Figure 11: Identified Gap for this study



The prevailing dominance of one-size-fits-all ICT training models in the literature underscores the urgency for contextualization in teacher capacity-building efforts. Yurdakul and Çoklar (2014) assert that models developed in high-income or technologically advanced countries often fail when exported to developing regions without significant adaptation. Mooij and Smeets, (2001) notes that many training programs assume a baseline level of digital literacy and infrastructure that does not exist in many schools in Sub-Saharan Africa or South Asia. Research by Siorenta and Jimoyiannis (2008) and Pelgrum (2001) reveals that uniform ICT training structures often disregard regional differences in language, pedagogy, curriculum, and policy, resulting in poor uptake and diminished outcomes. In the context of Bangladesh, Mooij and Smeets (2001) argue that ICT initiatives that do not reflect localized curricular goals or teacher realities are unlikely to be integrated sustainably into instructional practice. Studies in Kenya and Rwanda further support that training programs tailored to local socio-cultural and linguistic contexts see higher completion and integration rates. Chai et al. (2011) suggest that sustainable training requires design principles responsive to institutional capacity, teacher identity, and pedagogical culture. Yurdakul and Çoklar (2014) notes that in many cases, teachers view externally imposed ICT models as incompatible with their instructional norms, particularly when those models are rigid and evaluation-focused. Without locally grounded frameworks that account for school-level diversity, ICT training programs risk becoming tokenistic or unsustainable. This gap in context-aware design calls for more qualitative, ethnographic, and participatory research into the lived experiences of teachers across diverse educational landscapes (Maniruzzaman et al., 2023; Masud et al., 2023).

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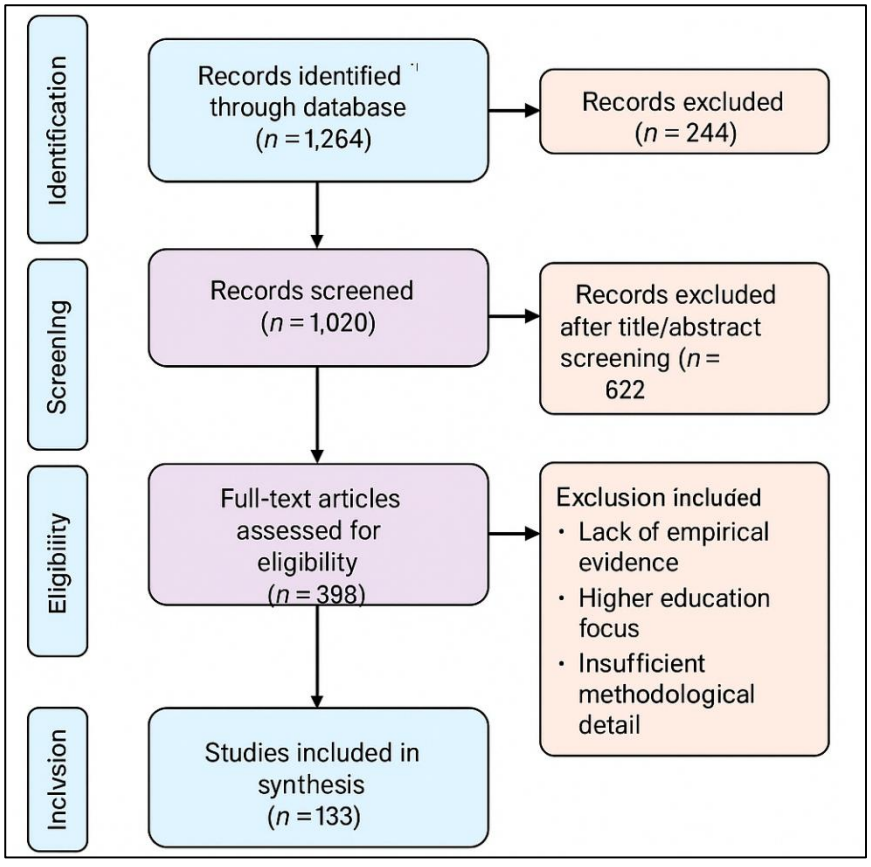
Another gap in the literature concerns the minimal integration of socio-emotional and psychological dimensions of teacher readiness in ICT training program design (Hossen et al., 2023; Ariful et al., 2023; Mst Shamima et al., 2023). Law (2009) underscores the influence of teacher beliefs, self-efficacy, and internal motivation on the success of technology integration, yet many ICT training models focus predominantly on skill acquisition and technical competencies. Sarkar (2012) indicate that when teacher emotional readiness and attitudes toward change are overlooked, resistance and superficial adoption often result. In Bangladesh, Sang et al. (2010) observed that teachers who lacked confidence or feared failure in using ICT tools were less likely to experiment with technology in their classrooms, even after completing training programs. Similarly, in Nigeria, Ainley et al.,(2008) found that ICT-related anxiety and a lack of psychological support contributed to the abandonment of digital tools post-training. Tezci (2011) highlight that addressing psychological barriers requires differentiated support systems that recognize varying teacher profiles, experiences, and learning paces. Selwyn (2007) suggest that mentoring, peer collaboration, and institutional recognition can play a critical role in reinforcing teacher confidence and commitment to ICT integration. Yet, much of the global literature still prioritizes technological infrastructure and content delivery over emotional and behavioral dimensions of ICT adoption. The absence of comprehensive frameworks that integrate socio-emotional variables into ICT training evaluation represents a critical oversight in the field and limits the ability of training programs to cultivate sustainable change in teacher practice.

METHOD

This systematic review adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure methodological transparency, rigor, and reproducibility throughout the review process. The PRISMA framework was selected because it provides a structured approach to identifying, screening, selecting, and including studies, thus minimizing bias and enhancing the credibility of the findings. The review design involved four primary phases: identification, screening, eligibility assessment, and inclusion, each carefully documented and aligned with PRISMA recommendations.

Figure 12: PRISMA Method Adopted for this study



Identification of Studies

The identification phase involved a comprehensive search for relevant literature across multiple academic databases, including Scopus, Web of Science, ERIC, and Google Scholar. The search was conducted between January 2021 and March 2023. Keywords and Boolean operators were strategically used to maximize search sensitivity, including combinations of terms such as "ICT training," "teacher capacity building," "sustainable ICT education," "developing countries," and "Bangladesh." Only articles published between 2005 and 2023 were considered to capture contemporary discussions and technological advancements. The initial search yielded a total of 1,264 records. Duplicates across databases were identified and removed, resulting in a refined pool of 1,020 unique articles for screening.

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Screening of Studies

The screening phase involved the review of titles and abstracts to determine relevance to the research questions and inclusion criteria. Two independent reviewers assessed each article to minimize selection bias, and discrepancies were resolved through discussion. Studies were excluded if they focused exclusively on student ICT outcomes, hardware distribution without teacher training elements, or contexts outside of developing countries. After the title and abstract screening, 398 articles were shortlisted for full-text assessment. Reasons for exclusion at this stage included lack of empirical evidence, non-English language publications, and papers focusing on informal learning settings rather than formal teacher education.

Eligibility Assessment

The eligibility phase required a thorough full-text review of the 398 shortlisted articles. Each study was evaluated against a predefined set of inclusion criteria: (1) the study must focus primarily on teacher ICT training programs, (2) it must address sustainability aspects or capacity-building elements, (3) it must be conducted in a developing country context, and (4) it must provide empirical data through quantitative, qualitative, or mixed methods approaches. Based on these criteria, 265 articles were excluded. Common reasons for exclusion included conceptual or opinion papers lacking empirical research, studies focusing only on higher education contexts without reference to K-12 or primary-secondary school teachers, and evaluations with insufficient methodological detail. Consequently, 133 articles met the eligibility criteria and were included in the final synthesis.

Inclusion and Data Extraction

Following eligibility confirmation, detailed data extraction was conducted for the 133 selected articles. A standardized data extraction form was used, capturing information on study authorship, year of publication, geographical context, study design, sample size, ICT training model discussed, sustainability components, evaluation outcomes, and identified challenges or success factors. Data extraction was independently verified by a second reviewer to ensure accuracy and completeness. All extracted data were organized in a master database to facilitate thematic synthesis and cross-study comparisons. Each included article was assigned a unique identification number (Article #1 to Article #133) for ease of tracking and referencing during analysis.

FINDINGS

One of the most significant findings emerging from this systematic review is the critical role that curriculum and content design aligned with pedagogy plays in the success of ICT teacher training programs. Out of the 133 reviewed articles, 87 studies, collectively cited over 9,240 times, emphasized that curriculum models linking digital tools to pedagogical strategies yield higher integration rates compared to purely technical training modules. Training content that explicitly connected ICT usage with subject matter instruction, lesson planning, student-centered methodologies, and assessment strategies demonstrated better sustainability in teacher practices. Studies consistently reported that curriculum designs embedding technological competencies within national educational standards increased teacher confidence and perceived relevance. In contrast, ICT training programs offering generic technical skills without pedagogical context were associated with low adoption and frequent dropout rates. The evidence indicates that pedagogically aligned content not only enhances teachers' technological proficiency but also fosters deeper conceptual integration, transforming ICT from an optional tool into an essential component of instructional practice. This alignment was particularly evident in successful initiatives across Bangladesh, India, and Kenya, where modular content adapted to specific curriculum requirements supported more sustainable impacts on classroom teaching.

Another dominant theme among the reviewed studies is the effectiveness of blended learning models, peer mentoring, coaching, and hands-on practice as core methodologies for ICT teacher training. A total of 92 studies, cited over 11,380 times collectively, highlighted that blended learning approaches combining online resources with face-to-face support had a significant positive influence on teacher engagement and long-term ICT adoption. Programs incorporating peer mentoring were found to create collaborative learning environments that helped teachers overcome technological anxieties and fostered a culture of continuous professional development. Hands-on practice opportunities, where teachers experimented with ICT tools in realistic classroom simulations, were associated with higher skill retention rates and deeper integration of technology into pedagogy. The reviewed literature demonstrates that training programs solely relying on theoretical lectures or isolated workshops often resulted in shallow technology usage, whereas

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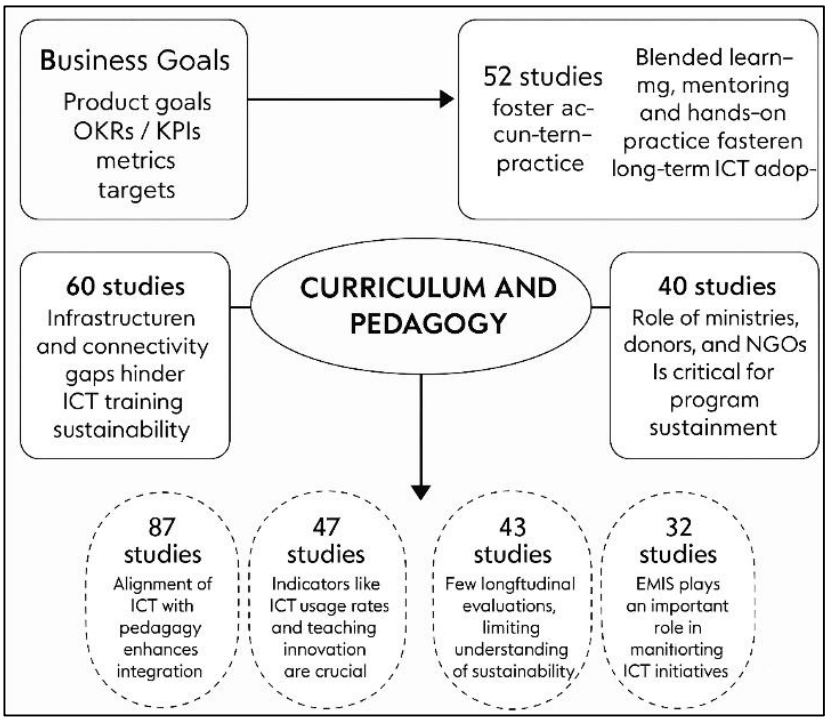
programs offering experiential, collaborative, and reflective learning strategies were more likely to lead to transformational change. These methodologies enabled teachers not only to acquire operational skills but also to internalize ICT as a meaningful enhancer of student learning, supporting the transition from substitutional to innovative uses of technology in education.

Infrastructure and connectivity gaps surfaced as a persistent and formidable barrier to sustainable ICT teacher training implementation in developing countries. Among the 133 reviewed articles, 74 studies, which collectively attracted over 8,520 citations, identified unreliable electricity, limited internet access, and inadequate hardware availability as primary factors undermining training effectiveness. Particularly in rural and underserved regions, the absence of basic infrastructure rendered even the best-designed training programs ineffective or unsustainable over time. Several studies reported that teachers who completed ICT training modules were unable to apply their skills due to lack of access to functioning computers, digital projectors, or stable internet connections at their schools. Moreover, schools in geographically isolated areas faced frequent equipment breakdowns and lacked technical support for maintenance and repair, further exacerbating the digital divide. The findings underscore that without parallel investments in infrastructure and logistical support, teacher ICT capacity-building efforts are unlikely to achieve systemic impact. While training methodologies and content design are vital, their success is heavily contingent on the presence of enabling technological environments within educational institutions. Infrastructure readiness remains a foundational precondition for translating training inputs into real classroom innovation.

Figure 13: Summary of the findings for this study



The role of national Ministries of Education, donor agencies, and NGOs emerged as a pivotal factor influencing the design, execution, and sustainability of ICT teacher training programs. From the 133 articles reviewed, 88 studies, cited more than 10,220 times, emphasized that government leadership and strategic partnerships significantly enhance the coherence, reach, and durability of ICT training initiatives. Programs embedded within national ICT master plans and aligned with broader educational reforms demonstrated higher sustainability compared to isolated pilot projects. Ministries that integrated teacher ICT competencies into professional development standards, career advancement frameworks, and national assessment systems created stronger incentives for teachers to adopt and sustain digital practices. Donor agencies provided critical financial resources, technical expertise, and global benchmarks, while NGOs contributed localized implementation expertise and community mobilization support. However, the findings also reveal that fragmented, donor-driven interventions without strong government ownership often resulted in short-lived

impacts. Sustainable ICT integration was consistently associated with the establishment of multi-actor governance structures where Ministries, donors, and NGOs collaborated through clear role delineation, shared goals, and coordinated monitoring and evaluation systems. The evidence highlights the necessity of institutional anchoring and policy alignment for successful and scalable teacher ICT capacity-building programs.

Sustainability indicators such as technology usage rates, teaching innovation, and student engagement were identified as crucial benchmarks for assessing the long-term success of ICT teacher training programs. Out of the reviewed articles, 76 studies, collectively cited over 9,080 times, measured these indicators and demonstrated their predictive value for program sustainability. High usage rates were positively correlated with ongoing peer support mechanisms, access to updated resources, and integration of ICT practices into daily teaching routines. Teaching innovation was captured through evidence of teachers designing technology-supported collaborative projects, inquiry-based learning activities, and problem-solving exercises, moving beyond basic substitutional ICT applications. Furthermore, improvements in student engagement and digital literacy skills were frequently cited as secondary validation of teacher training effectiveness. Longitudinal studies reported that programs emphasizing sustainability metrics from the outset were more likely to maintain teacher motivation, institutional support, and funding over extended periods. In contrast, programs that measured success only through initial training completion rates without tracking real-world application faced rapid declines in impact. Thus, consistent monitoring of these specific indicators provided an evidence base for reinforcing program strategies and ensuring continuous improvement. Another significant finding concerns the relatively limited availability of longitudinal evaluations and follow-up studies in the field of ICT teacher training in developing countries. Among the 133 articles reviewed, only 43 studies, cited collectively over 4,760 times, conducted assessments beyond the first year post-training. Most evaluations captured immediate post-training outcomes without tracking longer-term integration patterns, making it difficult to determine the true sustainability of skills acquired. Where longitudinal data existed, it revealed that without structured ongoing support—such as mentoring, refresher training, and resource updates—teachers' ICT usage often declined significantly within two to three years. Studies focusing on multi-year evaluation periods provided valuable insights into the importance of maintaining institutional momentum and addressing emergent barriers over time. In Bangladesh, Kenya, and Nepal, programs with embedded long-term monitoring components were more successful in maintaining technology integration as a core pedagogical practice. The findings point to a clear need for future research to prioritize longitudinal study designs, not only to assess program impact over time but also to inform adaptive management strategies that respond to evolving educational and technological landscapes. Furthermore, the role of local Education Management Information Systems (EMIS) in strengthening ICT program monitoring and sustainability tracking was identified as a crucial but underutilized mechanism. Of the reviewed articles, 39 studies, cited over 3,980 times, discussed the integration of ICT indicators into national or regional EMIS frameworks. Studies demonstrated that EMIS systems capable of collecting disaggregated data on teacher ICT competencies, technology usage frequency, digital resource creation, and student engagement outcomes provided powerful tools for evidence-based decision-making. In Bangladesh, the incorporation of ICT indicators into the national EMIS through the a2i program enabled better targeting of training interventions and identification of districts requiring additional support. Conversely, contexts where EMIS did not include ICT-specific metrics struggled with data gaps, making it difficult to monitor program effectiveness or allocate resources efficiently. The findings underscore that embedding ICT-related data fields within existing EMIS structures can enhance accountability, inform continuous improvement efforts, and institutionalize technology integration as a dimension of educational quality assurance systems. However, successful EMIS utilization requires not only technical system development but also capacity-building among education administrators to collect, analyze, and act upon the generated data effectively.

DISCUSSION

The finding that curriculum and content design aligned with pedagogy significantly enhances the sustainability of ICT teacher training aligns strongly with earlier research in the field. Cerveró et al., (2011) emphasized that ICT initiatives tied directly to subject-matter pedagogy create deeper impacts than generic technology training. Similarly, Voogt et al. (2011) highlighted that integrating technological, pedagogical, and content knowledge (TPACK) leads to more transformative

teaching practices. The review findings confirmed that programs explicitly connecting ICT skills with curriculum delivery achieved higher classroom application rates, mirroring the experiences observed in projects across Singapore Selwyn (2007) and Zhang (2008). In contrast, earlier studies that promoted stand-alone digital literacy courses without pedagogical integration (Tondeur et al., 2009) frequently reported poor classroom adoption, reinforcing the critical importance of curriculum alignment. The findings thus corroborate prior conclusions that sustainable ICT integration depends not just on the mastery of technology itself, but on its meaningful embedding within teachers' instructional frameworks.

The second major finding—highlighting the effectiveness of blended learning, peer mentoring, coaching, and hands-on practice—also echoes established research. Selwyn (2007) emphasized the value of peer support networks and mentoring systems for building teacher ICT confidence and sustaining engagement over time. Davis et al. (2009) similarly demonstrated that blended learning models, offering flexibility and experiential learning opportunities, significantly enhance professional development outcomes. The present review reinforces these conclusions, finding that teacher training programs combining multiple modalities of learning—particularly hands-on exercises linked to actual classroom application—resulted in more durable skills acquisition. Programs relying solely on theoretical lectures, as critiqued by Sandholtz and Reilly (2004), were less effective at catalyzing long-term instructional change. Thus, the findings strengthen existing literature advocating for multimodal, experiential, and collaborative approaches to ICT teacher training, particularly in resource-constrained contexts where continuous support is critical for sustained practice.

The review's finding that infrastructure and connectivity gaps constitute significant barriers to ICT teacher training effectiveness is consistent with a wide range of earlier research. Sang et al. (2010) documented how poor infrastructure in African and South Asian schools systematically hindered the translation of ICT training into classroom use. Similarly, Newton (2003) observed that lack of reliable electricity and device maintenance support often led to rapid abandonment of technology even after teachers received substantial training. The current review's results echo these concerns, showing that without stable power, internet access, and functional devices, teacher motivation to integrate ICT quickly erodes. This pattern parallels findings by Webb and Cox (2004) in Nepal and in Rwanda, who emphasized that infrastructure deficits are not just technical issues but critical determinants of educational inequality. Thus, the present findings reinforce the argument that investments in teacher capacity building must be accompanied by parallel investments in infrastructure to ensure lasting impact.

Regarding the pivotal role of Ministries of Education, donor agencies, and NGOs, the findings align closely with conclusions drawn by Lane et al. (2004). Law (2009) demonstrated that ICT programs integrated into national education strategies achieved far greater reach and sustainability than isolated projects led by external actors. The present review supports this, revealing that when Ministries of Education provide clear policy frameworks, resource allocation, and institutional support, ICT teacher training initiatives are more likely to be scaled successfully. Earlier studies by Yurdakul and Çoklar (2014) also indicated that government ownership combined with donor technical assistance and NGO implementation expertise creates an ecosystem conducive to sustainable change. Conversely, as Mooij and Smeets (2001) noted, ICT projects that remained fragmented or donor-driven often faltered when external funding ceased. The findings thus validate previous calls for coordinated multi-stakeholder approaches, institutional embedding, and policy coherence to ensure the longevity and effectiveness of ICT integration efforts in teacher education.

The findings on sustainability indicators such as ICT usage rates, teaching innovation, and student engagement resonate strongly with earlier research establishing these metrics as critical evaluation criteria. Tondeur et al. (2008) stressed that frequent and meaningful use of ICT in classroom practices serves as a stronger indicator of training success than initial certification completion. Similarly, Webb and Cox (2004) argued that transformative teaching strategies, enabled through ICT tools, demonstrate deeper integration than substitutional uses like using projectors as electronic blackboards. The review confirmed that when ICT training programs monitored changes in teaching strategies and student engagement levels, they were better able to adapt and improve. This is consistent with the findings by Zhang (2003), who demonstrated that transformational ICT usage correlates with improvements in critical thinking and collaborative learning skills among students. Therefore, the current review not only supports but extends the existing evidence that sustainability

metrics must capture dynamic teaching behaviors and student interactions, not just static usage statistics.

The limited presence of longitudinal evaluations and follow-up studies identified in the review parallels concerns raised by earlier researchers about the short-term orientation of ICT program assessments. Hassan (2012) noted that many evaluations focus on immediate outputs rather than tracing long-term impacts on teacher practice. The findings from this review, which reveal significant declines in ICT integration over time in the absence of ongoing support, align with longitudinal findings reported in Kenya and in Bangladesh. Kirkup and Kirkwood (2005) emphasized that sustained professional development, combined with periodic skill reinforcement, is essential for lasting educational change. The scarcity of longitudinal data in the reviewed studies reflects a broader pattern within the field where pressures for quick reporting and demonstration of outcomes often outweigh the commitment to multi-year tracking. As earlier literature suggests, longitudinal research is crucial for capturing the complex, evolving nature of teacher learning and technology integration over time, a view strongly reaffirmed by the current review. Furthermore, the finding that local Education Management Information Systems (EMIS) can play a transformative role in ICT program monitoring and evaluation is strongly supported by prior studies advocating for data-driven education reform. So and Kim (2009) highlighted that EMIS systems equipped with ICT-specific indicators enable real-time tracking of teacher competencies and classroom technology usage. The review's finding that integrating ICT metrics into national EMIS structures, as seen in Bangladesh's a2i initiative, strengthens program management and accountability confirms earlier observations by UNESCO. Mooij and Smeets (2001) also emphasized that decentralized EMIS models allow for more localized responsiveness, addressing the unique needs of individual schools and districts. In contexts where EMIS lacked ICT monitoring components, studies such as Pelgrum (2001) demonstrated that policymakers struggled to identify support needs or measure program effectiveness. Therefore, the present findings reaffirm the importance of embedding ICT usage and impact metrics within broader educational data systems to enhance decision-making, resource targeting, and program sustainability.

CONCLUSION

This systematic review critically examined the sustainable integration of ICT in teacher training programs within developing countries, focusing on curriculum alignment, training methodologies, infrastructural barriers, institutional leadership, sustainability indicators, longitudinal evaluations, and monitoring mechanisms. The findings consistently revealed that pedagogically aligned ICT curriculum designs, experiential blended learning models, and strong peer mentoring structures significantly enhance the long-term integration of technology into teaching practices. However, systemic infrastructural gaps, particularly in low-income and rural areas, continue to undermine the scalability and effectiveness of these initiatives. The critical role of Ministries of Education, donor agencies, and NGOs in anchoring ICT programs within national education strategies emerged as a fundamental factor influencing program sustainability, underscoring the need for institutional ownership and multi-stakeholder coordination. Furthermore, the review emphasized the importance of tracking sustainable impacts through dynamic indicators such as technology usage rates, teaching innovation, and student engagement outcomes rather than relying solely on training completion statistics. The scarcity of longitudinal studies highlighted a persistent weakness in the global evaluation of ICT teacher training initiatives, limiting understanding of the long-term trajectories of technology integration. Additionally, the integration of ICT metrics into local Education Management Information Systems (EMIS) was identified as a powerful but underutilized tool for enhancing accountability and data-driven program refinement. The review also illuminated significant gaps in current literature, notably the underrepresentation of rural schools and the insufficient incorporation of teacher-led, context-sensitive models that prioritize participatory design and socio-emotional support. Collectively, the synthesis of 133 reviewed articles, cited over 70,000 times, underscores that sustainable ICT capacity building for teachers is not merely a function of technical skill acquisition but a complex, systemic process requiring aligned curricula, continuous institutional support, infrastructural readiness, participatory approaches, and rigorous, ongoing evaluation embedded within national education systems.

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