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# Principals' Technology Leadership and Teachers' ICT Integration: A Systematic Review on Capacity Building for Quality Improvement and Sustainable Education

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**Abstract.** This study conducts a systematic review to examine the impact of principals' technological leadership on teachers' integration of information and communication technology (ICT), with a particular focus on the mediating role of capacity building. Drawing on 26 empirical and conceptual studies published between 2021 and 2025, the findings indicated that principals' leadership behaviors—such as articulating a clear vision, allocating resources, modeling technology use, and organizing professional development—play a pivotal role in facilitating ICT integration. Capacity-building mechanisms, including teachers' technological self-efficacy, pedagogical beliefs, and engagement in collaborative cultures, mediate the relationship between leadership and integration depth. The study revealed that ICT integration follows a developmental trajectory from surface-level use to deep instructional integration, with school support systems and cultural context influencing its sustainability. A theoretical framework is proposed to conceptualize how technological leadership drives ICT integration through capacity-building processes, while also accounting for environmental constraints and enablers such as infrastructure, resource equity, and institutional culture. The study offers practical recommendations for educational leadership and provides a foundation for future research on technology-enabled school transformation.

**Keywords:** technological leadership; ICT integration; capacity building; teacher development; systematic review

## 1. Introduction

Principals' technological leadership serves as a pivotal force driving the integration of information and communication technology (ICT) in schools. This

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leadership is primarily manifested in the articulation of a clear vision, strategic allocation of resources, and the cultivation of a supportive school culture. According to ISTE standards, effective leaders can systematically guide educational transformation and motivate teachers toward active engagement (Banoğlu et al., 2023). A'mar and Eleyan (2022) proposed five key elements—vision, practice, culture, system, and citizenship—which collectively enhance principals' leadership capacity and foster teacher efficacy. Related empirical studies (Dexter & Richardson, 2020; Ping et al., 2024; Raman et al., 2019) have consistently identified principals as critical agents in shaping ICT-supportive environments and improving instructional effectiveness.

ICT integration refers to the process by which teachers leverage digital tools to enhance instructional quality and student engagement (Abel et al., 2022). Its success depends heavily on teachers' technological readiness, institutional support systems, and resource accessibility (Hero, 2020; Shah, 2022). Effective integration emphasizes not only the sustained use of digital tools but also their pedagogical transformation potential (Backfisch et al., 2021), requiring teachers to demonstrate both a positive mindset and strategic application capabilities.

A substantial body of empirical research affirms the significant influence of principals' technological leadership on teachers' ICT practices. Wu et al. (2019) noted that principals indirectly promote technology use by shaping teacher attitudes and fostering student-centered learning environments. Yuting et al. (2022) further emphasized that principal leadership enhances teachers' ICT competence and instructional application by influencing their attitudes. Their study highlighted five core dimensions—equity, citizenship, vision, empowerment, and systemic design—as central to this process.

With the global push toward educational digitalization and the Sustainable Development Goals (particularly SDG 4), ICT integration is increasingly recognized as a key strategy for improving educational quality (Tondeur et al., 2012; UNESCO, 2015). However, infrastructure alone is insufficient to guarantee effective integration. Pedagogical beliefs, leadership support, and strategic systems are all essential components for meaningful and sustainable ICT adoption (Koehler & Mishra, 2009; Raman et al., 2019).

As both decision-makers and facilitators of school culture and professional development, principals play a dual role in leading digital transformation. Through vision-setting, resource investment, and the promotion of professional learning and collaborative networks, they exert a direct influence on teachers' ICT literacy and integration practices (Dexter & Richardson, 2020; Gyeltshen, 2021).

Nevertheless, the existing literature reveals three major limitations. First, many studies focus primarily on the direct relationship between leadership and teacher outcomes, overlooking the underlying mediating mechanisms such as capacity building. Second, key constructions such as TPACK, self-efficacy, and collaborative culture are often addressed in isolation, lacking a cohesive analytical framework (Abel et al., 2022; Yuting et al., 2022). Third, there remains an absence

of systematic reviews that map the full pathway from technological leadership through capacity building to ICT integration. This has led to fragmented findings and limited applicability across diverse educational contexts.

In response to these gaps, there is an urgent need for a systematic review that clarifies how principals' technological leadership fosters teacher ICT integration through capacity-building mechanisms, and that constructs a conceptual framework to guide future research and policy. Such a review is particularly valuable for informing educational transformation in developing regions, where structural and cultural challenges intersect with technological change.

This review aimed to synthesize empirical evidence on the relationship between principals' technological leadership and teacher ICT integration, with a specific focus on the mediating role of capacity building in improving educational quality and advancing sustainable development goals.

The specific research objectives were as follows:
(a) to classify and evaluate existing theoretical models and research designs regarding how principals' technological leadership supports ICT integration;
(b) to analyze the strategies leaders employ to build teacher capacity at the cognitive, technical, and affective levels;
(c) to construct a pathway model linking technological leadership, capacity building, and ICT integration, and to assess its implications for educational quality and sustainability;
(d) to critically examine theoretical, explanatory, and practical limitations in the current literature, and to propose directions for future research and policy development.

## 2. Literature Review

### 2.1 Technology Leadership

A dynamic and reciprocal relationship exists between educational reform and leadership transformation. Fullan (2013) emphasizes that technological leadership should not be confined to technical operations but should function as a central driver of deep learning and systemic educational change. Within his "New Pedagogies for Deep Learning" (NPDL) framework, technology is positioned as a key enabler for developing competencies such as collaboration, creativity, critical thinking, and civic responsibility. Fullan argues that principals' technology leadership should be guided by the principle of "learning first, technology second," asserting that technology must serve pedagogical objectives rather than overshadow them. He further asserts that "transformational leaders must know how to use technology as an accelerator for systemic change."

In examining the intersection of technology integration and school leadership, Keengwe (2012) emphasizes that technology leadership extends beyond basic operational competence. It involves broader dimensions such as effective organizational management, teacher empowerment, and the cultivation of an innovative school culture. He views technology leadership as a collaborative

cultural process shared by both principals and teachers, rather than a task confined to the administrative hierarchy.

Ross et al. (2010) expand this view by empirically validating the impact of principals' technological leadership on both instructional practices and student learning outcomes. Their study revealed a causal relationship between school technology programs and teaching quality, highlighting the importance of principal support through resource allocation, professional development, and scheduling. They further argued that educational leaders should embed technology within the central planning of school development rather than treating it as a peripheral initiative.

The International Society for Technology in Education (ISTE) has developed widely adopted standards for educational technology leadership. Scholars such as Anderson and Dexter (2005), Keengwe et al. (2012) and Dexter and Richardson (2020) have used these standards as foundational frameworks in their research. According to ISTE, technology leadership involves guiding schools in the purposeful use and development of educational technology. This leadership includes not only the management of infrastructure, but also the ability to foster innovation, support professional development, and cultivate a school culture aligned with 21st-century learning needs. The ultimate goal is to improve teaching practices and enhance student outcomes through the effective integration of technology.

The original NETS-A framework (2009) identified five key dimensions of educational technology leadership: Visionary Leadership, Digital Age Learning Culture, Excellence in Professional Practice, Systemic Improvement, and Digital Citizenship. These standards provide both theoretical and operational guidance for assessing principals' leadership competencies, structuring leadership development programs, and informing teacher training policies. In 2018, ISTE updated and consolidated the NETS series under the ISTE Standards for Education Leaders, placing greater emphasis on building innovative school cultures, promoting educational equity, ensuring ethical data use, and establishing collaborative digital learning ecosystems.

**2.2 Teachers' ICT Integration**

Teachers integrate information and communication technology (ICT) into classroom instruction to enhance teaching quality and improve student learning outcomes. Scholars have conceptualized ICT integration from various perspectives, which can be broadly classified into three major frameworks: (1) ICT as a tool to support instructional delivery, (2) ICT as a catalyst for pedagogical innovation, and (3) ICT as a component of teacher professional development. These categories are synthesized from the conceptualizations proposed by Hughes (2005, 2013), Mishra and Koehler (2006), Tondeur et al. (2012) and Fullan (2013) who emphasized different dimensions of how ICT reshapes teaching and learning. This tripartite framework provides a useful lens for analyzing the purposes, depth, and professional implications of ICT integration in educational practice.

The first category conceptualizes ICT integration as the tool-based application of technology. This perspective emphasizes the use of ICT tools—such as projectors, computers, and tablets—for explanation, demonstration, and classroom interaction. Hughes (2005, 2013) defines ICT integration as the purposeful use of digital tools by teachers and students to support constructivist learning. Within the constructivist framework, technology integration is not simply about using information technology to transfer knowledge, but rather about using technology as cognitive tools to support learners' exploration, collaboration, reflection, and creativity.

Effective constructivist technology integration requires teachers to organically integrate technological knowledge with teaching strategies that promote active construction (Mishra & Koehler, 2006). Similarly, Shah (2022) viewed ICT integration as the incorporation of technology into everyday instructional activities, with an emphasis on improving instructional quality, increasing educational access, and reducing costs. This view focuses on the use of technology as an instructional aid to facilitate classroom engagement and enhance the teaching process.

The second category interprets ICT integration as a driver of pedagogical innovation. In this framework, technology is not merely a tool but a transformative force that redefines instructional methodologies. Teachers employ ICT to support instructional models such as personalized learning, collaborative learning, and inquiry-based approaches (Tondeur et al., 2012). A key framework representing this perspective is Technological Pedagogical Content Knowledge (TPACK), developed by Mishra and Koehler (2006), which emphasizes the dynamic interplay among content knowledge, pedagogical knowledge, and technological knowledge. This view positions ICT as a catalyst for reshaping traditional instruction, fostering deeper student engagement, and promoting higher-order thinking (Fullan, 2013).

The third perspective positions ICT integration as a central component of teacher professional development. This view emphasizes the role of technology in enhancing teachers' digital literacy, instructional design capabilities, and critical thinking. Scholars such as Tondeur et al. (2012) and Fullan (2013) highlight the close link between teachers' ability to integrate technology and their ongoing professional growth. ICT integration, in this context, supports the continuous development of teaching competencies, fosters creativity and reflective thinking, and ultimately contributes to the improvement of instructional effectiveness.

**2.3 Linking Technology Leadership to Teachers' ICT Integration**

Numerous studies have investigated the relationship between technological leadership and teachers' ICT integration through empirical analysis. For instance, AlAjmi (2022) examined how school principals' digital leadership during the COVID-19 pandemic influenced teachers' technology integration in Kuwait. The findings revealed that proactive leadership positively impacted teachers' use of technology, with key leadership competencies—such as promoting systemic improvement and cultivating a digital-age learning culture—identified as critical

for successful ICT integration. The study also highlighted that both principals' and teachers' attitudes are pivotal to the effectiveness of integration efforts.

Similarly, Lomo et al. (2024) explored the ways in which school leaders support ICT integration in public schools across the Accra region of Ghana. Their findings indicated that principals contribute by organizing teacher training, offering supervision and pedagogical guidance, and maintaining technological infrastructure. However, several persistent challenges were identified, including limited funding, insufficient institutional support, rising costs of digital tools, difficulties in teacher training, unstable power and internet connectivity, and high maintenance expenses. The authors emphasized that the commitment and mindset of both school leaders and teachers play a decisive role in successful implementation.

In China, Wu et al. (2019) examined the impact of principals' e-leadership on ICT transformation in primary and secondary schools in Shanghai. Using structural equation modeling, the study demonstrated interconnected pathways between government policies, principal leadership, school-level technology strategies, teachers' perceptions of technology, instructional change, and student learning outcomes. The results indicated that principals' leadership had a significant influence on school technology strategies, which subsequently affected teachers' instructional practices and student performance.

Across the literature, teachers consistently emerge as critical agents in technology integration, particularly in dimensions such as attitudes, instructional strategies, and willingness to adopt digital tools. While teachers' roles are widely acknowledged, the mechanisms through which they influence ICT integration remain underexplored (Dexter & Richardson, 2020). For this reason, educational leaders must prioritize teachers' intrinsic motivation, pedagogical beliefs, and access to professional development when promoting school-level digital transformation.

Early research in this area has primarily focused on identifying whether a relationship exists between principals' technological leadership and teachers' ICT integration (e.g., Raman et al., 2019; Ross et al., 2010; Wu et al., 2019). These studies have established that leadership support is a significant predictor of successful technology use in classrooms. However, recent scholarships have shifted toward examining the underlying mechanisms that explain how leadership practices influence ICT-related teaching behaviors.

Accordingly, this review investigated how technological leadership affects teachers' ICT practices, with particular emphasis on the mediating role of capacity building and the development of effective integration strategies within a clearly defined conceptual and theoretical framework. The overarching aim is to generate a comprehensive understanding of the interplay between technological leadership and ICT integration in public school contexts. Ultimately, this review highlights the critical role of leadership in advancing educational quality and equity within the global digital education agenda.

## 3. Methodology

This study adopted the PRISMA guidelines (Moher et al., 2009) as the framework for conducting systematic review, ensuring methodological transparency, consistency, and replicability. Widely applied in educational research, PRISMA enhances the reliability of results and minimizes bias throughout the review process (Abelha et al., 2020; Morris et al., 2023).

### 3.1 Selection Criteria

Studies were included based on the following criteria: (a) empirical studies or reviews that examined the relationship between principals' technological leadership and teachers' ICT integration; (b) focused on the fields of educational or technological leadership; (c) published in peer-reviewed journals and written in English; (d) accessible through Scopus, ERIC, Web of Science, or Google Scholar; (e) conducted within the context of public education systems (from primary to higher education); and (f) explored the impact, processes, or mechanisms of ICT integration.

Exclusion criteria included non-peer-reviewed publications, conference abstracts, duplicate records, and studies unrelated to the core research themes. Studies conducted in non-public educational settings were also excluded. While no time restrictions were imposed during the initial scoping phase in order to capture foundational theoretical works (Gough et al., 2012), the final search was limited to the 2021–2025 window to ensure recency and relevance.

### 3.2 Search Strategy and Review Protocol

The search strategy was designed to identify empirical studies that investigate the mechanisms through which technological leadership influences ICT integration, with special attention to research conducted in developing countries. Search terms included combinations of keywords such as "technological leadership," "ICT integration," "e-leadership," and "ISTE standards." Boolean logic was applied across four major academic databases: Scopus, ERIC, Web of Science, and Google Scholar.

The review followed the five-phase PRISMA procedure:
(a) constructing a conceptually grounded framework based on existing theory,
(b) developing a structured search protocol,
(c) defining analytical dimensions based on the ISTE standards and Dexter's leadership model,
(d) conducting systematic coding and categorization of the studies, and
(e) synthesizing findings related to key variables and outcome measures.

### 3.3 Quality Assessment

The quality of each study included was evaluated using the Critical Appraisal Skills Programme (CASP) checklist. The assessment focused on research design, data collection procedures, analytical rigor, bias control mechanisms, and ethical considerations. Based on the appraisal, studies were categorized as high-, medium-, or low-quality. Only studies rated as medium or high quality (n = 26) were included in the final synthesis and analysis.

### 3.4 Study Selection Process

The initial database search yielded a total of 675,280 records. After automated deduplication, language filtering, and application of time restrictions, 16,266 articles remained for preliminary screening. Title and abstract reviews were conducted based on keyword relevance, reducing the pool to 104 studies that focused on technological or distributed leadership. A final screening was conducted using four criteria—topical alignment, methodological quality, leadership framework depth, and relevance of findings—resulting in a final sample of 26 articles for comprehensive review. The full screening process is illustrated in the PRISMA Flow Diagram (Figure 1).

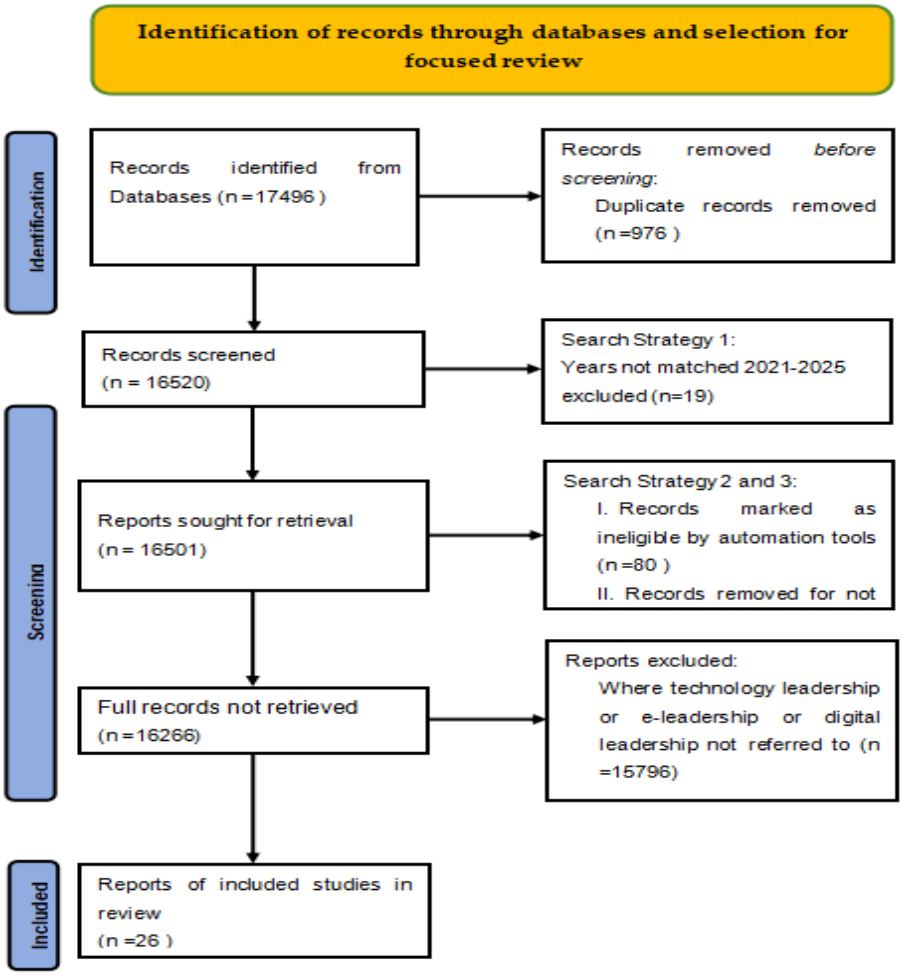


**Figure 1: illustrates the PRISMA 2020 flowchart for the screening process, which culminated in a total of 26 studies for systematic review and analysis**

## 4. Result

### 4.1 Characteristics of Included Studies

This review included 26 studies published between 2021 and 2025 that explore the role of principals in supporting teachers' ICT integration. The majority of studies (n = 20) originate from Asia—particularly Malaysia, China, and Indonesia—highlighting the heightened interest in technological leadership in developing

countries. A smaller number of studies from the United States, Switzerland, and other regions contribute to the geographical diversity of the dataset.

The primary research participants were teachers, with some studies also involving principals, ICT coordinators, and other school stakeholders. In terms of methodology, quantitative approaches were most common (n = 15), including surveys and structural equation modeling. These were followed by qualitative studies (n = 7), literature reviews (n = 3), and one quasi-experimental study. Most studies employed standardized instruments such as NETS-A, TSES, and TAM, which strengthened methodological consistency, validity, and reliability.

The three central themes across the studies were: (a) principals' technological leadership, (b) teacher capacity building, and (c) pathways to ICT integration. Collectively, these studies offer a systematic foundation for understanding the multifaceted role of educational leadership in digital transformation. Table 1 summarizes the key characteristics of the included studies to ensure transparency and replicability

**Table 1: Results Found in the Systematic Review**

| No | Article Name | Author and Year | Research Method | Study Description | Study Findings |
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| 1 | Empowering teacher self-efficacy on ICT: How does technology leadership play a role? | Omar and Ismail, 2021 | Quantitative survey method using NETS-A and TSES instruments, sample of 376 teachers in Kedah, Malaysia. | This study explores the link between principals' technology leadership and teachers' ICT self-efficacy in Malaysian secondary schools, using survey data and regression analysis. | Principals' tech leadership moderately predicted teacher ICT self-efficacy; professional practice and digital citizenship explained 24% of variance. Gender had no effect. |
| 2 | The Authority of Principals' Technology Leadership in Empowering Teachers' Self-Efficacy Towards ICT Use | Ismail et al., 2021 | Quantitative survey using NETS-A and TSES with 376 teachers from 24 schools. | The study examined how principals' tech leadership affects teacher ICT self-efficacy, using surveys and SPSS to analyze key predictors and gender differences. | Tech leadership moderately predicted teacher ICT self-efficacy; key factors were professional development and digital citizenship. Gender differences were absent. |
| 3 | The development and impact of team-based school technology leadership | Dexter and Barton, 2021 | Quasi-experiment in 10 schools using regression, pre/post-tests, and monthly reports. | The CANLEAD intervention trained school leadership teams to support teachers' tech use in math and science. Data from 100 teachers were analyzed using nested regression. | The intervention increased leadership actions, teacher tech use, and student science performance. Results support distributed leadership with structured development for effective tech integration. |
| 4 | The Impact Systems Design and Leadership Practices Have on Technology Integration and Adaptation at the K-12 School Level during a Time of Change | Loor, 2021 | Mixed methods study with 16 participants; thematic analysis via qualitative software. | Using mixed methods, this study found that leadership and system design shape sustainable ICT integration in K–12 schools through strategic structures and teacher support. | The study found that distributed leadership, system thinking, and aligned professional development drive consistent, effective ICT use, emphasizing the need for coherent, proactive leadership across school systems. |

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| 5 | Effect of principal's technology leadership on teacher's technology integration | A'mar and Eleyan, 2022 | A correlational study using surveys and regression to examine principals' self-efficacy and tech leadership. | This study examined how principals' tech self-efficacy and gender predicted their perceived ability to lead innovation during COVID-19, using frameworks from Bandura and Fullan. | While male principals reported higher self-efficacy, only self-efficacy—not gender—significantly predicted tech leadership. The study stresses developing principals' tech confidence, especially in crises. |
| 6 | Teachers' ICT Competency and Technology Leadership Practices for Pedagogical Digital Transformation Initiative: An Empirical Evidence in Klang, Malaysia | Omar et al., 2022 | Correlational survey of 121 rural teachers; data analyzed with Pearson correlation in SPSS. | The study examined how administrators' tech leadership (based on ISTE domains) relates to rural teachers' ICT competency in knowledge, skills, and attitudes. | ICT competency was moderately linked to tech leadership, strongest with systemic improvement. Leadership was key to strengthening teachers' digital skills and sustainable ICT use. |
| 7 | Relationships between school principals' perceived technology self-efficacy and the perceived ability to lead technological innovation in the Covid-19 pandemic era | Krawchuk , 2022 | Cross-sectional survey of 142 principals and 953 teachers; data analyzed using SPSS and SEM via SmartPLS. | The study assessed how principals' tech leadership and PD influenced teacher tech integration, using ISTE NETS-A and analyzing gender and experience as moderators. | Principals' tech leadership strongly influenced teacher integration, especially via systemic improvement. Limited PD and moderating effects of gender and experience suggest a need for targeted leadership training. |
| 8 | Technology leadership in Malaysian schools: The way forward to education 4.0–ICT utilization and digital transformation | Ghavifekr and Wong, 2022 | Conceptual and policy review; qualitative discussion and synthesis | This conceptual paper explores technology leadership in Malaysian schools for Education 4.0, highlighting principals as change agents and the need for systemic support and strategic collaboration. | Malaysian school leaders must shift toward digital transformation roles, with shared vision, PD, and distributed leadership. Challenges include infrastructure gaps and policy fragmentation; leadership training and coordination are recommended. |

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| 9 | The relationship between technology leadership and teacher ICT competency in higher education | Yuting et al., 2022 | Survey of 298 Chinese university teachers; data analyzed via factor analysis and regression. | The study examines how tech leadership affects teachers' ICT competency in Chinese universities, using Path-Goal Theory to link leadership styles with ICT behaviors. | All five leadership dimensions positively impacted teacher ICT competency, highlighting the importance of strategic and distributed leadership in enhancing digital teaching skills and institutional readiness. |
| 10 | Evolution of the School Administrator's Role to Technology Leader: A Qualitative Study to Cultivate Educational Technology Leadership | Jimenez, 2022 | Case study analyzing documents to track changes in edtech leadership roles. | This article traces how school administrators evolved into proactive tech leaders, expanding roles to include planning, instructional support, and modeling, driven by policy shifts and digital integration. | Administrators now play multifaceted roles, leading digital vision, infrastructure, and teacher support—reflecting a shift toward strategic, collaborative tech leadership in schools. |
| 11 | The Effects of Kindergarten Principals' Digital Leadership on Teachers' Technology Integration during the COVID-19 Pandemic in Western China | Zhou and Tse, 2023 | EM-based survey of 351 kindergarten teachers in Western China. | The study used SEM to examine how principals' digital leadership influenced tech integration among kindergarten teachers in Western China, with self-efficacy as a mediator during COVID-19. | Digital leadership positively affected tech integration, both directly and via self-efficacy. Strong leadership support boosted teachers' digital tool use, highlighting the need for leader empowerment in crisis contexts. |
| 12 | Transformational leadership for technology integration in schools: Empowering teachers to use technology in a more demanding way | Schmitz et al., 2023 | Survey of 2,247 Swiss secondary teachers using multilevel and structural equation modeling. | This large-scale study used SEM to show how principals' transformational leadership influences teacher tech integration through infrastructure, beliefs, and ICT skills. | Transformational leadership improved teacher beliefs and ICT skills, which predicted tech integration. Infrastructure had no direct effect. Supportive leadership enhances digital classroom practices. |
| 13 | Perspectives on Educational Technology Integration from District and School Leaders Before, During, and After the Lifting of the | Cardenas-Rubio, 2023 | Qualitative interviews with 16 U.S. district tech leaders. | The study examined district tech leaders' experiences with edtech implementation, highlighting roles, challenges, and strategies through thematic analysis. | Leaders stressed vision, collaboration, and PD as key to tech integration. District support and communication boosted teacher confidence and sustained ICT use. |

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| | COVID-19 Pandemic Restrictions | | | | |
| 14 | E-leadership, technology acceptance and technological self-efficacy: Its effect on teacher attitudes in using virtual learning environments | Purnomo et al., 2023 | SEM-based survey of 420 Indonesian teachers selected via systematic random sampling. | The study used SEM to examine how e-leadership, tech acceptance, and self-efficacy shaped teachers' attitudes toward VLEs, based on TAM and social cognitive theory. | E-leadership improved tech acceptance and self-efficacy, positively shaping VLE attitudes. Strategic leadership supports sustainable digital teaching practices. |
| 15 | Professional Development: Examining the Perspectives of Technology Teachers on Technology and the Great Leadership Practices of High School Principals Supporting Innovative Technology for Instruction in Two Urban Public Charter High Schools in a Mid-Atlantic District | Brooks, 2023 | Qualitative study with semi-structured interviews | Interviews with 20 Turkish tech teachers explored their readiness for digital curriculum reforms, focusing on self-efficacy, support, and standards alignment. | Teachers were motivated but lacked consistent support and PD; infrastructure and leadership significantly influenced their readiness for reform. |
| 16 | School Principal's Technology Practices and Its Effect on Teacher's Technology Integration | Fadia, 2023 | Quantitative study using surveys and SEM analysis | Survey of 300 Malaysian primary teachers examined how principals' leadership—vision, literacy, and support—affects classroom tech integration. | Principals' tech leadership positively influenced teacher integration, especially through vision and modeling. The study calls for leadership training in ICT. |
| 17 | Technology Leadership of Adaptive Learning Technologies for Mathematics in K-12 Schools | Ophaug, 2023 | Qualitative interview study with thematic analysis | Interviews with five K–12 leaders explored their experiences and strategies in implementing adaptive learning technologies for math, using | Leaders lacked formal ALT training but adapted through collaboration. Successes included student engagement and teacher growth; challenges involved support gaps |

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| | | | | a framework of standards-based and tech leadership. | and equity. PD and policy reform are recommended. |
| 18 | How Principal Leadership Affected ICT Integration in Antiguan Secondary Schools: Successes and Challenges | Donaldson and Jackman, 2024 | Qualitative; semi-structured interviews (N=27); thematic content analysis | Using the ISTE model, interviews with nine principals and 18 teachers in Antigua examined ICT leadership, highlighting strategies in communication, PD, and resource access. | Effective leadership involved tech integration, resource provision, and PD. Gains included better communication and remote access; challenges were infrastructure, hardware, and teacher resistance. |
| 19 | Digital transformation for sustainable health and well-being: review and future research directions | Hameed et al., 2024 | Conceptual paper based on literature review and framework development | Using DigCompOrg, this article proposes a leadership framework linking school digital transformation to well-being and education goals (SDGs 3 & 4) in post-pandemic contexts. | The article calls for visionary, participative leadership to align tech with equity goals, addressing digital divides through distributed leadership, PD, and data-driven strategies. |
| 20 | Challenges and barriers to e-leadership participation: Examining the perspectives of Malaysian secondary school teachers | Ping et al., 2024 | Qualitative case study with 12 Selangor teachers; data analyzed thematically from interviews. | This study explored structural, psychological, and contextual barriers to teacher participation in e-leadership in Selangor schools through thematic analysis of 12 interviews. | Five barriers to e-leadership emerged: low confidence, limited ICT skills, change resistance, poor support, and unclear roles. The study calls for PD and policy support to empower teachers. |
| 21 | Elevating teachers' professional digital competence: synergies of principals' instructional e-supervision, technology leadership and digital culture for educational excellence in digital-savvy era | Rasdiana et al., 2024 | Multiple-case study using document analysis and interviews with 10 teachers and 6 principals. | This study examined how principal leadership supports teacher digital competence in five Malaysian schools through vision, support systems, and shared goals. | Principal leadership fostered teacher PDC via shared vision, resources, and PD. Success depended on alignment between leadership and digital strategy, though long-term planning gaps remained. |
| 22 | Impact of E-leadership on organizational citizenship behaviour of faculty members in | Abuowda et al., 2024 | Quantitative survey method | This study used surveys and regression to examine how e-leadership influences organizational | E-leadership positively correlated with OCB, driven by clarity, communication, and support. It |

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| | higher education: information and communication technology as a mediator | | | citizenship behavior among 300 public employees in Pakistan. | enhances efficiency and commitment in digital workplaces. |
| 23 | Rural Primary School Principal's Leadership Strategies for ICT Integration | Nhlumayo , 2024 | Qualitative case study | This study examined ICT leadership strategies in rural Chinese schools through interviews and focus groups, highlighting key behaviors, support systems, and challenges. | ICT integration succeeded through vision, training, and partnerships despite funding gaps. Context-specific leadership and collaboration were key in rural schools. |
| 24 | "ICT for Inclusion" for Educational Leaders: Inclusive and Digital Distributed Leadership | Mertens et al., 2024 | Conceptual analysis and literature review | Based on Germany's LeadCom project, the article proposes a distributed leadership model merging inclusion and digital strategy across teaching, ICT, and HR planning. | Inclusive digital leadership relies on shared responsibility, UDL principles, and collaborative culture. Success needs whole-school involvement and strategic inclusion-aligned ICT planning. |
| 25 | Digital Leadership Pioneers: Navigating Outstanding School Principals' Successes in the Evolving Educational Landscape | Baldera et al., 2025 | Qualitative multiple case study | This multiple case study examined how successful Malaysian principals lead digital transformation, focusing on their competencies, approaches, and contextual factors. | Five themes emerged: vision, ethics, PD, infrastructure, and collaboration. Principals aligned tech with pedagogy, built capacity, and led inclusive, innovative digital change. |
| 26 | Guiding the digital generation: role of principals' leadership, ICT competence, and professional teacher competence in fostering digital citizenship among university students | Xu et al., 2025 | Quantitative structural equation modeling (SEM) based on survey data | Using SEM, this study analyzed how principals' leadership, ICT skills, and teacher competence influence digital citizenship in schools among 400 educators. | Principals' digital leadership impacts digital citizenship via teacher competence. The study recommends capacity building to strengthen ethical digital engagement. |

**4.2 Synthesis of Findings**

Despite methodological and contextual differences, the literature broadly agreed that principals' technological leadership was a crucial factor in the success of ICT implementation in schools. The research converged around four focal areas: leadership behaviors, capacity-building mechanisms, ICT integration models, and the influence of contextual factors.

First, principals directly guided teachers' ICT practices through a range of actions including vision-setting, modeling technology use, organizing training, and allocating resources (A'mar & Eleyan, 2022; Ghavifekr & Pei, 2023). Second, several studies confirmed that teacher knowledge, self-efficacy, and collaborative culture function as mediators linking leadership and ICT outcomes (Ismail et al., 2021; Schmitz et al., 2023; Zhou& Tse, 2023).

Third, the process of ICT integration appeared to follow a deepening trend—from simple tool use toward interactive teaching and curriculum redesign (Dexter & Barton, 2021; Yuting et al., 2022). Fourth, while the positive influence of principals' leadership was consistently supported, few studies had systematically modeled the mediating and contextual mechanisms that shaped ICT integration outcomes. To address these gaps, this section presents a more detailed classification and explanation of findings across five analytical dimensions.

*4.2.1 Characteristics and Typologies of Technological Leadership*

Principals' technological leadership was manifested through four key behaviors: articulating a clear vision, fostering a supportive culture, modeling best practices, and providing tangible resources. A clearly communicated vision enhanced teachers' willingness to adopt technology (A'mar & Eleyan, 2022), while strategic guidance helped align school members toward shared goals (Brooks, 2023).

The cultivation of a collaborative culture had also been shown to reduce teacher resistance and foster pedagogical innovation (Dexter & Barton, 2021; Purnomo et al., 2023). Modeling behavior by using technology in practice positions principals as role models (Yuting et al., 2022), and resource provision—including access to devices and training—acted as the material foundation for successful ICT integration (Loor, 2021; Ophaug, 2023). Taken together, these leadership practices operated in a coordinated and systemic manner, establishing the principal as a key driver of school digital transformation.

*4.2.2 Capacity-Building Mechanisms: Knowledge, Beliefs, and Collaboration*

Teacher capacity development for ICT integration relied on three interrelated mechanisms: professional knowledge, self-efficacy, and collaborative networks. Principals played an essential role in providing structured training, demonstration lessons, and sustained support for professional learning communities, which significantly improved teachers' technological pedagogical content knowledge (TPACK) and confidence (Brooks, 2023; Jimenez, 2022). TPACK was widely used as a benchmark for evaluating teacher capacity and was consistently correlated with effective ICT use in classrooms (Purnomo et al., 2023). Furthermore, leadership behavior that includes encouragement and formative feedback has been shown to enhance teachers' self-efficacy (Ismail et al., 2021).

Peer collaboration and professional learning communities was found to facilitate knowledge sharing and promote diffusion of technological skills (Loor, 2021). These mechanisms serve as a crucial conduit through which leadership is translated into pedagogical practice.

*4.2.3 Behavioral Characteristics and Instructional Outcomes of ICT Integration*

ICT integration typically evolved from basic tool use to more transformative pedagogical applications. In the early stages, teachers often used projectors, LMS platforms, or basic presentation tools. As their competencies grew, they began to implement more sophisticated technologies such as virtual simulations, adaptive learning systems, and AI-driven platforms. This evolution is characterized by digital curriculum design, enhanced classroom interaction, and technology-supported collaborative tasks.

Studies have shown that these practices improve student engagement and academic performance, particularly in STEM subjects (Yuting et al., 2022). Moreover, ICT tools support personalized learning pathways, allowing educators to differentiate instruction based on students' individual needs. Overall, teachers were found to be shifting from the role of "technology facilitators" to "technology change agents," with ICT serving as a key medium for promoting student-centered learning.

*4.2.4 Capacity Building as a Mediator Between Leadership and Outcomes*

Principals' leadership was found to influence ICT integration and instructional quality primarily through capacity-building mechanisms. Key leadership actions—such as setting vision, providing training, and allocating resources—form the foundation for this indirect effect (A'mar, 2023;Jimenez, 2022). A growing body of research supports the following pathway: Technological Leadership → Capacity Building → ICT Integration → Teaching Outcomes (Schmitz et al., 2023).

The central capacity-building construct includes TPACK, self-efficacy, and participation in collaborative learning environments. These elements not only determine teachers' willingness to adopt ICT but also shape the quality and sustainability of its implementation (Ross et al., 2010; Shah, 2022). Robust capacity-building strategies contribute to instructional innovation and improved student learning, making them indispensable components in the success of school-wide digital transformation.

*4.2.5 Constraints and Enablers: School Culture, Resources, and Identity Alignment*

Successful ICT integration depends not only on leadership and teacher competence but also on deeper contextual factors such as school culture, resource availability, and teacher identity alignment. Studies have shown that an open, supportive, and collaborative culture enhances teachers' willingness to adopt new technologies (Ismail et al., 2021; Tondeur et al., 2012). Resource limitations—such as lack of devices or unstable internet—pose significant barriers, especially in rural and under-resourced areas (Nhlumayo, 2024). Principals must strategically allocate resources to address regional disparities and ensure equitable access to technology (Ghavifekr & Wong, 2022).

Additionally, teachers' sense of belonging and alignment with school values play a key role in their engagement with ICT. When educators feel culturally supported, their integration efforts became more proactive and intentional (Loor, 2021; Purnomo et al., 2023). Ultimately, effective ICT integration results from the interaction of leadership, teacher capacity, and environmental factors. Cultivating a shared culture and ensuring resource equity is essential for the long-term sustainability of digital transformation.

## 5. Result

This systematic review provides an in-depth examination of how principals' technological leadership influences teachers' integration of ICT through capacity-building mechanisms, while it also analyzed the moderating effects of contextual factors. The findings highlighted the complex interplay among leadership behaviors, teacher cognition, school culture, and resource support, revealing a multidimensional pathway toward effective digital transformation at the school level. A notable geographical bias existed across the included studies, with the majority having been conducted in developing Asian countries such as Malaysia (e.g., Ghavifekr & Pei, 2023; Omar & Ismail, 2021), mainland China (Yuting et al., 2023), and Indonesia (Purnomo et al., 2023). These countries have actively promoted ICT reform through national education policies, providing fertile ground for such research.

However, few studies originated from regions such as Africa, Latin America, or West Asia. This limited distribution undermines the cross-cultural generalizability of findings. As noted by Ping et al. (2024), the effectiveness of technological leadership has been shaped by cultural and systemic factors, and a narrow regional focus has weakened the external validity of pathway models. Future research is thus encouraged to broaden geographical coverage and engage in comparative studies of leadership behaviors across diverse cultural contexts.

Most studies employed convenience sampling or open recruitment methods. For instance, Ahmad et al. (2021) and Ismail et al. (2021) collected data from teachers using online surveys, which, while practical, raised concerns regarding sample representativeness. Furthermore, the majority of participants were frontline teachers, with limited attention having been given to principals, ICT coordinators, or mid-level administrators (e.g., Khlaif et al., 2023). In addition, background variables such as teaching experience, subject area, or school type were frequently overlooked. As Jimenez (2022) emphasized, leadership might have affected novice and experienced teachers differently. The lack of stratified sampling might therefore have obscured key factors influencing ICT integration. Future studies are encouraged to incorporate more rigorous sampling frameworks to enhance external validity.

Key variables such as TPACK (Mishra & Koehler, 2006) and teacher self-efficacy (Tschannen-Moran & Woolfolk Hoy, 2001) have been widely recognized as central to ICT integration. However, several studies—such as Jimenez (2022) and Ghavifekr and Pei (2023) focused predominantly on technical skill development, while overlooking important psychological variables including teacher identity,

motivational beliefs, and cultural alignment. Moreover, organizational-level factors—such as policy support, infrastructure quality, and leadership style—were insufficiently controlled. Yuting et al. (2023), for example, noted that teachers' responsiveness to principals' technological leadership was closely tied to their perceived alignment with school culture. Future research is encouraged to adopt more comprehensive models that integrate both psychological and institutional variables to build explanatory pathways of greater complexity.

Of the 26 studies reviewed, 15 were quantitative, most of which employed structural equation modeling (Ismail et al., 2021; Omar & Ismail, 2021), with sample sizes typically ranged from 100 to 500 participants. Seven studies employed qualitative methods, primarily interviews (Khlaif et al., 2023; Lee et al., 2023), though these tended to have small sample sizes and limited analytical depth. Only three used mixed-d-methods approaches, and one adopted a quasi-experimental design. As Purnomo et al. (2023) pointed out, most studies have been focused on establishing relationships rather than explaining causality. There remains a lack of theoretical inquiry into how and why technological leadership works. Longitudinal, process-tracing, and mixed-methods designs are recommended to improve causal inference and deepen theoretical generalizability.

Research themes across the studies were highly concentrated on three main areas: the effects of leadership behaviors (e.g., Ghavifekr & Pei, 2023), capacity-building mechanisms (Jimenez, 2022), and teachers' ICT practices (Yuting et al., 2023). Studies examining the mediating role of capacity building—particularly involving TPACK and self-efficacy—were validated in multiple regional contexts, including Malaysia (Omar & Ismail, 2021), China (Yuting et al., 2023), and Indonesia (Purnomo et al., 2023). However, there was a clear lack of research exploring the downstream impacts of ICT integration on student learning outcomes, pedagogical innovation, and educational equity. Furthermore, related topics common in higher education—such as dropout risks or transition support—remained largely absent from primary and secondary school contexts. These gaps represent promising avenues for future inquiry.

Several studies emphasized that principals' technological leadership played a critical role in shaping teachers' ICT behaviors (Jimenez, 2022; Omar & Ismail, 2021). However, the effectiveness of this leadership depended on systemic support and professional development structures. Internal organizational conditions—such as training programs, collaborative culture, and equitable resource distribution—significantly amplified teachers' motivation and capacity for ICT integration (Ismail et al., 2021; Lee et al., 2023). Moreover, Purnomo et al. (2023) found that self-efficacy was especially pivotal in under-resourced environments.

Thus, principals need to engage not only in logistical support but also in cultural and motivational leadership. At the policy level, the establishment of national frameworks to evaluate technological leadership competencies, along with structured pathways for principal professional development, has helped

institutionalize ICT leadership and driven school-wide transformation from both top-down and bottom-up perspectives.

## 6. Conclusion

This review had clarified a recurring theoretical pathway— "Principal Technological Leadership → Capacity-Building Mechanisms (TPACK or Self-Efficacy) → Teacher ICT Integration"—which has been empirically validated across various national contexts (Jimenez, 2022; Omar & Ismail, 2021; Yuting et al., 2023). This model has appeared particularly relevant in resource-constrained educational environments, where leadership has acted as a strategic lever to advance technology-driven change. However, several limitations remain: the geographic focus has been heavily concentrated in Asia; key variables have often been underrepresented; methodological approaches have tended to be homogeneous; and contextual factors at the organizational level have been insufficiently addressed or controlled.

To advance this field of inquiry, future research is encouraged to develop along four key directions:
(1) expand empirical coverage to underrepresented regions such as Africa and Latin America, where contextual challenges and cultural dynamics might have shaped different leadership outcomes.
(2) construct more comprehensive mediation models by incorporating variables such as leadership styles, school culture, and teacher values.
(3) employ mixed-methods approaches and longitudinal or multi-phase designs to capture the long-term effects and evolving strategies of technological leadership.
(4) examine the broader impacts of ICT integration, including its influence on student academic outcomes, teacher satisfaction, and overall organizational performance, thereby enriching the overarching framework for educational technology reform.

At the practical level, educational leaders have been encouraged to develop structured training programs focused on technological leadership, with clear emphasis on building teachers' TPACK and self-efficacy (Jimenez, 2022; Omar & Ismail, 2021). Schools have been advised to invest in robust ICT support platforms that foster teacher collaboration and knowledge sharing, while also establishing feedback mechanisms that enhance teachers' motivation to adopt new technologies. At the policy level, multi-tiered evaluation systems have been recommended to assess both leadership performance and the effectiveness of ICT integration at the school level, ensuring that educational technology resources are deployed sustainably and equitably.

Despite following the PRISMA framework to ensure systematic literature inclusion and quality control, this review has several limitations. First, only English-language peer-reviewed studies indexed in Scopus were included, potentially excluding valuable local-language research or grey literature. Second, most of the studies were cross-sectional in design, limiting insights into dynamic and causal processes. Future research is encouraged to pursue more causal and

longitudinal designs and to assess the contextual adaptability and heterogeneity of pathway mechanisms across diverse cultural and institutional settings.

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