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Evaluating ICT integration models and their effects on learning competencies

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ABSTRACT

This systematic review evaluates models of Information and Communication Technology (ICT) integration in education and examines their effects on learning competencies. Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, the review searched Scopus for English-language, peer-reviewed journal articles published from 2014 through 2024. The search identified 117 records, which were used to map the broader research landscape through author-keyword co-occurrence analysis in VOSviewer. After screening and eligibility assessment, 19 studies were retained for systematic evidence synthesis. The bibliometric analysis identified prominent connections among higher education, ICT, e-learning, blended learning, technology adoption, assessment, and learning outcomes. The systematic synthesis showed that ICT-supported approaches can strengthen learner engagement, collaboration, digital competence, and, in some contexts, academic performance. However, the evidence was heterogeneous, and many reported outcomes were based on teacher, student, or administrator perceptions rather than direct competency measures. Positive effects were more consistently reported when ICT use was pedagogically aligned and supported by teacher competence, sustained professional development, reliable infrastructure, managerial commitment, and alignment with curricula and assessment. Frameworks such as Technological Pedagogical Content Knowledge, the Technology Acceptance Model, and instructional-design models help explain different aspects of adoption and implementation, but no single framework adequately captures the technological, pedagogical, and institutional conditions involved. The review concludes that effective ICT integration requires coordinated attention to instructional design, teacher readiness, learner needs, infrastructure, and organizational support. Future research should prioritize longitudinal, comparative, and competency-based evaluations across diverse educational settings.

1. Introduction

The integration of Information and Communication Technology (ICT) has reshaped educational delivery, instructional design, assessment, and communication. Early adoption centered on personal computers, internet access, and digital learning resources, whereas more recent developments have expanded ICT use to learning-management systems, mobile applications, online platforms, data-driven assessment, and interactive learning environments. These developments have supported a gradual movement from predominantly teacher-centered instruction toward more participatory and learner-centered approaches. Nevertheless, technology does not improve learning automatically; its educational value depends on how well it is connected to pedagogy, curriculum, assessment, and learner needs (Arlinwibowo et al., 2022; Timotheou et al., 2023).

Mobile devices and interactive applications have further extended learning beyond conventional classrooms. Smartphones and tablets allow learners to access materials, communicate, collaborate, and complete learning

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activities across locations and schedules. Mobile learning may support motivation and participation because it provides flexible and context-responsive access to educational content (Basil & Ndijuye, 2019; Sautière et al., 2019). Gamification and interactive applications may also increase learner interest and participation, although their effects depend on instructional design, implementation quality, and the characteristics of the learners and learning environment (Oliveira et al., 2021; Procopio, 2024).

Recent developments have extended ICT integration to artificial-intelligence-based applications used for academic support, content generation, feedback, and interactive learning. Lavidas et al. (2024) examined the determinants of humanities and social sciences students' intentions to use artificial-intelligence applications for academic purposes, extending technology-acceptance research to emerging AI tools. Aravantinos et al. (2024) systematically reviewed AI-supported educational approaches in primary-school settings and demonstrated the growing diversity of AI applications across teaching and learning contexts. These studies reinforce the need to evaluate emerging technologies not only according to user interest or adoption but also according to their pedagogical alignment, learner suitability, institutional support, and contribution to demonstrable educational outcomes.

The COVID-19 pandemic accelerated the adoption of online and distance-learning technologies and exposed substantial differences in institutional preparedness. Educational institutions had to transfer courses, assessment, communication, and student support to digital environments within a short period. This transition demonstrated the potential of ICT to maintain educational continuity, but it also revealed weaknesses in infrastructure, teacher competence, learner access, and institutional support (Laumer, 2023; Redhana et al., 2024). Earlier research had already emphasized that successful implementation requires professional development, technical assistance, leadership, and opportunities for educators to apply ICT meaningfully rather than merely reproduce conventional instruction through digital media (Ale et al., 2017; Sahlin et al., 2016). During rapid transitions to online teaching, limited preparation and inadequate resources continued to restrict effective implementation (Akram et al., 2021).

Educational policy has also shaped the scale and direction of ICT integration. Governments and educational authorities increasingly include digital literacy, technology access, innovative pedagogy, and teacher development in national education strategies (Bouchebcheb, 2023; Teoh et al., 2022). Policies targeting rural, low-income, and otherwise underserved populations are particularly important because unequal access to devices, connectivity, and technical support can widen existing educational disparities (Kumar, 2024; Teoh et al., 2022). Where governments and institutions provide sustained infrastructure, training, and implementation support, improvements in digital participation and engagement appear more attainable (Balla, 2024; Kumar, 2024).

Despite these developments, evidence regarding the effects of ICT on learning remains inconsistent. Studies have reported improvements in engagement, digital literacy, access, and selected academic outcomes, but other findings indicate that the effects are modest, context-dependent, or difficult to separate from differences in pedagogy and institutional capacity (M. Higgins, 2019; Webbet al., 2017). Higgins et al. (2019), for example, reported only small positive associations between technology use and learning outcomes, while Oliveira et al. (2021) observed that emergency remote education highlighted substantial differences among technologies, users, and implementation conditions. These findings suggest that the presence of technology is a weak indicator of educational effectiveness unless researchers also consider how, why, and under what conditions it is used.

Recent evidence reinforces the importance of contextual conditions. ICT integration is more likely to support learning when institutions provide robust infrastructure, appropriate resources, prepared teachers, and sustained organizational support aligned with curricula and assessment. Evidence from Balkh associated positive ICT-learning relationships with teacher preparedness, resource access, and administrative backing, while also identifying infrastructure barriers requiring targeted intervention (Hakimi et al., 2024). Similar findings from India and Egypt indicate that infrastructure, teacher training, and institutional commitment contribute to more effective ICT use and create stronger conditions for potential learning gains (Rawal, 2024; Badran et al., 2021). Managerial support may also increase the frequency and consistency of educational software use (Szyszka et al., 2022).

Teacher readiness is particularly important because educators must select technologies, connect them to disciplinary content, organize learning activities, and assess whether technology-supported instruction achieves its intended outcomes. Higher levels of teacher digital competence and sustained professional development are associated with stronger ICT implementation and better online-teaching readiness (Dai, 2023; Aidoo et al., 2022; Arhin et al., 2024; Abella & Rosa, 2023). However, positive attitudes do not necessarily lead to regular or

pedagogically meaningful use. Studies in Cambodia, Nepal, and Tanzania have shown that limited access, insufficient training, infrastructure shortages, and weak professional-development provision can constrain implementation even when teachers recognize the value of ICT (Pang et al., 2022; Dawadi, 2022; Shekaoneka & Arthur, 2024). These findings are consistent with earlier evidence that educators may feel unprepared to integrate technology despite increasing expectations that they do so (Basil & Ndiaye, 2019).

The effectiveness of ICT is therefore moderated by interactions among teacher competence, infrastructure, pedagogical design, organizational support, and the characteristics of the educational context. Uneven infrastructure, variable teacher preparation, and weak alignment between technology and pedagogy help explain why similar tools produce different outcomes across settings (Hakimi et al., 2024; Pang et al., 2022; Shekaoneka & Arthur, 2024). Inadequate implementation procedures and insufficient instructional or technical skills may further reduce the educational value of digital tools (Dawadi, 2022). Reliable infrastructure and continuing professional development appear especially important because they allow teachers to move beyond occasional technology use toward sustained integration in teaching, learning, and assessment (Rawal, 2024; Dai, 2023; Aidoo et al., 2022; Arhin et al., 2024; Abella & Rosa, 2023; Szyszka et al., 2022).

Several frameworks have been developed to explain or guide ICT integration. Technological Pedagogical Content Knowledge emphasizes the interaction of technology, pedagogy, and disciplinary content; the Substitution, Augmentation, Modification, and Redefinition model describes different levels of technology-supported task transformation; and the Technology Acceptance Model explains how perceived usefulness and ease of use shape adoption. Other instructional-design and evaluation frameworks focus on implementation processes, institutional readiness, professional development, and program outcomes. Although these models provide useful analytical perspectives, they frequently address only part of the integration process. Some concentrate on teacher knowledge, others on acceptance, task transformation, or program evaluation. Consequently, they may not fully account for the combined influence of infrastructure, leadership, curriculum, assessment, teacher readiness, and learner characteristics.

A further limitation of the literature is that references to “learning outcomes” often combine substantially different forms of evidence. Some studies measure achievement or competency through tests and performance tasks, whereas others infer effects from satisfaction, motivation, engagement, technology-use frequency, or stakeholder perceptions. This distinction is important because positive attitudes toward ICT do not necessarily demonstrate deeper learning, critical thinking, or transferable problem-solving competence. Concerns therefore remain about whether technology-supported activities produce meaningful learning or merely increase access, convenience, and short-term engagement (Webb et al., 2017).

Against this background, the present systematic review critically evaluates ICT integration models and examines their reported effects on learning competencies. The review uses two analytically distinct corpora. The 117 records initially retrieved from Scopus are used to map the broader thematic landscape through author-keyword co-occurrence analysis. The 19 studies that met all eligibility criteria provide the basis for the systematic evidence synthesis. This separation allows the bibliometric analysis to identify broad patterns in the literature while ensuring that conclusions about models, implementation conditions, and learning competencies are derived only from eligible studies.

The review has five objectives: (1) to identify and categorize the principal models and frameworks used to integrate ICT into educational environments; (2) to examine evidence concerning their effects on academic performance, digital competence, engagement, collaboration, and related learning outcomes; (3) to analyze how infrastructure, teacher preparedness, institutional support, and policy conditions facilitate or constrain implementation; (4) to identify methodological and practical limitations in the current evidence base; and (5) to propose directions for research, policy, and educational practice.

The study addresses the following research questions:

1. What models and frameworks are used to guide or evaluate ICT integration in education, and how are they applied across educational contexts?
2. What evidence is available regarding the effects of ICT integration models on learning competencies and educational outcomes?
3. Which teacher-, learner-, institution-, and system-level factors facilitate or hinder successful ICT integration?

4. What conceptual, methodological, and contextual gaps remain in the literature, and what are their implications for future research and practice?

The review is guided by the hypothesis that ICT integration is more likely to produce positive learning-related outcomes when technology use is pedagogically aligned and supported by teacher competence, sustained professional development, reliable infrastructure, appropriate assessment practices, and organizational commitment. Conversely, ICT initiatives are expected to produce weaker or inconsistent outcomes when these enabling conditions are absent.

The study contributes theoretically by integrating evidence on pedagogical models, teacher competence, technology acceptance, institutional readiness, instructional design, and learning outcomes. Rather than treating ICT as an independent intervention, it conceptualizes effective integration as the product of interactions among technology, pedagogy, people, and organizational conditions. This perspective extends earlier efforts to explain the mechanisms through which ICT may influence teaching and learning (Arlinwibowo et al., 2022; Timotheou et al., 2023).

The review also has practical significance. Its findings can help educators distinguish between technology availability and educationally meaningful use, assist institutions in designing professional-development and support systems, and inform policymakers seeking to improve infrastructure and equitable access. These issues became especially visible during the rapid expansion of online and blended learning, which exposed limitations in teacher preparation, resource allocation, and institutional support (Ale et al., 2017; Sahlin et al., 2016). Sustained policies supporting infrastructure, professional development, assessment alignment, and access are therefore essential for realizing the educational potential of ICT (Bouchebcheb, 2023; Teoh et al., 2022).

2. Literature Review

Research on ICT integration in education encompasses digital tools, pedagogical practices, teacher competence, technology adoption, institutional leadership, and evaluation of implementation quality. The literature therefore extends beyond determining whether technology is present in a classroom. It also examines how technology is aligned with disciplinary content, instructional strategies, assessment, learner characteristics, and institutional conditions.

Theoretical and conceptual frameworks in this field serve different purposes. Some frameworks guide the pedagogical integration of technology, others explain technology acceptance and use, and still others address institutional transformation, leadership, or the evaluation of integration quality. Treating these frameworks as interchangeable can obscure important conceptual differences. Accordingly, this review organizes the literature around four functional orientations: pedagogical, technological or adoption-oriented, institutional, and evaluative. This classification provides a basis for comparing prominent frameworks and interpreting their reported relationships with learning competencies.

2.1 Concepts of ICT Integration in Education

ICT integration refers to the purposeful incorporation of digital technologies, resources, and communication systems into teaching, learning, assessment, and educational management. Meaningful integration requires more than classroom access to hardware or software. It involves selecting technologies that support clearly defined curricular objectives, pedagogical activities, assessment practices, and learner needs. From this perspective, technology is not an isolated intervention but one component of a broader instructional and organizational system.

A central goal of ICT integration is the development of digital competence among educators and learners. Digital competence includes the ability to locate and critically evaluate information, communicate and collaborate through digital environments, create digital content, solve technology-related problems, and use technology safely and ethically (Falloon, 2020). For teachers, it additionally includes the ability to select appropriate tools, design technology-supported learning activities, monitor student progress, and evaluate whether technology contributes to intended educational outcomes.

ICT may support learning competencies by enabling interactive, adaptive, and collaborative activities. Multimedia resources, simulations, virtual laboratories, and electronic assessment tools can help learners visualize complex concepts, receive timely feedback, and monitor their progress (Salemink et al., 2017). Online discussion

forums, shared documents, and digitally mediated group projects can also support communication, collaboration, and digital literacy (Schuijff & Dijkstra, 2019). These affordances are particularly relevant to competencies such as critical thinking, problem-solving, collaboration, self-regulation, and information literacy.

Nevertheless, the availability of digital tools does not ensure meaningful integration. Weak internet connectivity, outdated devices, inadequate technical support, and limited teacher preparation remain substantial barriers, particularly in rural and underserved settings (Tondeur et al., 2021). Socio-economic inequalities may further produce unequal access to devices, connectivity, suitable learning environments, and digital support, thereby reinforcing rather than reducing educational disparities (Akram et al., 2021). ICT integration must therefore be evaluated in relation to both instructional design and the conditions under which implementation occurs.

2.2 Learning Theories Underpinning ICT Integration

Several learning theories explain how ICT can contribute to teaching and learning by addressing different dimensions of the integration process. Constructivism emphasizes active knowledge construction, connectivism explains learning through digital networks, Cognitive Load Theory guides the design of multimedia environments, and Diffusion of Innovations Theory accounts for the adoption and spread of technological practices within educational organizations. Together, these perspectives show that effective ICT integration involves cognitive, social, pedagogical, and institutional mechanisms rather than the simple introduction of digital tools.

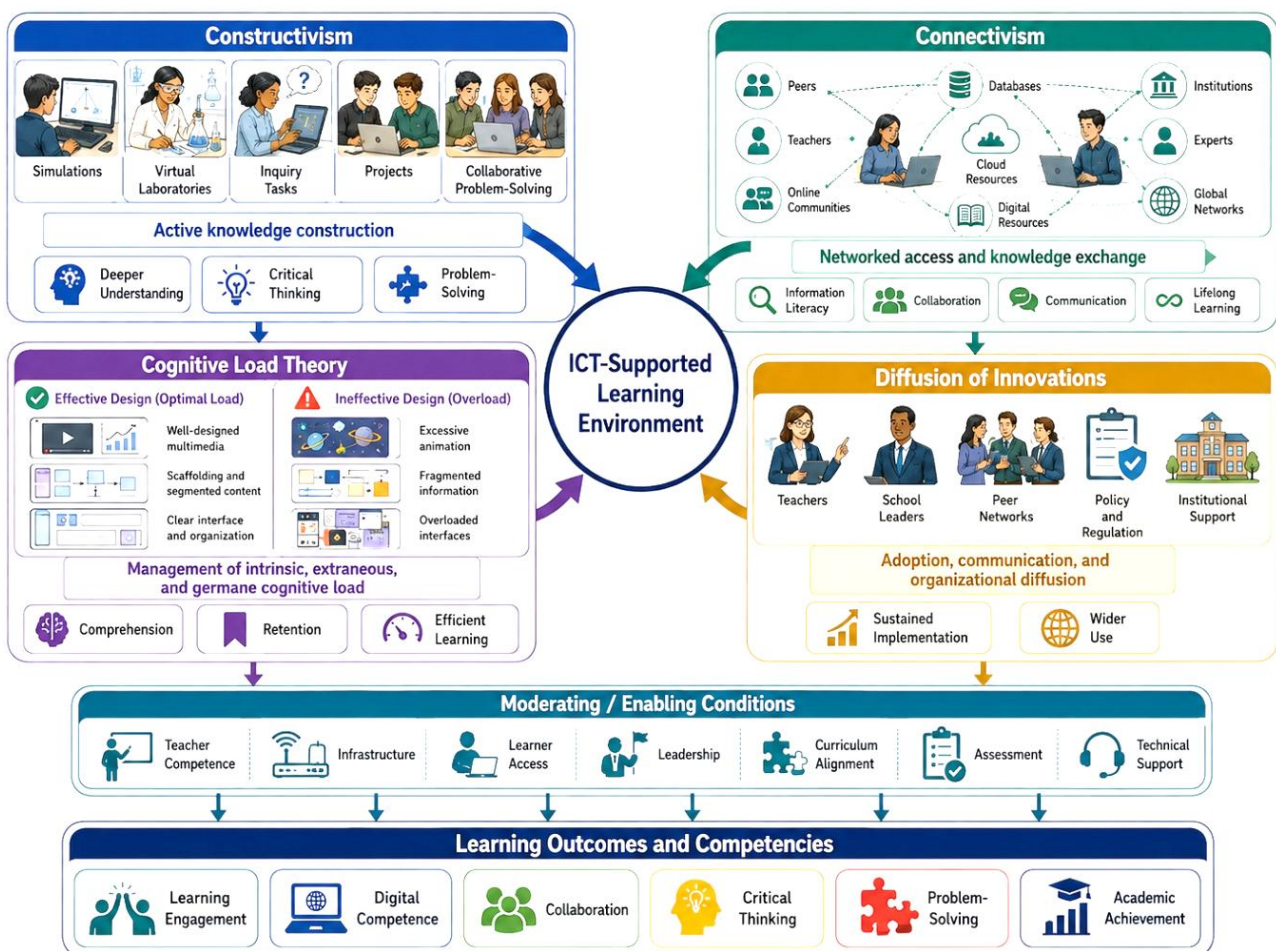


Figure 1. Theoretical mechanisms linking ICT-supported learning environments to learner processes and competencies through constructivism, connectivism, Cognitive Load Theory, and Diffusion of Innovations Theory.

Figure 1 integrates these theoretical perspectives within an ICT-supported learning environment. Constructivism explains how simulations, virtual laboratories, inquiry tasks, projects, and collaborative problem-solving may support active knowledge construction, deeper understanding, critical thinking, and problem-solving.

Connectivism highlights networked access to peers, teachers, experts, institutions, databases, and digital resources, supporting information literacy, communication, collaboration, and lifelong learning. Cognitive Load Theory clarifies why well-organized multimedia, scaffolding, segmentation, and clear interfaces may improve comprehension and retention, whereas fragmented information, excessive animation, and overloaded interfaces may impede learning. Diffusion of Innovations Theory extends the analysis to teachers, school leaders, peer networks, policy, and institutional support that influence whether ICT practices are adopted and sustained. These mechanisms operate through enabling conditions such as teacher competence, infrastructure, learner access, leadership, curriculum alignment, assessment, and technical support, which jointly shape learning engagement, digital competence, collaboration, critical thinking, problem-solving, and academic achievement.

Constructivism conceptualizes learners as active participants who develop knowledge through experience, inquiry, reflection, and interaction. In technology-supported environments, constructivist principles are reflected in simulations, virtual laboratories, inquiry-based tasks, project-based activities, and collaborative problem-solving. These approaches allow learners to test ideas, receive feedback, revise their understanding, and construct meaning rather than passively receive information (Piltan et al., 2017; Zajda, 2021). Their effectiveness, however, depends on appropriate scaffolding, clear learning objectives, and alignment between digital activities and disciplinary content.

Connectivism extends this emphasis on participation by focusing on learning through networks of people, information, technologies, and digital resources. In connected learning environments, knowledge is distributed across multiple sources rather than located solely in an instructor or textbook. Social media, online communities, discussion platforms, shared repositories, and collaborative software enable learners to access diverse perspectives, exchange information, and update their knowledge through continued interaction (Glassner & Back, 2020; Piltan et al., 2017). Connectivism is therefore particularly relevant to information literacy, digital communication, collaborative knowledge construction, and lifelong learning. However, access to extensive networks also requires learners to evaluate source credibility, manage information overload, and participate ethically in digital environments.

Cognitive Load Theory offers a complementary perspective by emphasizing the limitations of working memory during learning. Technology-supported materials can improve learning when they organize information coherently, coordinate visual and verbal representations, segment complex content, and minimize unnecessary processing. Conversely, excessive animation, fragmented interfaces, irrelevant information, simultaneous media elements, or poorly coordinated multimedia may increase extraneous cognitive load and undermine comprehension (De Jong, 2010; Otieno, 2023; Paas & Van Merriënboer, 2020). The educational value of multimedia therefore depends on instructional design quality rather than on the quantity or novelty of digital features.

Diffusion of Innovations Theory explains how new technologies and practices are adopted and sustained within educational organizations. Adoption is influenced by perceived relative advantage, compatibility with existing practices, complexity, opportunities for experimentation, and the visibility of results. Communication networks, peer influence, leadership, policy, technical support, and organizational culture further shape whether an innovation moves from initial experimentation to routine practice (Lawrence & Tar, 2018). The theory is particularly useful for explaining institutional change and differences in adoption rates, although it does not independently determine whether an adopted technology is pedagogically appropriate or improves learning.

Taken together, these theories provide complementary explanations of ICT integration. Constructivism and connectivism describe how learners may construct and exchange knowledge; Cognitive Load Theory informs the design of digital materials and interfaces; and Diffusion of Innovations Theory explains how practices spread and become institutionalized. None of these perspectives alone provides a complete account of integration quality. A comprehensive interpretation must also consider pedagogical alignment, teacher competence, learner characteristics, infrastructure, leadership, assessment, and the strength of evidence concerning educational outcomes.

2.3 Functional Classification of ICT Integration Frameworks

ICT integration frameworks can be classified according to the principal functions they serve. Pedagogical frameworks focus on the relationship between technology, teaching methods, learning activities, and disciplinary content. Adoption-oriented frameworks explain users' intentions and behaviors toward particular technologies. Institutional frameworks address leadership, policy, infrastructure, professional development, and system-wide

change. Evaluative frameworks provide criteria for judging the quality, scope, and practical usefulness of integration. Although these categories overlap, distinguishing them clarifies what each framework can and cannot explain (Mohebi, 2021; Sánchez et al., 2022; Sackstein et al., 2022).

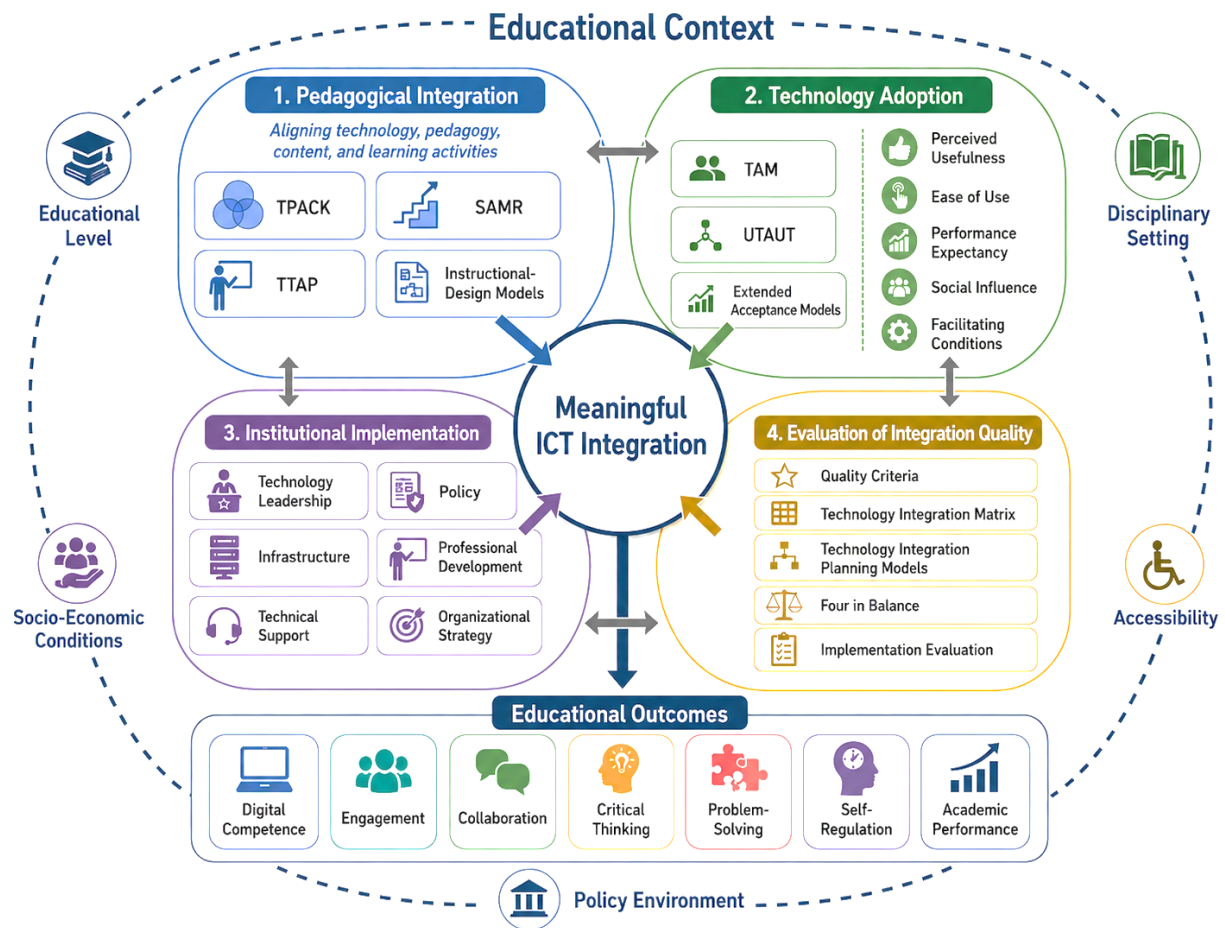


Figure 2. Functional architecture of ICT integration frameworks in education, showing the convergence of pedagogical, adoption-oriented, institutional, and evaluative functions toward meaningful ICT integration and educational outcomes within contextual conditions.

Figure 2 integrates these four functional orientations into a single conceptual architecture. Pedagogical frameworks, including TPACK, SAMR, TTAP, and instructional-design models, guide the alignment of technology with content, pedagogy, and learning activities. Adoption-oriented frameworks, such as TAM and UTAUT, explain how perceived usefulness, ease of use, performance expectancy, social influence, and facilitating conditions shape technology acceptance. Institutional frameworks address the leadership, policy, infrastructure, professional development, technical support, and organizational strategies needed to sustain implementation. Evaluative frameworks assess the quality, coherence, and practical effectiveness of integration through criteria such as the Technology Integration Matrix, Technology Integration Planning models, Four in Balance, and implementation evaluation. The convergence of these functions around meaningful ICT integration emphasizes that no single framework is sufficient. Their effectiveness is also conditioned by educational level, disciplinary setting, accessibility, socio-economic conditions, and the policy environment. Together, these dimensions influence whether ICT contributes to digital competence, engagement, collaboration, critical thinking, problem-solving, self-regulation, and academic performance.

2.3.1 Pedagogical Integration Frameworks

Technological Pedagogical Content Knowledge (TPACK) is a pedagogical knowledge framework that describes the forms of expertise teachers need to integrate technology meaningfully. It includes technological

knowledge, pedagogical knowledge, and content knowledge, as well as their intersections: technological pedagogical knowledge, technological content knowledge, pedagogical content knowledge, and TPACK itself (Mohebi, 2021; Nguyen et al., 2024; Timotheou et al., 2023). The framework emphasizes that effective integration occurs when teachers understand not only how a technology functions but also how it interacts with subject matter, instructional strategy, and learner needs.

TPACK is therefore primarily a framework of teacher knowledge and instructional competence rather than a model of technology adoption. It can guide lesson design, professional development, and assessment of teachers' perceived or demonstrated integration competence. However, high self-reported TPACK does not necessarily demonstrate that teachers use technology effectively in practice or that student competencies improve. Such claims require classroom observations, performance assessments, or direct measures of student learning (Jang et al., 2021; Mohebi, 2021; Sackstein et al., 2022).

The Substitution, Augmentation, Modification, and Redefinition (SAMR) model serves a different pedagogical function. It classifies technology-supported tasks according to the extent to which technology changes their design. Substitution involves replacing a conventional tool without substantial functional change; augmentation adds functional improvement; modification enables significant task redesign; and redefinition enables activities that would otherwise be difficult or impossible (Kharki et al., 2021; Nair & Chuan, 2021; Rahmadi, 2021; Shamir-Inbal & Blau, 2021; Wiyono et al., 2022).

Unlike TPACK, which focuses on teachers' integrated knowledge, SAMR focuses on the transformation of learning tasks. It can support reflection on whether technology merely reproduces conventional instruction or enables new forms of participation, collaboration, representation, and knowledge creation. However, progression toward modification or redefinition should not automatically be interpreted as superior learning. A technologically complex task may remain poorly aligned with curricular goals, learner readiness, or assessment. SAMR therefore describes the nature of task transformation but does not independently measure pedagogical quality or learning effectiveness.

TPACK and SAMR are complementary rather than interchangeable. TPACK addresses the knowledge educators require to make instructional decisions, whereas SAMR describes how technology changes a learning task. Both emphasize pedagogical integration, but neither primarily explains why educators accept or reject a technology.

2.3.2 *Technology-Acceptance Frameworks*

The Technology Acceptance Model (TAM) explains technology adoption through perceived usefulness and perceived ease of use. These beliefs influence attitudes, intentions, and subsequent use. In educational research, TAM is frequently applied to learning-management systems, mobile applications, virtual environments, and other instructional technologies (Asad et al., 2021; Islam & Lum, 2024; Jang et al., 2021). Extended versions may include motivation, social influence, technical support, self-efficacy, or organizational conditions.

TAM differs conceptually from TPACK and SAMR because it explains whether users are likely to adopt a technology rather than how it should be integrated pedagogically. A teacher may perceive a tool as useful and easy to use but employ it only to reproduce teacher-centered practices. Conversely, a pedagogically valuable application may be rejected because it is difficult to use or inadequately supported. Technology acceptance is therefore an enabling condition for integration, but it is not equivalent to integration quality.

The Unified Theory of Acceptance and Use of Technology (UTAUT) provides a broader adoption model. It identifies performance expectancy, effort expectancy, social influence, and facilitating conditions as determinants of behavioral intention and technology use. It also incorporates moderators such as age, gender, experience, and voluntariness (Rahman et al., 2021; Thongsri et al., 2018, 2019; Venkatesh et al., 2012). Compared with TAM, UTAUT places greater emphasis on social and organizational conditions, making it particularly useful for studying technology adoption within schools and universities.

Nevertheless, UTAUT remains primarily an adoption framework. It can explain why teachers or students intend to use technology and how institutional conditions influence that intention, but it does not directly establish whether the resulting instructional practices are well designed or improve learning competencies. Reviews of educational technology frameworks consistently distinguish TAM and UTAUT from pedagogically oriented frameworks such as TPACK and SAMR (Sackstein et al., 2022; Sánchez et al., 2022).

2.3.3 Institutional and Technology-Leadership Frameworks

Institutional frameworks address the organizational conditions required to implement and sustain ICT. Their focus includes strategic leadership, policy, infrastructure, professional development, technical support, resource allocation, organizational culture, and evaluation. This orientation is particularly important because classroom integration is influenced by decisions made beyond the individual teacher.

Technology-leadership models position school and university leaders as agents who establish a shared vision, allocate resources, support teacher development, monitor implementation, and address ethical or legal concerns. Research on digital transformation emphasizes that leadership quality, institutional strategy, access to technology, professional learning, and organizational evaluation shape the depth and sustainability of ICT integration (Bisri et al., 2023; Plageras et al., 2023; Yuliandari et al., 2023). Principal e-leadership, governance arrangements, and institutional decision-making may therefore influence whether individual adoption develops into coordinated organizational change (Razak et al., 2023; Xu & Phongsatha, 2024).

Institutional frameworks differ from TPACK and SAMR because they focus on organizational capacity rather than individual teacher knowledge or task design. They also differ from TAM and UTAUT because they address the governance and support structures through which adoption is enabled, coordinated, and evaluated. Professional digital-competence frameworks may bridge these levels by incorporating pedagogical, technological, ethical, attitudinal, and professional-identity dimensions (McDonagh et al., 2021).

The institutional perspective helps explain why similar technologies produce different results across settings. Teachers with adequate competence may still be unable to integrate ICT when connectivity, technical support, planning time, leadership, or incentives are insufficient. Conversely, extensive infrastructure investment may have limited educational value when institutions neglect pedagogical development and curriculum alignment.

2.3.4 Evaluative and Quality-Oriented Frameworks

Evaluative frameworks differ from adoption models because they are designed to judge the quality, scope, coherence, and practical value of technology integration. Tondeur et al. (2021), for example, proposed criteria for assessing conceptual technology-integration models and determining how effectively they connect research with educational practice. This evaluative orientation considers whether a framework provides adequate theoretical grounding, practical guidance, contextual sensitivity, and applicability to meaningful and sustainable implementation.

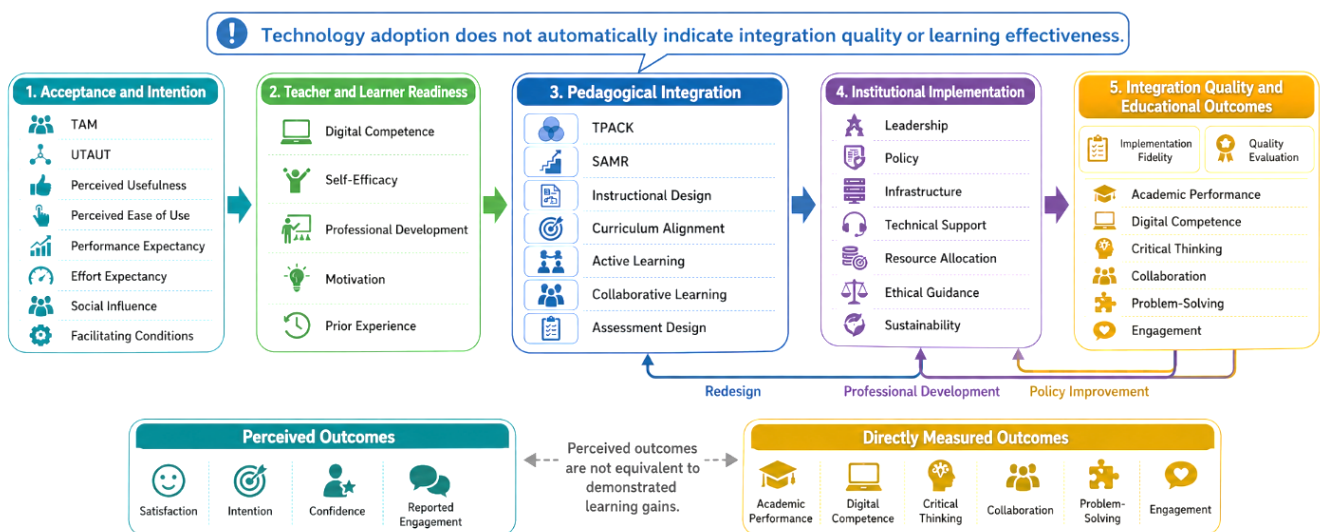


Figure 3. Conceptual pathway from technology acceptance to educational impact, distinguishing acceptance, readiness, pedagogical integration, institutional implementation, and directly measured educational outcomes.

Figure 3 positions evaluation as the final stage of a broader pathway from technology acceptance to educational impact. Acceptance-oriented constructs, including perceived usefulness, ease of use, performance expectancy, social influence, and facilitating conditions, influence whether users are willing to adopt technology.

However, adoption must be accompanied by teacher and learner readiness, pedagogical integration, and institutional support before educational effects can be expected. The figure therefore distinguishes perceived outcomes, such as satisfaction, intention, confidence, and reported engagement, from directly measured outcomes, including academic performance, digital competence, critical thinking, collaboration, problem-solving, and engagement. Feedback pathways further show that evaluation should inform instructional redesign, professional development, and policy improvement. This pathway emphasizes that technology adoption alone does not demonstrate integration quality or learning effectiveness.

Practice-oriented frameworks such as the Technology Integration Matrix, Technology Integration Planning models, and Four in Balance are frequently used to examine how technology is aligned with pedagogy, infrastructure, teacher expertise, leadership, and organizational conditions (Bisri et al., 2023; Sánchez et al., 2022; Tondeur et al., 2021). Unlike TAM and UTAUT, these frameworks are not primarily intended to predict behavioral intention or technology use. Instead, they help educators and institutions evaluate the depth, coherence, enabling conditions, and sustainability of integration.

Neither TPACK nor SAMR alone provides a comprehensive measure of integration quality. TPACK may be used to assess teachers' integrated knowledge, while SAMR may be used to classify the extent of task transformation. However, a broader evaluation also requires evidence concerning implementation fidelity, accessibility, learner participation, curriculum and assessment alignment, infrastructure, leadership, sustainability, and directly measured learning outcomes. Evaluative frameworks are therefore necessary to determine whether technology acceptance and pedagogical use develop into effective, equitable, and sustainable integration (Sackstein et al., 2022; Tondeur et al., 2021).

2.4 Empirical Evidence on ICT Integration

Empirical research generally indicates that ICT can support engagement, digital literacy, collaboration, problem-solving, and selected academic outcomes. However, the magnitude and consistency of these effects vary across technologies, pedagogical approaches, learner groups, and institutional contexts. Positive results are more likely when technology is integrated into active learning, collaborative inquiry, formative assessment, and appropriately designed instructional tasks.

TPACK-informed professional development has been associated with improved teacher confidence, digital competence, and technology-supported instructional design. Jammeh et al. (2024) reported positive outcomes from TPACK-informed implementation in smart-classroom chemistry instruction, while Webb et al. (2017) found that TPACK-related training in nursing education supported digital literacy and engagement. Nevertheless, these findings do not imply that TPACK itself produces learning gains. TPACK functions as a framework for teacher knowledge and professional development, while effects on students depend on how that knowledge is translated into classroom practice.

SAMR-informed implementation has been associated with redesigning tasks to support critical thinking, collaboration, and problem-solving. Teoh et al. (2022) reported that technology-supported task transformation could encourage educators to move beyond direct substitution. However, the educational value of such transformation depends on curriculum alignment, instructional support, and the quality of the learning activities. The use of a higher SAMR category should therefore be interpreted as a description of task change rather than direct evidence of improved competency.

Blended learning combines online and face-to-face instruction and may provide flexibility while preserving interpersonal interaction. Hsu et al. (2017) and Setuju et al. (2023) associated blended approaches with improved engagement, study behaviors, and academic performance in higher-education and vocational contexts. Game-based and gamified learning may similarly support motivation and participation, with Procopio (2024) reporting positive outcomes in elementary mathematics. These approaches are most effective when digital activities are integrated with clear learning goals rather than used primarily for novelty or entertainment.

The empirical literature also contains cautious or inconsistent findings. Higgins et al. (2019) reported relatively small and context-dependent associations between technology use and learning outcomes. Such variability indicates that access to technology is insufficient to explain learning effects. Teacher preparation, infrastructure, socio-economic conditions, instructional quality, implementation duration, and measurement choices may all moderate outcomes (Akram et al., 2021; Basil & Ndijuye, 2019).

A further interpretive problem is that studies frequently use engagement, satisfaction, intention to use, or perceived competence as substitutes for direct learning outcomes. These indicators are educationally relevant, but they do not necessarily demonstrate improvements in academic achievement, critical thinking, collaboration, or problem-solving. Empirical claims should therefore distinguish measured competencies from stakeholder perceptions and implementation-related outcomes.

2.5 Implementation Challenges and Methodological Approaches

The most consistently reported implementation barriers are inadequate infrastructure, unreliable connectivity, insufficient access to devices, limited technical support, and uneven teacher preparation. Schools with limited resources may struggle to sustain digital learning activities even when educators and learners hold positive attitudes toward ICT (Timotheou et al., 2023; Wiyono et al., 2022).

Teacher preparedness is equally important. Educators must understand how to connect technology with content, pedagogy, learner characteristics, and assessment. Short-term technical training may improve familiarity with tools but may not develop the pedagogical judgment needed for meaningful integration. Sustained professional development, classroom-based mentoring, collaborative planning, and opportunities for reflection are therefore more likely to support durable changes in practice (Basil & Ndiaye, 2019; Liu et al., 2022).

Institutional leadership and policy also shape implementation. Technology initiatives may remain fragmented when institutions lack a shared vision, implementation standards, monitoring procedures, incentives, or alignment with curriculum and assessment. Conversely, managerial and technical support can facilitate sustained use by ensuring that teachers have access to resources, professional learning, and timely assistance.

Studies of ICT integration have used diverse methodological approaches. Case studies provide detailed accounts of implementation processes and contextual barriers but often have limited transferability (Akram et al., 2021). Quasi-experimental studies permit comparisons between instructional conditions but may not fully control differences in teachers, learners, or implementation quality (González & Muñoz-Repiso, 2017). Meta-analyses estimate average effects across studies, although their conclusions depend on the comparability and quality of the included evidence (Arlinwibowo et al., 2022). Mixed-methods designs combine quantitative outcomes with qualitative explanations of participant experience and institutional context (Laumer, 2023).

This methodological diversity is valuable, but it complicates synthesis. Studies differ in their definitions of ICT integration, duration of implementation, educational level, outcome measures, and methodological rigor. Self-reported competence and satisfaction are particularly common, whereas classroom observations, objective performance measures, longitudinal evidence, and comparison groups are less frequent. Conclusions about effectiveness must therefore be weighted according to study design and the type of outcome measured.

2.6 Research Gaps and Conceptual Synthesis

Several gaps remain in the literature. First, longitudinal studies are needed to determine whether reported improvements persist after initial implementation or professional development. Short-term increases in motivation, confidence, or technology use may not translate into sustained changes in teaching practice or learning competencies (Basil & Ndiaye, 2019).

Second, more comparative research is required across educational levels, disciplines, institutional types, and socio-economic contexts. ICT integration may operate differently in primary schools, vocational education, universities, rural settings, and well-resourced urban institutions (Akram et al., 2021). Greater contextual diversity would improve understanding of which models are transferable and which require substantial adaptation.

Third, digital literacy and socio-emotional outcomes remain less frequently examined than achievement, satisfaction, and engagement. Further research should evaluate how ICT affects information evaluation, digital communication, ethical participation, self-regulation, collaboration, and learner well-being (Oliveira et al., 2021).

Fourth, studies should distinguish technology adoption from pedagogical integration and integration quality. TAM and UTAUT can explain acceptance and use, but they cannot determine whether technology is pedagogically aligned. TPACK can describe teacher knowledge, but it does not independently demonstrate classroom effectiveness. SAMR can characterize task transformation, but it does not establish that redefined tasks improve

learning. Technology-leadership frameworks explain organizational support, while evaluative frameworks assess the scope and quality of implementation.

These distinctions suggest that no single framework adequately captures the complete ICT integration process. A more comprehensive evaluation requires attention to at least four interconnected dimensions: pedagogical alignment, user acceptance and competence, institutional capacity, and implementation quality. Effective integration is most likely when teachers possess the knowledge to connect technology with pedagogy and content, users perceive the technology as useful and manageable, institutions provide sustained leadership and resources, and outcomes are evaluated through direct and contextually appropriate measures.

Accordingly, this review treats ICT integration as a multilevel process rather than a single technological intervention. It evaluates not only the models used to guide adoption and instructional practice but also the conditions under which those models are implemented and the strength of evidence connecting them to learning competencies.

3. Method

This study used a systematic-review design complemented by bibliometric thematic mapping to examine ICT integration models and their relationships with learning competencies and related educational outcomes. The methodology followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework to support transparent study identification, screening, eligibility assessment, and reporting. Two analytically distinct corpora were used: the 117 records retrieved from Scopus were analyzed to map the broader thematic landscape, whereas only the 19 studies meeting all eligibility criteria were included in the systematic evidence synthesis.

3.1 Database Selection

Scopus was selected as the sole bibliographic database because it provides broad multidisciplinary coverage of educational technology, pedagogy, learning sciences, and information systems. It also provides standardized bibliographic metadata that can be exported for screening and bibliometric analysis. Database indexing was not treated as evidence of methodological quality; the quality and relevance of individual studies were assessed separately during screening and appraisal.

3.2 Search Strategy

The search strategy was designed to retrieve studies addressing three principal concepts: ICT integration, integration or evaluation models, and learning-related outcomes. The Boolean search string was:

("Integration of Information and Communication Technology" OR "ICT integration" OR "ICT in Education") AND ("evaluating models" OR "evaluation models" OR "assessment models") AND ("learning competencies" OR "student competencies" OR "educational outcomes" OR "learning outcomes")

The search terms were intentionally broad because terminology varies across educational levels, disciplines, technologies, and theoretical traditions. The final search was conducted in Scopus on 2 May 2025.

3.3 Search Refinement

The search was limited to English-language journal articles published from 2014 through 2024, including both boundary years. The final Scopus search syntax was:

ALL (("Integration of Information and Communication Technology" OR "ICT integration" OR "ICT in Education") AND ("evaluating models" OR "evaluation models" OR "assessment models") AND ("learning competencies" OR "student competencies" OR "educational outcomes" OR "learning outcomes")) AND PUBYEAR > 2013 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (DOCTYPE, "ar"))

The expressions $\text{PUBYEAR} > 2013$ and $\text{PUBYEAR} < 2025$ ensured that studies published in both 2014 and 2024 were included. The language and document-type limits restricted the results to English-language journal articles. Peer-review status and empirical relevance were subsequently verified during screening.

3.4 Eligibility Criteria

Eligibility criteria were applied to the 117 retrieved records to identify studies suitable for systematic evidence synthesis. Because ICT integration can influence learning indirectly through teacher competence, technology acceptance, leadership, or institutional readiness, the review included studies reporting direct learner outcomes as well as empirical evidence on conditions closely related to ICT-supported teaching and learning. However, these outcome types were differentiated during synthesis so that institutional or perceptual findings were not presented as direct evidence of improved student competence.

3.5 Study Selection and Screening

The final Scopus search identified 117 records. These records formed the broader bibliometric corpus and were also screened for eligibility for the systematic evidence synthesis. The records were checked for duplication and assessed through a staged screening process involving title and abstract screening, publication-type and empirical-design assessment, and full-text eligibility review.

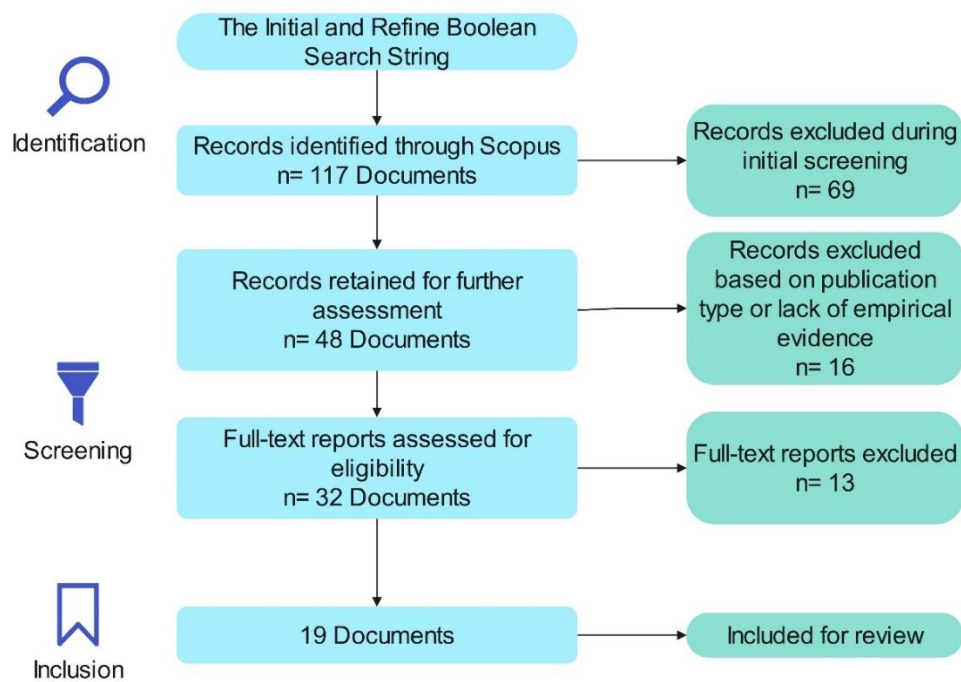


Figure 4. PRISMA flow diagram of the study-selection process from 117 Scopus records to 19 studies included in the systematic evidence synthesis.

Figure 4 summarizes the study-selection process and clarifies the distinction between the broader bibliometric corpus and the final systematic-review corpus. Of the 117 records retrieved from Scopus, 69 were excluded during the initial title, abstract, and record-level screening because they did not sufficiently address ICT integration, relevant educational models or approaches, or learning-related outcomes. The remaining 48 records underwent further assessment, after which 16 were excluded because they did not meet the empirical-study or publication-type criteria. Full texts were assessed for 32 reports, and 13 were subsequently excluded because they did not directly examine an eligible ICT integration model or implementation approach, did not report outcomes relevant to the review questions, or otherwise failed to meet the predefined inclusion criteria. Consequently, 19 studies were included in the final systematic evidence synthesis. The 117 retrieved records were retained for bibliometric mapping, whereas conclusions concerning ICT integration models and learning competencies were based exclusively on the 19 eligible studies.

Screening decisions and reasons for exclusion were documented throughout the review process to support transparency and reproducibility. The staged procedure ensured that the final evidence corpus consisted only of empirical studies that met the predefined criteria for educational relevance, model or implementation focus, and learning-related outcomes.

3.6 Data Extraction

A standardized data-extraction form was developed for the 19 included studies to ensure that comparable information was recorded consistently. The extracted variables are summarized in **Table 1**.

Table 1. Data extracted from the included studies

Data category	Information extracted
Bibliographic information	Author names, publication year, and study location
Educational context	Educational level, institutional setting, participant group, and the instructional or organizational problem addressed
Methodological characteristics	Research design, sample size, participant characteristics, data-collection methods, and analytical procedures
ICT integration	ICT tools, platforms, learning environments, integration approaches, and theoretical or evaluative frameworks
Learning-related outcomes	Academic performance, digital competence, engagement, motivation, collaboration, problem-solving, assessment outcomes, and other directly measured competencies
Implementation-related outcomes	Teacher competence, technology acceptance, professional development, institutional readiness, leadership, infrastructure, and technical support
Study limitations	Sampling limitations, design weaknesses, measurement constraints, contextual limitations, and threats to transferability
Future directions	Recommendations for research, policy, professional development, technology design, and implementation

The extracted outcomes were classified according to the type of evidence reported. Direct learning outcomes included test performance, task completion, demonstrated digital competence, and other objective or performance-based measures. Perceived outcomes included self-reported engagement, satisfaction, confidence, motivation, or perceived improvement. Teacher-related outcomes included digital competence, pedagogical knowledge, self-efficacy, and professional-development effects, whereas institutional outcomes included readiness, leadership, infrastructure, policy, and organizational support. This classification reduced the risk of interpreting technology acceptance, satisfaction, or perceived improvement as equivalent to objectively measured learning gains.

3.7 Evidence Synthesis

The included studies differed substantially in educational level, participant group, intervention, theoretical framework, research design, implementation duration, and outcome measurement. A statistical meta-analysis was therefore not conducted because the studies did not provide sufficiently comparable effect estimates or outcome measures.

Instead, the review used a structured narrative synthesis. Quantitative findings were summarized descriptively, while qualitative and mixed-methods findings were synthesized thematically. This approach is consistent with systematic reviews in which substantial methodological and outcome heterogeneity makes pooled analysis inappropriate (Caffery et al., 2024).

The synthesis proceeded through four stages. First, studies were grouped according to the principal function of the framework or approach examined: pedagogical integration, technology adoption, institutional implementation, or evaluation. Second, findings were categorized by outcome type, including student learning, engagement, collaboration, digital competence, teacher competence, acceptance, and institutional readiness. Third, contextual factors such as educational level, infrastructure, professional development, leadership, and technical support were compared across studies. Finally, the direction of reported findings was classified descriptively as positive, mixed or inconclusive, null, or negative where such classification was supported by the reported evidence.

Direction-of-effect counting was used only as a descriptive aid and not as a substitute for effect-size estimation or statistical inference.

3.8 Bibliometric and Thematic Mapping

Bibliometric mapping was conducted using the 117 records initially retrieved from Scopus to provide a broader overview of the research landscape. This bibliometric corpus was analytically distinct from the 19-study systematic-review corpus. The broader corpus was used to identify relationships among author keywords, thematic clusters, and temporal differences in research emphasis; it was not used to determine whether an ICT model improved learning competencies.

Bibliographic metadata, including authors, titles, abstracts, author keywords, publication years, and source information, were exported from Scopus and imported into VOSviewer version 1.6.17. Author-keyword co-occurrence analysis was selected because author keywords more directly represent the concepts emphasized by the original researchers than automatically generated index terms. The exported dataset contained 413 author keywords. Identical, duplicate, and non-substantive keywords were excluded during data preparation.

The analysis applied full counting, meaning that every occurrence of a keyword within a document contributed equally to the network. A minimum occurrence threshold of two was used, and all author keywords meeting this threshold were retained for mapping. Association-strength normalization was applied to construct the network. In the visualization, node size represents keyword occurrence, link thickness indicates co-occurrence strength, and node color denotes thematic-cluster membership.

Three bibliometric outputs were generated. The network visualization was used to identify relationships and cluster membership among author keywords. The overlay visualization displayed differences in the average publication year associated with each keyword. The density visualization showed areas with the highest concentration of related keywords. The network and overlay visualizations were included in the main analysis, while the density visualization was used as supplementary evidence. The overlay map was interpreted as indicating differences in average publication year rather than direct evidence of growth or decline in publication volume.

3.9 Quality Appraisal

Because the included studies employed heterogeneous quantitative, qualitative, mixed-methods, action-research, development, and program-evaluation designs, quality appraisal focused on methodological and reporting transparency rather than assigning a single pooled risk-of-bias score. A structured appraisal matrix informed by the Quality Improvement Minimum Quality Criteria Set and SQUIRE-based reporting guidance was applied to the included studies (Wollny et al., 2022; Sivadanam et al., 2024). The appraisal domains are presented in **Table 2**.

Table 2. Methodological quality-appraisal domains

Appraisal domain	Assessment focus
Research purpose	Clarity of the research problem, aims, and research questions
Study context	Description of the educational, institutional, and organizational setting
Research design	Appropriateness of the design for the stated research questions
Participants and sampling	Clarity of participant selection, sample characteristics, and recruitment procedures
Intervention or integration approach	Description and replicability of the ICT intervention, model, platform, or implementation strategy
Data sources and instruments	Appropriateness, validity, reliability, and transparency of data-collection tools
Data analysis	Alignment between research questions, analytical procedures, and reported findings
Comparison and baseline evidence	Availability and adequacy of comparison groups, pre-intervention measures, or baseline data where relevant
Implementation fidelity	Evidence that the intervention or integration process was delivered as intended
Outcome classification	Clear distinction between directly measured outcomes and perceived or self-reported outcomes
Limitations	Transparent reporting of methodological, contextual, and measurement limitations
Sustainability and transferability	Consideration of long-term implementation, scalability, and applicability to other settings

Each appraisal domain was rated as met, partially met, not met, or not reported. The appraisal results did not automatically determine study inclusion because the review aimed to represent a diverse empirical evidence base. Instead, methodological quality informed the interpretive weight assigned to each finding. Greater weight was given to studies with direct outcome measures, transparent procedures, appropriate analyses, baseline or comparison evidence, and clearly described implementation processes. More cautious interpretation was applied to findings derived from small samples, self-report measures, uncontrolled post-intervention assessments, or inadequately described methods.

4. Results and Analysis

4.1 Study Selection and Overview

The 19 studies addressed diverse dimensions of ICT integration, including teacher digital competence, professional development, technology acceptance, e-learning readiness, mobile and blended learning, technology-supported assessment, instructional design, institutional leadership, and implementation evaluation. The detailed study-level synthesis—including context, methodology, ICT integration, findings, limitations, and future directions—is presented in **Table 3**.

Table 3. Synthesis results of the selected studies

Author(s)/Year	Context and Problem	Methodological Approach	ICT Integration Used	Key Findings, Limitations, and Future Directions
Wahyuni et al. (2022)	Indonesian vocational-school competency standards underrepresented vocational and technological skills needed for industry-aligned teaching.	Analytic Hierarchy Process with six purposively selected experts. Four competency criteria and 21 sub-criteria were ranked using pairwise comparisons in Expert Choice; CR < 0.10 indicated consistency.	ICT was treated as a teacher-competency domain covering instruction, communication, assessment, and continuing professional development.	Findings: Pedagogical competence ranked highest (0.435) and technological competence lowest (0.074); within technology, ICT for instruction ranked first (0.579). Limitations: Small, province-specific expert panel and no test of teacher or student outcomes. Future: Validate with broader samples and examine implementation effects.
Sola Özgüç and Cavkaytar (2016)	A Turkish special-education school sought to integrate technology into sixth-grade science for students with mild intellectual disability.	Three-stage action research with 11 students, two teachers, parents, and advisory groups. Six students were focal cases, but complete pre-post test data were available for four; evidence included videos, observations, interviews, artifacts, and criterion-referenced tests.	Tablets, an interactive board, multimedia, web activities, and daily digital assessments were embedded in individualized education plans.	Findings: Four students improved from 12% to 56%, 6% to 83%, 36% to 98%, and 12% to 70%; participation and collaboration also improved. Limitations: Single class, incomplete data, no comparison group, and substantial researcher support. Future: Replicate across subjects and test sustained teacher mentoring and home-school use.
Roemintoyo et al. (2022)	Indonesian entrepreneurship classes relied on static modules and rarely incorporated ICT or local contexts.	ADDIE-based research and development. Two media experts, two subject experts, four teachers, and 54 students evaluated the product through observations, document review, and feasibility questionnaires.	A self-paced computer application combined local-context content, text, images, video, practice questions, and evaluation activities.	Findings: Expert and user ratings were favorable; the overall student rating was approximately 84.7%. Limitations: The study measured feasibility, not entrepreneurial competence or achievement, and the product covered limited topics and devices. Future: Test learning effects experimentally and expand content and platform accessibility.

Author(s)/Year	Context and Problem	Methodological Approach	ICT Integration Used	Key Findings, Limitations, and Future Directions
Joshi et al. (2023)	Digitally trained Nepalese mathematics teachers shifted rapidly to online instruction during COVID-19.	Cross-sectional survey of 456 teachers using a 13-item instrument. Descriptive statistics, CFA, SEM, correlations, and variable-importance analysis examined resource development, sharing, integration, and assessment.	Teachers created and shared digital materials, used LMSs, whiteboards, visualization tools, forums, quizzes, rubrics, and online forms.	Findings: Resource sharing and integration predicted online assessment practices and explained 58% of their variance; resource development had no significant direct effect. Limitations: Self-report, trained and male-dominated sample, cross-sectional design, and no student outcomes. Future: Use broader samples and direct measures of learning and assessment quality.
Msiza et al. (2020)	A South African paperless-classroom initiative faced concerns about readiness, devices, connectivity, training, and support.	Qualitative case study with three teachers, six learners, and three school-management members. Interviews and a learner focus group were analyzed thematically; ADDIE served as an evaluative lens.	Learner tablets, teacher laptops, smartboards, digital textbooks, Wi-Fi, and online resources supported paperless instruction.	Findings: Enthusiasm was offset by inadequate training, unreliable connectivity, uneven device access, weak technical support, theft, and off-task use. Limitations: Very small purposive sample, perception-based evidence, and no observed or measured learning outcomes. Future: Conduct readiness assessments, provide sustained training and support, strengthen security, and evaluate learning effects.
Esteve-Mon et al. (2016)	Self-report tools were considered insufficient for assessing preservice teachers' applied digital competence.	Educational Design Research with 187 Spanish education students and 22 experts across iterative cycles; the final performance test involved 13 students. Evidence included questionnaires, expert review, usability checks, and a rubric.	ETeach3D, an OpenSim–Moodle virtual school, presented six authentic collaborative tasks across classroom, workshop, and staff-room settings.	Findings: Final performance averaged 2.62/4 versus self-perception of 2.97/4, with weaker pedagogical than basic digital skills. Limitations: Very small final sample, local validity, and no longitudinal competence gain. Future: Test larger samples, psychometric properties, transferability, and broader professional competencies.
Uslu (2017)	Turkey's learner-centered curriculum contrasted with predominantly teacher-centered classroom technology use.	Concurrent mixed-method evaluation using the Holistic Evaluation Model. Data included pre–post scales from 532 teachers, questionnaires from 370, interviews with 12, and program documents.	A seven-day FATİH Project course covered interactive boards, digital resources, material development, lesson planning, and classroom integration.	Findings: Classroom and preparation use rose modestly from 3.02 to 3.31 ($d = 0.41$), mainly through presentations and demonstrations; student technology use did not improve significantly. Limitations: Self-report, no observations or control group, and perceived student outcomes only. Future: Add direct student measures, observations, longer follow-up, and differentiated mentoring.
Issa and Jaaron (2017)	Palestinian public secondary schools faced technological,	Mixed-methods study with 644 teachers across 11 directorates and interviews	Readiness was examined across technology, people,	Findings: Overall readiness was 3.66/5; training (3.39), ease of use (3.30), and content (3.09) required

Author(s)/Year	Context and Problem	Methodological Approach	ICT Integration Used	Key Findings, Limitations, and Future Directions
	organizational, and human-resource barriers to e-learning.	with eight experts. Surveys and thematic interviews assessed readiness, acceptance, training, and institutional conditions.	content, institutions, usefulness, ease of use, and training within an organizational–infrastructure–individual model.	improvement. Limitations: Gaza was excluded, sampling was partly non-random, and outcomes concerned readiness rather than learning. Future: Test the model with broader samples and link readiness to sustained implementation and student outcomes.
De Smet et al. (2016)	Flemish biology teachers implemented LMS learning paths and reported on school, teacher, and student-related conditions.	Qualitative interviews with 16 teachers from 13 schools. Transcripts were coded in NVivo using e-capacity and school/teacher/environmental frameworks; interrater agreement was 96%.	An LMS learning path combined digital objects, laboratory activities, worksheets, and teacher scenarios to support autonomous and collaborative learning.	Findings: Infrastructure, technical and pedagogical support, policy, and teacher competence constrained sustained use; teachers reported four poorer, six unchanged, and six better student outcomes. Limitations: Small specialized sample and perception-based outcomes. Future: Combine interviews with observations and student data and test across subjects and schools.
Orooji and Taghiyareh (2018)	A social-learning environment needed a scalable way to evaluate diverse learner-generated content.	Semester-long mixed-method field evaluation with 18 Iranian computer-engineering students. Platform logs, motivation measures, and a usability survey were analyzed descriptively and through correlation, regression, and reciprocity analyses.	COMVO enabled content-specific peer, self, and expert voting within a blended social-learning course.	Findings: Students produced 794 content items and 1,030 assessment actions; participation was associated with grades, and 75% preferred multi-label voting. Limitations: Small single-course sample, no comparison group, voluntary participation, and correlational outcomes. Future: Test larger courses, refine labels, and assess effects on self-regulation, assessment quality, and learning.
Divayana et al. (2021)	Existing ICT evaluation models did not explicitly prioritize improvement recommendations.	Development research using five Borg and Gall stages. Fourteen Balinese vocational teachers rated the preliminary model; a simulated case used author-generated data.	DIVAYANA combined eight evaluation stages with decision-support calculations to rank recommendations on policy, budget, infrastructure, readiness, and content.	Findings: The preliminary model received an 88.571% usability rating; in simulation, budget and infrastructure were top priorities. Limitations: Preliminary validation, small purposive sample, simulated data, no software, and no learning outcomes. Future: Complete development, build an application, and test real large-scale implementation and outcomes.
Oliwa (2022)	A Polish university evaluated students' satisfaction after an emergency shift to online learning.	Cross-sectional survey of 201 undergraduate and postgraduate students using LimeSurvey. Correlation, chi-square, and multivariate regression examined	The platform supported lectures, discussion, projects, multimedia, communication, virtual meetings,	Findings: 87.5% were satisfied with continued online study, especially access to materials and assessment; advanced and higher-performing students tended to be less satisfied. Limitations: One

Author(s)/Year	Context and Problem	Methodological Approach	ICT Integration Used	Key Findings, Limitations, and Future Directions
		satisfaction, demographics, and multiple-intelligence measures.	assessment, portfolios, and ICT-skill development.	institution, voluntary self-report, emergency context, contested theoretical framework, and no direct learning measures. Future: Compare delivery modes using validated instruments, platform data, and objective outcomes.
Adzifome and Agyei (2023)	Mobile-device ownership was high in Ghana, but institutional mobile learning remained weakly developed.	Cross-sectional descriptive survey of 222 distance and sandwich students selected accidentally from study centers. A validated questionnaire was analyzed descriptively.	Students used smartphones, tablets, laptops, social media, internet resources, BYOD arrangements, and Moodle for communication and study.	Findings: Device ownership reached 95.9%, yet only 6.8% accessed courses through Moodle and 90.1% relied mainly on print; support scored 2.96/5. Limitations: One university, accidental sampling, self-report, and no learning measures. Future: Use representative multi-institutional designs, objective LMS data, outcome measures, training, and institutional policy.
Khlaif and Farid (2018)	Palestine's Smart Learning Project sought student-centered ICT use across 50 resource-constrained middle schools.	Seven-month qualitative case study involving 30 schools, 30 principals, and 75 teachers. Interviews, observations, field notes, focus groups, thematic interpretation, and SWOT analysis were used.	Tablets, laptops, projectors, digital textbooks, networks, portals, social media, and classroom software supported project-, inquiry-, flipped-, game-, and collaborative learning.	Findings: Leadership, resources, and active roles improved, but only 42.3% of teachers were innovative users; 57.7% remained instrumental or traditional. Limitations: No direct student outcomes, limited student voice and analytic detail, plus privacy and infrastructure concerns. Future: Use longitudinal comparative designs, include learners, improve standards and training, and measure competencies.
Sangkawetai et al. (2020)	Thai STEM teachers often used ICT for simple preparation and presentation rather than student-centered, cognitively demanding learning.	Cross-sectional survey of 810 teachers from 619 schools using stratified random sampling. CFA and SEM examined self-efficacy, goal structures, and reported instructional strategies.	ICT-supported deep and student-centered learning included information synthesis, problem-solving, digital product creation, multimedia, communication, and collaboration.	Findings: ICT teaching self-efficacy strongly predicted reported deep learning with ICT ($\beta = .624$) and student-centered use ($\beta = .669$); the model explained 37% of each. Limitations: Thai STEM-only, self-report, cross-sectional design, and no student outcomes. Future: Add observations, student data, longitudinal designs, and non-STEM contexts.
Selim and Chiravuri (2015)	University instructors' acceptance of hybrid e-learning remained uncertain despite substantial institutional investment.	Instrument-development study with 606 instructors from four UAE universities. The sample was split for exploratory and confirmatory factor analyses of a 37-item questionnaire.	Hybrid learning combined face-to-face teaching with LMSs, online communication, forums, digital resources, and	Findings: Perceived learner benefits correlated most strongly with acceptance ($r = .73$), followed by self-efficacy ($r = .62$), technical support ($r = .31$), and IT attitude ($r = .23$). Limitations: Instrument validation, self-report, one national setting, male-dominated sample,

Author(s)/Year	Context and Problem	Methodological Approach	ICT Integration Used	Key Findings, Limitations, and Future Directions
			institutional ICT services.	and no instructional or student outcomes. Future: Test causal models and cross-context validity.
Turrado-Sevilla et al. (2020)	The study profiled educational innovation among primary teachers in León, Spain, including ICT-supported practices.	Ex-post-facto survey of 86 teachers selected through stratified random sampling. A 114-item questionnaire was analyzed using association tests and logistic regression.	ICT appeared within broader innovation through blended learning, games, shared documents, active learning, and cooperative approaches.	Findings: About three-quarters had participated in innovation; staff stability and age were associated with innovation, but school-type differences were not significant. Limitations: Small provincial sample, self-report, broad innovation focus, and no student or implementation outcomes. Future: Replicate broadly and assess sustainability, implementation quality, and student effects.
Weng and Tang (2014)	Taiwanese elementary schools needed evidence on whether technology leadership related to administrative effectiveness.	Cross-sectional instrument-development survey of 323 administrators from 82 public schools, following interviews, expert review, and a 211-person pilot. Correlation, regression, group comparisons, and CFA were used.	Leadership covered vision, modeling, resource support, evaluation, partnerships, training, and communication.	Findings: Technology leadership correlated with perceived administrative effectiveness ($r = .71$) and explained 51% of its variance. Limitations: Common-method and social-desirability risks, cross-sectional design, administrator-only data, poor RMSEA (.15), and no classroom or student outcomes. Future: Use longitudinal, multilevel, multi-informant designs with objective outcomes.
Wu et al. (2015)	New university teachers in Shanghai had strong disciplinary knowledge but limited pedagogical and ICT-integration preparation.	Mixed-method program evaluation with 162 teachers from 12 institutions. Immediate valid surveys totaled 144; six-month follow-up included 64 teachers and 43 department heads.	A 3.5-day TPACK- and TAM-informed module used collaborative course design, Moodle, Prezi, Mindomo, Camtasia, blended learning, PBL, flipped learning, inquiry, and assessment.	Findings: Participants reported positive acceptance, TPACK, later ICT use, and perceived student engagement and higher-order thinking. Limitations: No pretest or control group, no classroom observation or direct student data, limited follow-up, and implausibly high adjusted R^2 values (.981/.987). Future: Use controlled longitudinal designs, direct outcomes, independent model validation, and sustained mentoring.

4.2 Methodological Characteristics of the Included Studies

The included studies employed heterogeneous research designs. Eight studies used predominantly quantitative methods, including surveys, Analytic Hierarchy Process analysis, confirmatory factor analysis, structural equation modeling, regression, and instrument validation (Adzifome & Agyei, 2023; Joshi et al., 2023; Oliwa, 2022; Sangkawetai et al., 2020; Selim & Chiravuri, 2015; Turrado-Sevilla et al., 2020; Wahyuni et al., 2022; Weng & Tang, 2014). Four studies used qualitative approaches, including action research, interviews, classroom observations, focus groups, and thematic or SWOT analysis (De Smet et al., 2016; Khlaif & Farid, 2018; Msiza et al., 2020; Sola Özgüç & Cavkaytar, 2016).

Four studies adopted mixed-methods designs that combined questionnaires, interviews, document analysis, platform logs, or follow-up evidence (Issa & Jaaron, 2017; Orooji & Taghiyareh, 2018; Uslu, 2017; Wu et al., 2016). Three studies primarily used educational design or development research: Esteve-Mon et al. (2016) developed and iteratively evaluated a three-dimensional digital-competence assessment environment; Roemintoyo et al. (2022) used ADDIE to develop interactive multimedia; and Divayana et al. (2021) used selected stages of the Borg and Gall model to develop the DIVAYANA evaluation model. This methodological diversity enabled the review to capture classroom, teacher, institutional, and system-level dimensions of ICT integration. However, it also limited direct comparison across studies because the investigations differed substantially in participants, interventions, implementation duration, measurement tools, and outcome definitions.

4.3 Geographic and Temporal Distribution

The studies represented 14 national contexts across Asia, Europe, and Africa. Thirteen studies were conducted in Asian settings: Indonesia contributed three studies; Turkey and Palestine contributed two studies each; and China, Iran, Nepal, Taiwan, Thailand, and the United Arab Emirates contributed one study each. Four studies were conducted in Europe, including two in Spain and one each in Belgium and Poland. Two studies were conducted in Africa, one in Ghana and one in South Africa.

The studies covered primary, secondary, vocational, special, distance, and higher education. This contextual diversity demonstrates the broad relevance of ICT integration while also indicating that implementation conditions differ substantially across educational systems. Infrastructure, institutional governance, teacher preparation, learner access, and policy environments varied considerably across the included settings.

The publication period ranged from 2014 to 2023. Earlier studies emphasized technology leadership, hybrid-learning acceptance, digital-competence assessment, and institutional conditions (Selim & Chiravuri, 2015; Weng & Tang, 2014; Esteve-Mon et al., 2016). Studies published between 2017 and 2020 increasingly examined e-learning readiness, professional-development evaluation, learning-management systems, smart-learning initiatives, and educational innovation (De Smet et al., 2016; Issa & Jaaron, 2017; Khlaif & Farid, 2018; Msiza et al., 2020; Uslu, 2017). More recent studies focused on pandemic-related online learning, digital-resource practices, mobile learning, interactive multimedia, and the evaluation of ICT-based learning environments (Adzifome & Agyei, 2023; Divayana et al., 2021; Joshi et al., 2023; Oliwa, 2022; Roemintoyo et al., 2022).

4.4 ICT Integration Models and Frameworks

The included studies did not converge on a single model of ICT integration. Instead, they examined pedagogical, adoption-oriented, developmental, evaluative, and institutional frameworks serving different purposes.

4.4.1 Pedagogical and Teacher-Competence Frameworks

Wu et al. (2015) evaluated a professional-development program integrating TPACK with an extended Technology Acceptance Model. The program used learning-by-design and cognitive-apprenticeship principles to support newly appointed higher-education teachers in designing Moodle-based courses and using tools such as Prezi, Mindomo, and Camtasia. Participants reported positive motivation, perceived usefulness, intention to use ICT, and competence across TPACK domains. However, the study lacked a pre-intervention measure and control group, and perceived student-learning benefits were reported by teachers and department heads rather than measured directly.

Esteve-Mon et al. (2016) developed ETeach3D, a performance-based environment grounded in ISTE standards and Evidence-Centered Design. Unlike conventional self-report measures, ETeach3D assessed preservice teachers' digital competence through authentic professional tasks. The final assessment showed that participants performed better in basic digital skills than in pedagogical ICT use and technology-supported professional development. Performance scores were also lower than self-perception scores, illustrating that perceived competence may overestimate demonstrated performance.

Sangkawet et al. (2020) examined teachers' personal and ICT teaching self-efficacy, classroom goal structures, and reported use of ICT-supported deep and student-centered learning. ICT teaching self-efficacy was

the strongest predictor of teachers' reported use of ICT for deeper and more student-centered instructional strategies. Nevertheless, the study measured teachers' reported practices rather than observed instruction or student competencies. In this study, "deep learning" referred to meaningful and cognitively demanding learning rather than artificial-intelligence-based deep learning.

4.4.2 *Technology-Acceptance and Readiness Models*

Selim and Chiravuri (2015) developed and validated a five-factor instrument for university instructors' acceptance of hybrid e-learning. Perceived learner benefits showed the strongest association with hybrid-learning acceptance, followed by instructor self-efficacy, technical support, and attitudes toward information technology. The findings identified important adoption conditions but did not establish effects on classroom practice or student learning.

Issa and Jaaron (2017) assessed e-learning readiness through technology, people, content availability, institutional conditions, perceived usefulness, perceived ease of use, and training. Although the overall readiness score indicated that schools were generally ready with some improvements required, training, ease of use, and content availability remained below the stated readiness threshold. The proposed model emphasized the interaction of organizational support, infrastructure, and individual characteristics.

Adzifome and Agyei (2023) found high levels of mobile-device ownership and positive perceptions of mobile learning among distance and sandwich students. However, use was concentrated on internet searches and communication, while engagement with the institutional learning-management system remained limited. This finding indicates that device availability does not necessarily produce structured or institutionally integrated mobile learning.

4.4.3 *Instructional-Design and Development Models*

Roemintoyo et al. (2022) used the ADDIE model to develop interactive multimedia for craft and entrepreneurship education. Media experts, subject specialists, teachers, and students rated the product as feasible. However, the study assessed product quality and usability rather than changes in entrepreneurial competence, attitudes, or academic achievement. Therefore, the feasibility ratings should not be interpreted as evidence of learning effectiveness.

Msiza et al. (2020) used ADDIE as an evaluative lens to examine a South African paperless-classroom initiative. The study identified weaknesses in analysis, planning, training, implementation, and evaluation. Learners were generally enthusiastic, but limited formal training, unreliable connectivity, insufficient technical support, device theft, and off-task use constrained implementation. ADDIE was not directly implemented as an instructional intervention in this study; it was used to diagnose shortcomings in project design and delivery.

Divayana et al. (2021) developed the DIVAYANA model through five stages adapted from Borg and Gall. DIVAYANA combined evaluation with a decision-support mechanism for ranking recommendations related to policy, budget, infrastructure, teacher readiness, student readiness, and digital content. The reported score of 88.571% represented respondents' preliminary rating of the model's design and usability. It did not represent an 88.571% improvement in student performance or learning competence. The model remained at a preliminary development stage and was demonstrated partly through simulated data.

4.4.4 *Assessment and Evaluation Frameworks*

Orooji and Taghiyareh (2018) introduced COMVO, a content-dependent multi-label voting model embedded in the DoosMooc social-learning environment. COMVO supported peer, self-, and expert assessment of learner-generated resources and discussions. Students produced 794 content items and completed 1,030 assessment actions. Participation and receipt of votes were associated with course grades, but the correlational design did not demonstrate that COMVO caused higher achievement. The study primarily showed the feasibility and participation dynamics of crowdsourced assessment.

Uslu (2017) used the Holistic Evaluation Model to examine a seven-day educational-technology course within Turkey's FATİH Project. The model assessed context, inputs, process, participant learning, organizational support, use of acquired skills, student-learning outcomes, and cost effectiveness. Teacher-reported classroom ICT use

increased modestly, but the program mainly strengthened teacher-centered uses such as presentations and interactive-whiteboard demonstrations. Encouraging students to use technology did not improve significantly.

Wahyuni et al. (2022) used the Analytic Hierarchy Process to prioritize vocational-school teacher competencies. Pedagogical competence received the highest weight, followed by vocational, professional, and technological competence. Within the technological domain, ICT for instruction was prioritized over ICT for professional development, assessment, and communication. The study produced a competency-prioritization structure but did not test whether applying the structure improved teaching or student outcomes.

4.4.5 *Leadership and Institutional Models*

Weng and Tang (2014) conceptualized ICT integration through five technology-leadership dimensions: vision and management, modeling and guidance, supply and support, evaluation and research, and communication and inspiration. Technology leadership was strongly associated with administrators' perceptions of school-administration effectiveness. However, both constructs were rated by the same respondents, creating a risk of common-method bias, and the study did not measure classroom integration or student outcomes.

Khlaif and Farid (2018) showed that school leaders in the Palestinian Smart Learning Project moved from managing equipment toward developing technology cultures, supporting professional development, and encouraging collaborative planning. Nevertheless, only 42.3% of teachers were classified as innovative users, while most remained instrumental or predominantly traditional users. The findings indicate that infrastructure and leadership can enable change, but they do not guarantee pedagogical transformation.

4.5 *Evidence Concerning Learning Competencies*

The evidence concerning direct improvements in student competencies was more limited than the original literature narrative suggested. The studies reported outcomes related to academic performance, engagement, collaboration, digital competence, assessment participation, and perceived higher-order learning, but many of these outcomes were indirect, self-reported, or based on stakeholder perceptions.

4.5.1 *Directly Measured Student Outcomes*

Sola Özgüç and Cavkaytar (2016) provided the clearest direct pre- and post-intervention student-performance evidence. Four focus students with complete data improved from 12% to 56%, 6% to 83%, 36% to 98%, and 12% to 70%, respectively, after technology-supported science instruction. Classroom observations also suggested improved participation, peer interaction, collaboration, responsibility, and transfer of learning. However, the single-class action-research design, absence of a comparison group, incomplete post-test data, and substantial researcher involvement limit causal interpretation and generalizability.

Orooji and Taghiyareh (2018) used platform logs and course grades as objective indicators, but the relationship between assessment activity and grades was correlational. More active or academically stronger students may have participated more frequently, rather than participation itself causing higher achievement. No other included study provided strong controlled evidence that a specific ICT integration model directly improved student achievement or transferable competencies. This does not indicate that ICT lacked educational value; rather, it demonstrates that direct outcome measurement was uncommon in the included evidence base.

4.5.2 *Perceived and Indirect Student Outcomes*

Wu et al. (2015) reported that teachers and department heads perceived improvements in student engagement, collaboration, higher-order thinking, and satisfaction after the professional-development program. Because these outcomes were not confirmed through student assessments, surveys, observations, or learning analytics, they should be interpreted as stakeholder perceptions rather than demonstrated learning effects. Teachers in De Smet et al. (2016) reported mixed effects of an LMS-based biology learning path: four perceived lower-than-expected performance, six perceived no difference, and six perceived better-than-expected outcomes. Students adapted quickly to the platform, although enthusiasm sometimes declined after several lessons. These mixed perceptions indicate that digital learning paths did not benefit all classrooms or learners uniformly.

Oliwa (2022) found that 87.5% of surveyed students were satisfied with the opportunity to continue studying online during the pandemic. Students valued access to materials, online assessment, and opportunities to develop ICT competence. However, satisfaction was not a direct measure of academic performance or competency development. Adzifome and Agyei (2023) similarly found favorable perceptions of information access, communication, collaboration, and blended learning, but weak use of the institutional LMS and limited access to online tests and assignments. The study did not measure achievement or competency gains. Roemintoyo et al. (2022) reported positive student ratings of interactive multimedia, but these ratings demonstrated acceptability and feasibility rather than improved entrepreneurial attitudes, skills, or academic performance.

4.5.3 *Engagement, Collaboration, and Participation*

Several studies associated ICT with increased participation and collaboration. Sola Özgüç and Cavkaytar (2016) observed greater peer interaction and responsibility among students with mild intellectual disability. Orooji and Taghiyareh (2018) found that all respondents to the usability survey agreed that receiving votes increased enthusiasm for participation. Khlaif and Farid (2018) observed that students increasingly acted as researchers, presenters, negotiators, and content producers within smart-learning classrooms.

However, engagement was not uniformly positive. Msiza et al. (2020) reported that some learners used tablets for games, social media, and other non-academic activities. De Smet et al. (2016) found that initial enthusiasm for the LMS learning path sometimes declined. These findings show that access to interactive technology can create opportunities for engagement while simultaneously introducing distraction, classroom-management demands, and uneven learner participation.

4.6 *Teacher Competence and Professional Development*

Teacher competence emerged as one of the most consistent determinants of implementation quality. Wu et al. (2015), Esteve-Mon et al. (2016), Uslu (2017), Sangkawetai et al. (2020), and Wahyuni et al. (2022) all emphasized technological and pedagogical competence, although they measured it differently. Wu et al. (2015) found positive perceived TPACK outcomes after a short professional-development module, but technological knowledge received the lowest mean among the TPACK domains. Uslu (2017) found a modest increase in classroom and lesson-preparation ICT use, with weaker gains in communication, ethical use, and student technology participation. Both studies indicated that short-term training may increase confidence and basic use without necessarily producing sustained student-centered integration.

Esteve-Mon et al. (2016) further demonstrated that self-perceived competence exceeded performance-based competence. This discrepancy supports the need to combine self-report instruments with authentic tasks, observations, or digital artifacts when evaluating teachers' ICT capabilities. Sangkawetai et al. (2020) found that ICT teaching self-efficacy was strongly associated with reported deep and student-centered ICT use. Nevertheless, the cross-sectional self-report design did not establish that self-efficacy caused more effective teaching or improved student outcomes. Across these studies, professional development appeared more effective when it combined technical instruction with lesson design, subject-specific application, collaborative practice, mentoring, and continued support. One-off or short-duration training was frequently insufficient, particularly when participants differed substantially in prior competence.

4.7 *Institutional Readiness, Infrastructure, and Leadership*

Infrastructure and organizational support consistently shaped implementation. Issa and Jaaron (2017) identified limitations in content availability, training, ease of use, classroom access, preparation time, incentives, and technical support. Msiza et al. (2020) reported connectivity problems, uneven device distribution, insufficient training, limited technical personnel, and device-security issues. Adzifome and Agyei (2023) found that high mobile-device ownership coexisted with weak institutional support and limited LMS use.

De Smet et al. (2016) reported that unreliable infrastructure, inconsistent technical support, minimal pedagogical support, weak ICT policy, and limited professional development constrained sustained use of LMS learning paths. Sixty percent of the coded interview material concerned environmental conditions, compared with 24% concerning teacher-level factors and 16% concerning school-level factors.

Leadership was also important. Weng and Tang (2014) associated technology leadership with perceived administrative effectiveness, while Khlaif and Farid (2018) demonstrated that principals could support school technology cultures, collaborative planning, and professional development. However, leadership findings were generally based on perceptions or qualitative observations rather than longitudinal evidence linking leadership practices to improved classroom instruction or student competencies. These findings show that device provision alone is insufficient. Sustained ICT integration requires reliable connectivity, accessible platforms, technical and pedagogical support, leadership, professional development, implementation standards, and alignment with curriculum and assessment.

4.8 Bibliometric and Thematic Mapping

4.8.1 Network Visualization

The author-keyword co-occurrence network revealed six interconnected thematic clusters within the broader corpus of 117 Scopus records. The clusters represent recurring patterns of association among educational outcomes, technology adoption, instructional design, institutional implementation, and digitally supported learning. Because cluster membership was generated from keyword co-occurrence, the resulting groups should be interpreted as thematic associations rather than mutually exclusive conceptual categories or evidence of causal relationships.

Figure 5 shows that higher education, ICT, e-learning, and learning outcomes occupy prominent connecting positions across the network. Their centrality indicates that the literature frequently links technological systems and modes of delivery with institutional adoption, learner participation, instructional design, and educational outcomes. The visualization also demonstrates that conceptually related topics are distributed across several clusters rather than organized around a single dominant model. This pattern supports the review's broader interpretation of ICT integration as a multidimensional process involving pedagogical, technological, institutional, and evaluative components. However, node prominence and link strength indicate frequency and co-occurrence within the retrieved literature; they do not establish research quality, intervention effectiveness, or consistent improvement in learning competencies. The cluster interpretation was therefore considered alongside the detailed evidence synthesized from the 19 eligible studies.

The *first* cluster centered on learning outcomes and learner engagement, connecting learning outcomes with evaluation, motivation, collaborative learning, and e-portfolio use. This pattern indicates that the broader literature frequently discusses ICT in relation to both educational outcomes and participatory learning processes. Nevertheless, their thematic association does not demonstrate that such outcomes were measured directly or achieved consistently. The *second* cluster represented digital transformation and technology-enabled innovation, linking ICT with digital transformation and gamification. It suggests that ICT is often conceptualized as part of broader pedagogical and organizational change rather than merely as the provision of devices or software.

The *third* cluster focused on higher education, technology acceptance, online teaching, assessment, and COVID-19. This grouping reflects the prominence of institutional adoption, user acceptance, online delivery, and assessment practices in higher-education research, particularly during periods of rapid digital transition. The *fourth* cluster connected e-learning, online learning, educational technology, the ADDIE model, mobile learning, and educational psychology. These relationships highlight the interaction among digital modes of delivery, instructional design, learner characteristics, and technology-supported pedagogy.

The *fifth* cluster brought together technology adoption, information technology, open and distance education, information-technology management, mathematics education, and student engagement. It reflects the relationship among adoption processes, disciplinary applications, learner participation, and institutional management. The smaller sixth cluster was primarily associated with blended learning. Although more peripheral than the other clusters, blended learning remained connected to technology-adoption themes, flexible instructional delivery, and learning-related outcomes. Its position indicates a specialized bridging function rather than limited educational relevance. Overall, the network suggests that the broader literature is organized around interactions among technological systems, instructional design, institutional adoption, learner engagement, and educational outcomes. These thematic relationships provide contextual support for the systematic synthesis but should not be interpreted as direct evidence that particular ICT approaches improve learning competencies.

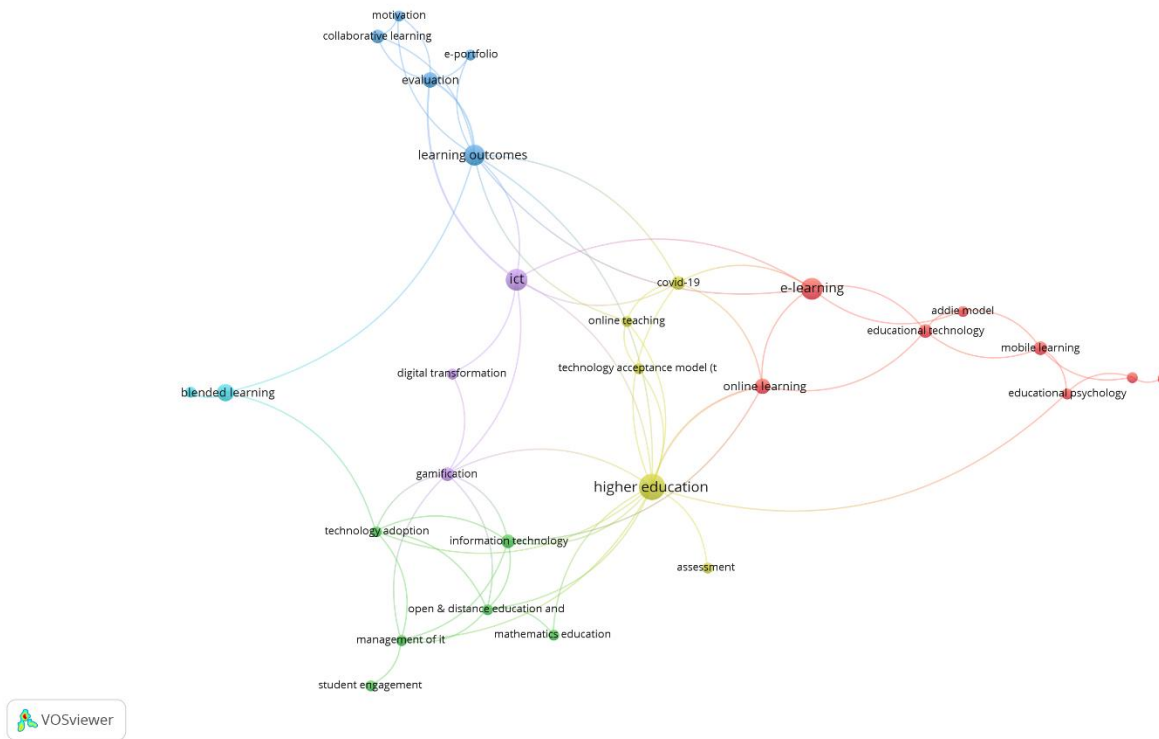


Figure 5. Network visualization of author-keyword co-occurrence in the broader Scopus-retrieved literature. Node size represents keyword occurrence, link thickness indicates co-occurrence strength, and colors denote thematic clusters.

4.8.2 Overlay Visualization

The overlay visualization revealed temporal differences in the average publication year of the author keywords. Earlier publications were more closely associated with blended learning, collaborative learning, motivation, e-portfolio use, and educational psychology. Publications from the middle of the review period increasingly emphasized ICT, e-learning, online learning, COVID-19, online teaching, technology adoption, digital transformation, and gamification. More recent publications placed greater emphasis on higher education, assessment, instructional-design models, open and distance education, and the management of ICT implementation.

Figure 6 shows how the thematic emphasis of ICT-integration research shifted across the review period. The earlier concentration on blended learning, collaboration, motivation, and educational psychology reflects an initial focus on combining digital and face-to-face instruction and on understanding learner participation. The middle period shows stronger attention to online learning, e-learning, COVID-19, technology adoption, and digital transformation, indicating the rapid expansion of digitally mediated education and the need to maintain teaching continuity. More recent keywords emphasize assessment, instructional design, higher education, open and distance education, and ICT management, suggesting growing attention to implementation quality, institutional coordination, and the evaluation of technology-supported learning. These temporal relationships complement the network analysis by showing when different themes were most strongly represented. However, the overlay visualization displays average publication years rather than publication growth, impact, or effectiveness. Therefore, the color progression should be interpreted as a change in thematic emphasis, not as evidence that particular topics are expanding, declining, or producing stronger educational outcomes.

Overall, the overlay pattern indicates a movement from early interest in blended and collaborative learning toward broader concerns with online delivery, digital transformation, assessment, instructional design, and institutional management. These patterns provide temporal context for the systematic findings but do not independently demonstrate the effectiveness or maturity of the identified themes.

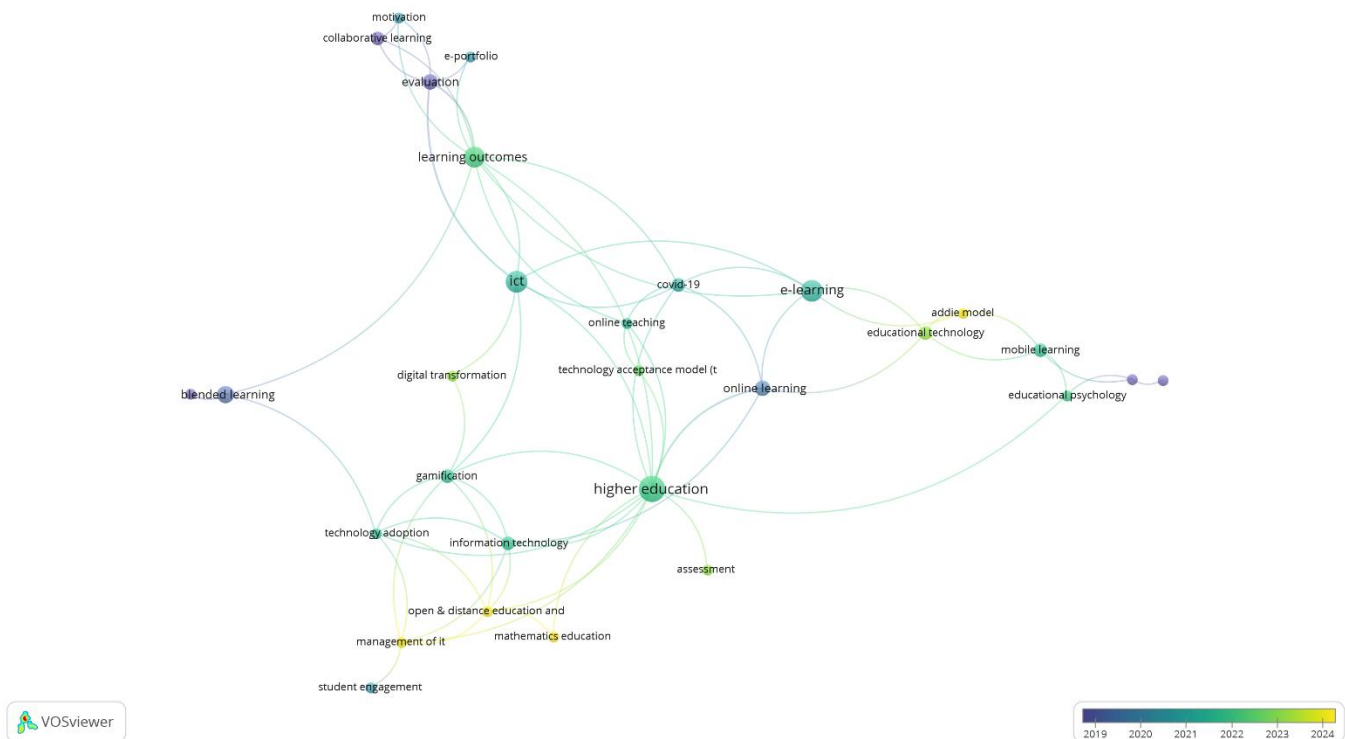


Figure 6. Overlay visualization of author keywords based on the average publication year of the documents in which they occurred.

4.9 Consistent and Contradictory Evidence Patterns

Four factors appeared consistently across the 19 studies: teacher competence, infrastructure and resources, organizational support and leadership, and pedagogical alignment. Positive implementation experiences were generally reported when teachers had adequate competence, technologies were accessible and reliable, institutions provided continued support, and digital activities were connected to instructional goals.

Nevertheless, the findings also revealed several contradictions. First, greater access did not always result in meaningful use. Ghanaian students reported high device ownership but limited LMS participation (Adzifome & Agyei, 2023), while South African students sometimes used devices for non-academic purposes (Msiza et al., 2020). *Second*, training improved confidence and reported technology use but did not consistently shift instruction toward student-centered practice. Uslu (2017) found that training mainly strengthened presentations and other teacher-centered applications, and Khlaif and Farid (2018) found that most teachers remained instrumental or traditional users despite participation in a smart-learning initiative. *Third*, positive stakeholder perceptions did not consistently correspond to direct learning evidence. Wu et al. (2015), Oliwa (2022), De Smet et al. (2016), and Roemintoyo et al. (2022) reported favorable perceptions, satisfaction, usability, or perceived outcomes, but did not directly establish improvements in student competencies. *Fourth*, sustainability remained uncertain. Several studies recommended sustained mentoring, technical support, policy development, infrastructure maintenance, and long-term evaluation, indicating that many initiatives had not yet demonstrated durable effects (Adzifome & Agyei, 2023; Issa & Jaaron, 2017; Msiza et al., 2020; Uslu, 2017; Wu et al., 2016).

Overall, the evidence supports the hypothesis that ICT integration is more likely to produce positive educational outcomes when technology is pedagogically aligned and supported by teacher competence, infrastructure, leadership, professional development, and institutional commitment. However, the evidence base does not support a general claim that ICT integration models consistently or substantially improve learning competencies. Direct competency measurement was uncommon, and many findings concerned readiness, acceptance, feasibility, or perceived outcomes rather than demonstrated student learning.

5. 5. Discussion

5.1 Interpretation of the Principal Findings

This review indicates that ICT integration can support learning, teaching, assessment, and educational management, but its effects are conditional rather than automatic. Across the 19 included studies, favorable outcomes were most often associated with pedagogically purposeful technology use, teacher competence, sustained professional support, reliable infrastructure, and institutional commitment. However, the strength and type of evidence varied considerably. Only a small proportion of the studies directly measured changes in student performance or competencies; many instead examined technology acceptance, teacher self-efficacy, institutional readiness, product feasibility, administrative effectiveness, or stakeholder perceptions. The findings therefore support a qualified rather than universal claim regarding the educational benefits of ICT.

Figure 7 organizes these heterogeneous findings along an evidence continuum that distinguishes implementation capacity, user perceptions, observed practice, and directly measured learning competencies. Evidence concerning device access, infrastructure, training, technical support, and institutional readiness indicates whether ICT can be implemented, but it does not demonstrate educational effectiveness. Measures of usefulness, ease of use, satisfaction, motivation, self-efficacy, and intention explain how users perceive or accept technology, whereas reported participation, collaboration, lesson redesign, and implementation fidelity provide information about classroom practice. The strongest basis for claims about learning impact comes from direct measures, including performance tasks, achievement assessments, digital artifacts, observed collaboration, problem-solving measures, digital-literacy instruments, and validated learning analytics. Methodological strength also depends on baseline data, comparison groups, sample adequacy, implementation-fidelity assessment, and longitudinal follow-up. The continuum does not imply that implementation or perception measures are unimportant; rather, these indicators answer different research questions. It emphasizes that favorable readiness, satisfaction, or technology-use results should not be interpreted as equivalent to demonstrated improvements in learning competencies.

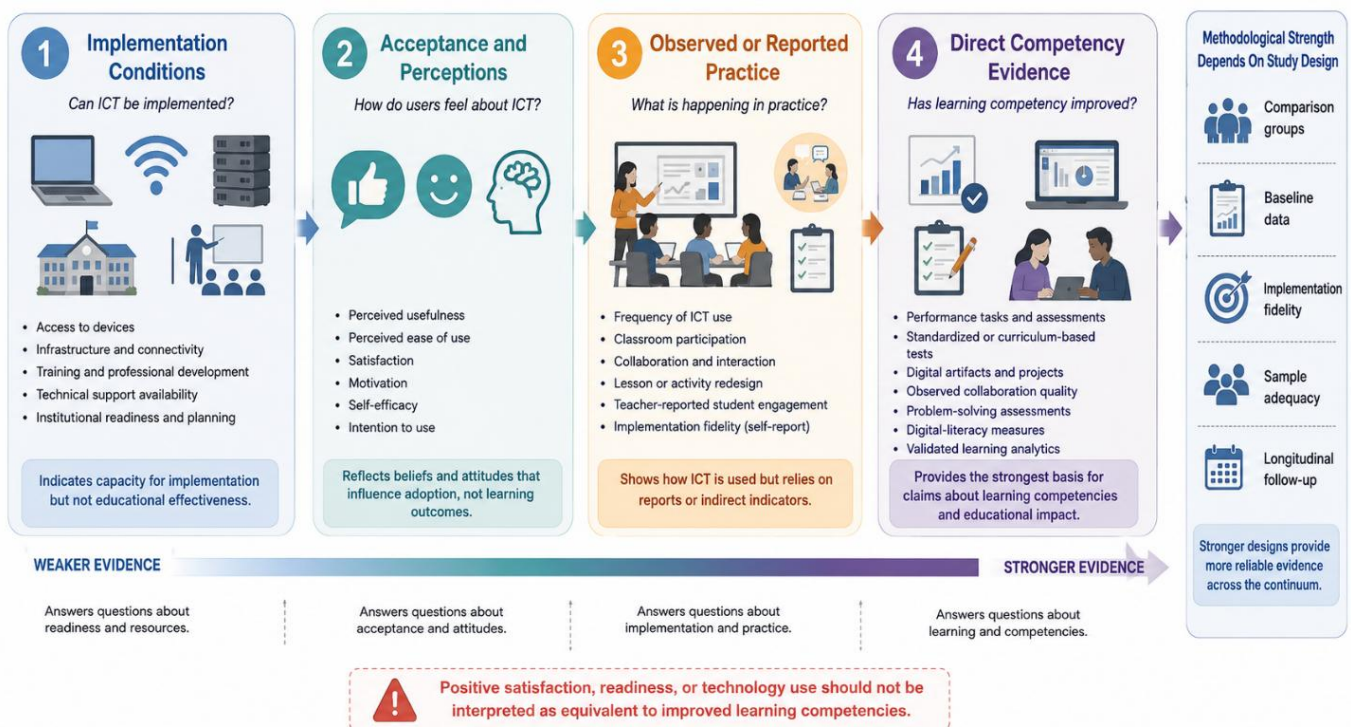


Figure 7. Evidence continuum for evaluating ICT integration outcomes, progressing from implementation capacity and user perceptions to observed practice and directly measured learning competencies.

The clearest direct evidence of student improvement was reported by Sola Özgüç and Cavkaytar (2016), who documented substantial pre–post performance gains among four students with mild intellectual disability following technology-supported science instruction. The intervention also appeared to support participation, collaboration,

responsibility, and transfer of learning. Nevertheless, the very small sample, incomplete outcome data, absence of a comparison group, and substantial researcher involvement limit causal interpretation and generalizability. Orooji and Taghiyareh (2018) reported associations between ICT-supported participation and course grades, but the correlational design could not establish that technology use caused higher achievement.

Most other learning-related findings were indirect or perception-based. Wu et al. (2015) reported that teachers and department heads perceived improvements in student engagement, collaboration, satisfaction, and higher-order thinking following an ICT-focused professional-development program. In contrast, De Smet et al. (2016) found mixed teacher perceptions of student performance in an LMS-based biology learning path: some teachers reported improvement, whereas others observed no difference or lower-than-expected outcomes. Oliwa (2022), Roemintoyo et al. (2022), and Adzifome and Agyei (2023) similarly reported favorable satisfaction, usability, feasibility, or access outcomes without directly demonstrating improvements in academic achievement or transferable competencies. These distinctions are essential because positive perceptions and implementation indicators cannot be treated as demonstrated learning gains.

The reviewed evidence also does not justify a broad claim that Problem-Based Learning or blended learning consistently and significantly improved critical thinking, collaboration, and problem-solving across the 19 included studies. Problem-based and project-oriented practices appeared in some interventions, particularly the professional-development program examined by Wu et al. (2015) and the Smart Learning Project investigated by Khlaif and Farid (2018), but they were not the dominant models represented in the final corpus. A more defensible interpretation is that active and student-centered uses of technology appear more promising than applications that merely reproduce teacher-centered presentation or information-delivery practices.

This interpretation is consistent with broader literature that was not included in the 19-study systematic synthesis. ICT-supported problem- and project-based learning has been associated with engagement, critical thinking, collaboration, and the application of disciplinary knowledge (Amin et al., 2020; Carrió et al., 2022; Maryani et al., 2022). More recent evidence has also linked ICT- or mobile-supported project-based learning with critical thinking, collaboration, and ICT literacy in vocational and general education (Rozan et al., 2024). These studies support the educational potential of active learning but should be interpreted as external corroborating evidence rather than findings generated by the present systematic-review corpus.

Blended learning may improve flexibility, participation, and study behavior when online and face-to-face components are coherently designed (Dewi et al., 2023; Hsu et al., 2017; Maryani et al., 2022; Setuju et al., 2023). Within the included studies, however, the evidence primarily concerned teacher acceptance, instructional practice, student satisfaction, or implementation conditions. Selim and Chiravuri (2015) examined instructors' acceptance of hybrid learning, Wu et al. (2015) reported teachers' subsequent use of blended approaches, and Adzifome and Agyei (2023) identified favorable student perceptions alongside limited use of the official LMS. Blended delivery should therefore not be treated as inherently effective because its outcomes depend on course design, interaction, learner support, assessment alignment, and implementation quality.

The broader evidence base identifies additional ICT-supported approaches that have been evaluated using more direct competency measures. A meta-analysis of 74 studies found that programming and coding instruction in K–12 education could support critical thinking, creativity, collaboration, problem-solving, and ICT literacy (Hu, 2023). Web 2.0 and ubiquitous-learning environments have also been associated with critical thinking and collaboration, although some evidence remains dependent on teacher-reported evaluations of student skills (Urooj & Farooq, 2023). AI-enabled systems, including conversational agents and intelligent tutoring tools, may support communication, collaboration, creativity, and problem-solving, with some studies reporting improvements in speaking and communication skills (Çelik et al., 2024). Integrated assessment systems have likewise been proposed to evaluate complex competencies such as teamwork and problem-solving through authentic digital tasks (Chamba & Chikusvura, 2024). Collectively, these studies strengthen the case for competency-oriented ICT design while reinforcing the need for direct, validated, and context-sensitive outcome measurement.

5.2 Adoption, Pedagogical Integration, and Integration Quality

A major theoretical implication of this review is the need to distinguish technology adoption from pedagogical integration and integration quality. The included studies demonstrate that these processes are related but conceptually distinct. Adoption concerns whether teachers and learners are willing and able to use a technology;

pedagogical integration concerns how technology is aligned with content, instruction, learning activities, and assessment; and integration quality concerns whether implementation is coherent, equitable, sustainable, and educationally effective.

Figure 8 shows how these processes form a conditional pathway from ICT adoption to learning competencies. Technology acceptance, shaped by perceived usefulness, ease of use, performance expectancy, social influence, and facilitating conditions, provides an initial basis for use. However, acceptance must be supported by teacher and learner readiness, including digital competence, self-efficacy, motivation, prior experience, and professional development. These conditions enable pedagogical integration through curriculum alignment, instructional design, active learning, collaboration, and assessment. Institutional leadership, infrastructure, policy, accessibility, maintenance, technical support, and organizational commitment are also required to sustain implementation. When these elements are aligned, ICT may contribute to critical thinking, collaboration, communication, problem-solving, digital literacy, self-regulation, and academic performance. Conversely, inadequate training, weak connectivity, teacher-centered substitution, limited support, unequal access, and poor assessment alignment may interrupt this pathway. The feedback mechanisms further indicate that evidence of outcomes should inform pedagogical redesign, professional development, and institutional planning. Thus, technology adoption is necessary but does not independently establish integration quality or learning effectiveness.

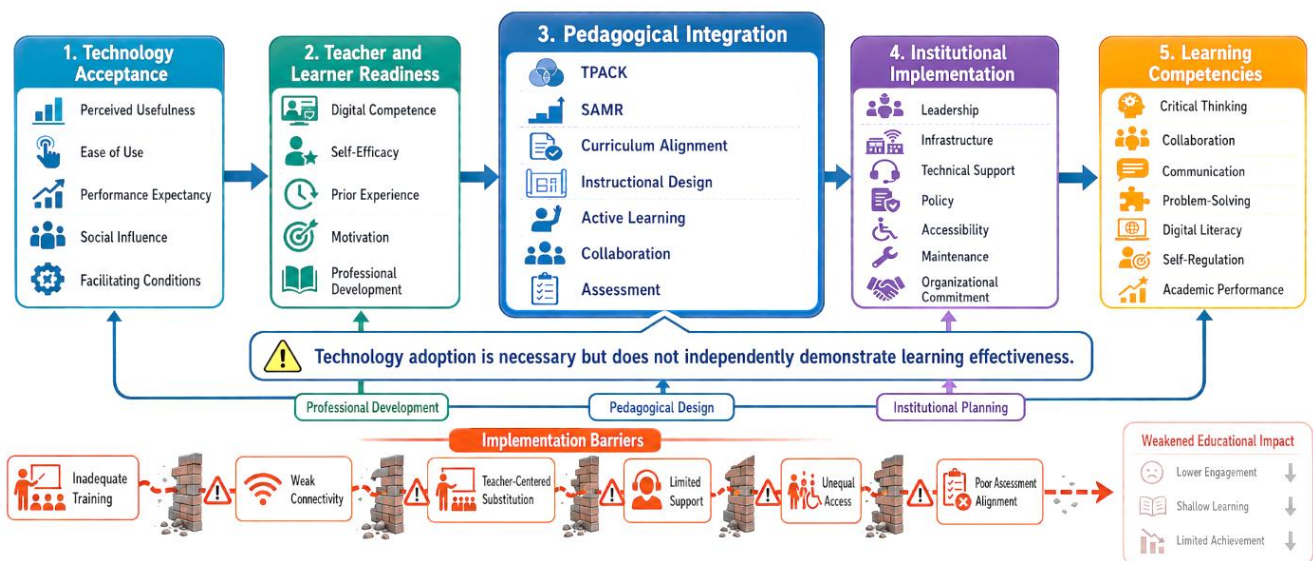


Figure 8. Pathway from ICT adoption to learning competencies, showing enabling conditions, institutional support, implementation barriers, and feedback mechanisms.

Technology Acceptance Model constructs such as perceived usefulness and ease of use can explain whether teachers or students are inclined to use a particular technology, but they do not establish whether its use is pedagogically appropriate or educationally effective. Selim and Chiravuri (2015), Issa and Jaaron (2017), and Wu et al. (2015) showed that perceived learner benefits, self-efficacy, ease of use, training, and technical support were associated with acceptance or readiness. However, these studies relied substantially on perceptions and self-reported practices, and they did not consistently demonstrate that acceptance resulted in student-centered instruction or measurable improvements in learning competencies.

This distinction qualifies interpretations of TAM as producing a direct progression from perceived usefulness to improved educational outcomes. Mater et al. (2022) and Nong et al. (2022) support the importance of perceived usefulness and ease of use in technology adoption, but adoption should be treated as an enabling condition rather than a sufficient explanation of educational effectiveness. A technology may be widely accepted yet used primarily for presentation, information delivery, communication, or administrative purposes. Conversely, a pedagogically valuable tool may remain underused because of technical complexity, insufficient training, limited preparation time, or weak organizational support.

TPACK addresses a different stage of the integration process by explaining the knowledge teachers require to combine technology, pedagogy, and disciplinary content. The findings of Wu et al. (2015), Esteve-Mon et al. (2016),

Sangkawet et al. (2020), and Wahyuni et al. (2022) support the importance of technological and pedagogical competence. Nevertheless, these studies also show that self-reported knowledge or confidence cannot be assumed to represent demonstrated teaching performance. Esteve-Mon et al. (2016), for example, found that participants' performance-based digital-competence scores were lower than their self-perceptions. Evaluating TPACK-related competence therefore requires performance tasks, classroom observations, instructional artifacts, or other direct measures in addition to self-report instruments.

SAMR can complement TPACK by helping educators examine whether technology substitutes for conventional tools or enables substantial task modification and redefinition. However, progression from substitution to modification or redefinition does not automatically guarantee deeper learning. The educational value of a redesigned task still depends on curriculum alignment, instructional clarity, learner readiness, disciplinary accuracy, accessibility, cognitive demand, and appropriate assessment. External evidence concerning active learning and technology-supported task redesign supports this interpretation (Amin et al., 2020; Carrió et al., 2022), but neither TPACK nor SAMR should be treated as a direct measure of learning impact.

The findings therefore support a multilevel interpretation of ICT integration. TAM and UTAUT explain acceptance and use; TPACK addresses teachers' integrated knowledge; SAMR describes the extent of technology-supported task transformation; instructional-design models guide the development process; technology-leadership frameworks address institutional capacity; and evaluative models assess implementation quality and outcomes. No single framework captures the complete pathway from initial adoption to sustained educational impact. A comprehensive evaluation must therefore combine evidence of acceptance, readiness, pedagogical practice, institutional support, implementation fidelity, equity, and directly measured learning competencies.

5.3 Relationship Between the Bibliometric and Systematic Findings

The bibliometric analysis of the 117 Scopus records reinforces this multidimensional interpretation. The author-keyword network connected learning outcomes and learner engagement with evaluation, collaboration, motivation, e-learning, higher education, technology adoption, instructional design, digital transformation, and institutional management. These clusters show that the wider research landscape encompasses pedagogical, technological, assessment-related, and organizational concerns.

However, bibliometric prominence should not be interpreted as evidence of educational effectiveness. A frequently occurring keyword indicates thematic attention, not the strength, direction, or quality of intervention effects. Similarly, cluster membership reflects patterns of keyword co-occurrence rather than causal or theoretically exclusive relationships. Semantically related concepts may appear in different clusters, and cluster composition can change when keyword thresholds or data-cleaning decisions are modified. Bibliometric clusters should therefore be interpreted alongside qualitative examination of the included studies rather than as stand-alone evidence (Doğan, 2023; Lazo et al., 2025).

The minimum occurrence threshold of two was appropriate for preserving thematic coverage in the relatively small 117-record corpus, although it also allowed several specialized terms to remain in the map. Threshold selection in VOSviewer is dataset-dependent: smaller corpora often require lower thresholds, whereas larger datasets can use higher cutoffs to focus on dominant concepts (Dogra & Parrey, 2022; Duan & Guo, 2021; Zhang, Wang, et al., 2024). The bibliometric findings were consequently used to describe the broader structure and temporal emphasis of the literature, while conclusions concerning learning competencies were based exclusively on the 19 eligible studies.

5.4 Teacher Professional Development and Sustained Practice

Teacher competence was one of the most consistent conditions associated with implementation quality. The included studies indicate that educators require more than operational knowledge of devices or platforms. They need opportunities to connect technology with subject content, learner characteristics, assessment, classroom management, and instructional goals. Short-term training can increase awareness, confidence, and basic use, but it does not necessarily transform pedagogy.

This limitation was particularly visible in Uslu (2017), where a seven-day course produced modest gains in ICT use but mainly strengthened presentations and other teacher-centered activities. Msiza et al. (2020) similarly found that a one-week training program was insufficient for teachers and learners with different levels of prior

competence. Wu et al. (2015) reported more promising design-oriented professional development, but the absence of baseline data, classroom observation, and direct student measures made it difficult to determine the durability and educational effects of the reported changes.

These results are consistent with external studies emphasizing the importance of robust professional development (Christian et al., 2021; Wen et al., 2023). Effective programs should combine technical instruction with lesson design, curriculum alignment, subject-specific application, assessment practice, implementation opportunities, and structured reflection. Training in LMSs and other digital resources is most valuable when educators can apply the tools in collaborative and interactive learning activities rather than learn isolated software procedures (Prayogi et al., 2022; Suwardika et al., 2024).

The wider professional-development literature also favors long-duration approaches with classroom-based follow-up. Instructional coaching, mentoring, professional learning communities, collaborative planning, and repeated opportunities for implementation are more likely to support sustained change than isolated workshops (Agyei, 2022; El-Hamamsy et al., 2023; Moosa & Ramnarain, 2023; Pečiuliauskienė et al., 2023; Pavez et al., 2024; Rasheed et al., 2024; Tirol et al., 2022). Programs that involve teachers in co-design and action research may further strengthen teacher agency, reflection, and local adaptation (Barksdale et al., 2021; Moosa & Ramnarain, 2023; Zhang, Ma, et al., 2024).

TPACK-focused professional development can contribute to stronger classroom integration when it is locally relevant and grounded in practice. Evidence suggests that such programs are most effective when teachers design, test, evaluate, and revise technology-supported lessons within their own contexts (Barksdale et al., 2021; Smiley, 2023). The practical implication is that professional development should be treated as an ongoing implementation system rather than a preliminary event completed before technology deployment. Schools should also foster collaborative professional cultures. Peer learning can support the exchange of lesson designs, troubleshooting strategies, assessment practices, and context-specific adaptations (Dotson et al., 2020). Such collaboration may reduce the isolation of individual innovators and support wider organizational uptake.

5.5 Infrastructure, Leadership, and Large-Scale Implementation

The included studies consistently showed that infrastructure and organizational support determine whether technology can be used regularly, equitably, and pedagogically. Issa and Jaaron (2017), De Smet et al. (2016), Khlaif and Farid (2018), Msiza et al. (2020), and Adzifome and Agyei (2023) identified recurring constraints involving connectivity, device access, digital content, technical support, preparation time, security, and institutional policy. These barriers often persisted even when teachers and students expressed positive attitudes toward ICT, indicating that willingness to use technology cannot compensate for weak implementation conditions.

Figure 9 presents these conditions as a multilevel system extending from learners and teachers to classrooms, institutions, and the wider policy environment. Learner-level factors include device access, digital competence, motivation, self-regulation, accessibility needs, and socio-economic circumstances. Teacher-level conditions include TPACK, digital self-efficacy, pedagogical beliefs, professional development, workload, and willingness to redesign instruction. At the classroom level, curriculum alignment, task design, formative assessment, collaboration, feedback, and implementation fidelity influence whether technology supports meaningful learning. Institutional factors include leadership, infrastructure, connectivity, technical support, professional-learning systems, resource allocation, and data governance, while system-level influences include funding, regulation, digital-equity policies, and rural–urban disparities. Alignment across these levels can support participation, digital competence, collaboration, critical thinking, problem-solving, and academic achievement. By contrast, weaknesses across one or more levels may produce unequal access, superficial technology use, teacher overload, inconsistent implementation, learner disengagement, and limited educational impact.

Reliable internet access and appropriate hardware remain essential, but infrastructure should be interpreted more broadly. It also includes accessible platforms, maintenance arrangements, technical personnel, instructional materials, data protection, user support, and continuity planning. Earlier research similarly shows that weak connectivity and insufficient equipment can restrict the educational value of ICT (Halabieh et al., 2022; Prayogi, 2023). Partnerships among schools, governments, communities, universities, and technology providers may help expand resources and expertise, but such arrangements require clearly defined responsibilities, sustainable funding, accountability, and alignment with educational priorities (Suciati et al., 2022).

Leadership determines whether technological resources are organized into a coherent and sustainable implementation strategy. Weng and Tang (2014) emphasized vision, modeling, resource support, evaluation, and communication, while Khlaif and Farid (2018) showed how school leaders could promote professional development, collaborative planning, and technology-oriented school cultures. Effective leadership should therefore extend beyond technology procurement to include instructional guidance, staff development, monitoring, and continuous improvement. Nevertheless, leadership effectiveness should be evaluated through observable changes in organizational practice, classroom conditions, and learner opportunities rather than administrators' perceptions alone.

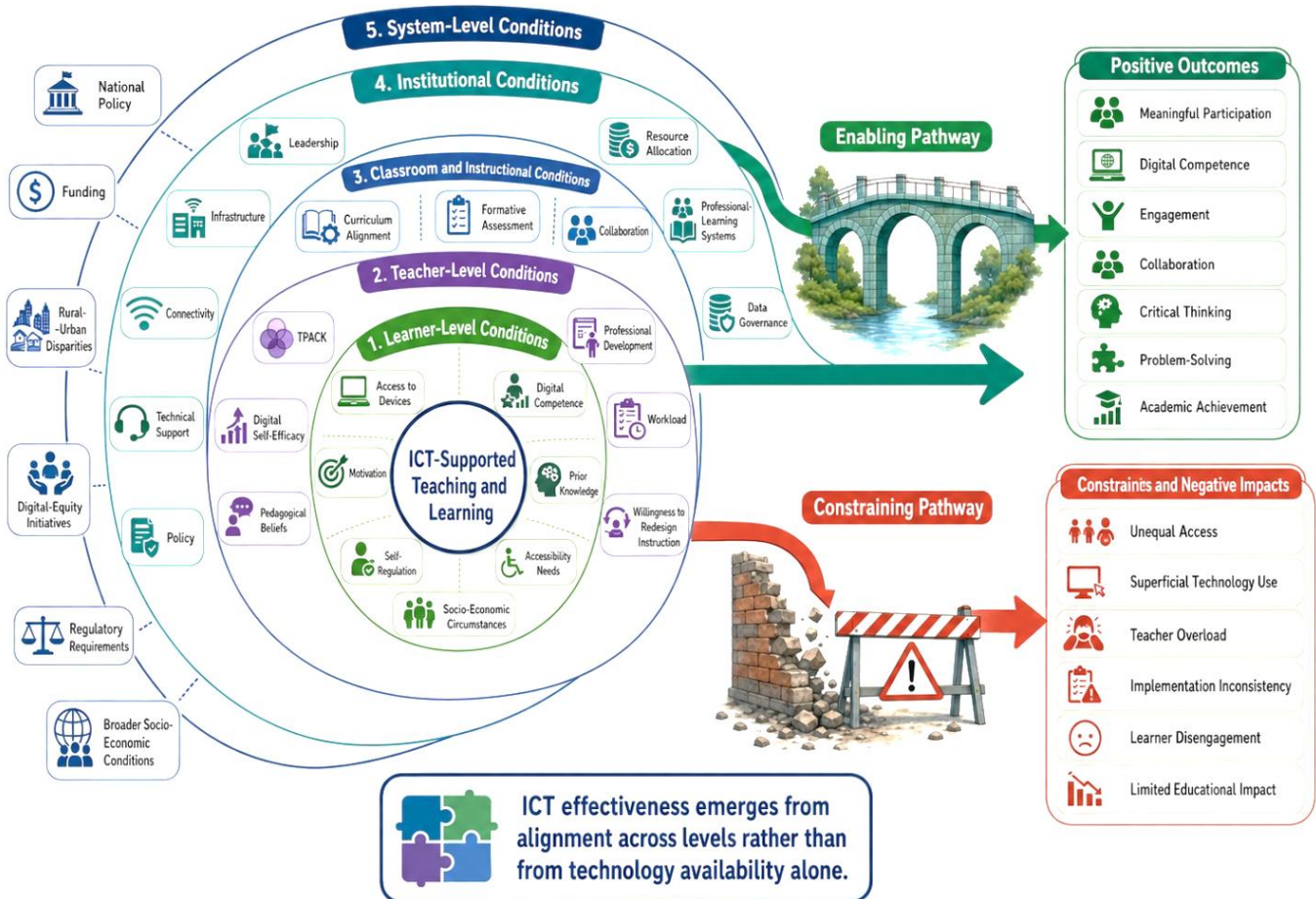


Figure 9. Multilevel conditions shaping ICT integration outcomes across learner, teacher, classroom, institutional, and system levels.

At scale, ICT can support multimodal and remote learning, continuity during disruptions, open educational resources, and wider access to learning materials. These benefits are more likely when digital tools are integrated with curriculum development, teacher competence, assessment, accessibility, and equity-oriented policy (Analyti et al., 2024; Liu, 2021; Natarajan et al., 2021; Salimi, 2025). Open repositories and digital resources can broaden participation, but only when learners possess the connectivity, devices, support, and digital literacy required to use them meaningfully.

Large-scale adoption may also reproduce or intensify inequality. Technology initiatives can widen disparities when access, skills, home support, accessibility, and opportunities for meaningful use differ by socio-economic status or geographic location (Liu, 2021; Muñoz & Valencia, 2023; Norman et al., 2022). The digital divide therefore extends beyond physical access to include differences in digital competence, quality of use, instructional support, and the educational benefits learners ultimately obtain from technology.

Infrastructure and socio-economic conditions also help explain differences between rural and urban implementation. Rural schools may experience unstable electricity, limited broadband, fewer devices, insufficient

technical support, and reduced access to professional development, whereas urban institutions often benefit from stronger infrastructure and institutional networks (Anlimachie et al., 2022; Chidakwa & Khanare, 2024; Mapisa & Makena, 2024; Rawal, 2024; Zeng, 2022). Equity-oriented policy should therefore target connectivity, digital literacy, teacher development, accessibility, local technical capacity, and sustained support rather than assume that uniform technology distribution will produce uniform educational outcomes (Chen, 2023; Gicheru & Mwangi, 2023; Liang et al., 2022; Thapa, 2022).

5.6 Substitution Versus Pedagogical Transformation

A recurring contradiction across the evidence concerns the difference between technology availability and transformed teaching. Some institutions had substantial device access or infrastructure but continued to use technology primarily for presentations, information delivery, or conventional assignments. Uslu (2017) found that professional development mainly increased teacher-centered uses, while Khlaif and Farid (2018) found that most teachers remained instrumental or traditional technology users despite the broader Smart Learning initiative. Adzifome and Agyei (2023) similarly found that high device ownership did not translate into regular use of the institutional LMS.

These findings indicate that ICT frequently substitutes for established practices unless curriculum, pedagogy, assessment, and professional competence are redesigned together. Technology-supported transformation requires educators to create tasks that enable inquiry, collaboration, knowledge construction, feedback, and authentic performance. It also requires institution-wide leadership, sustained professional development, and coherent curricular reform (Analyti et al., 2024; Hurtado-Mazeyra et al., 2022; Natarajan et al., 2021).

Active learning can provide an instructional structure for this transformation. External evidence indicates that PBL, project-based learning, inquiry, and blended models can support critical thinking and engagement when digital tools are used to investigate problems, develop products, exchange feedback, and apply knowledge (Amin et al., 2020; Carrió et al., 2022; Changwong et al., 2018; Dewi et al., 2023; Maryani et al., 2022). However, these pedagogies should not be recommended solely because they use technology. Their effectiveness depends on problem quality, scaffolding, interaction, assessment, disciplinary alignment, and teacher facilitation.

5.7 Contradictory and Context-Dependent Findings

The evidence contains several contradictions that challenge simplified claims about ICT effectiveness. *First*, technology sometimes increased engagement but also created distraction and classroom-management problems. Sola Özgüç and Cavkaytar (2016) observed improvements in participation and collaboration, whereas Msiza et al. (2020) reported non-academic device use and De Smet et al. (2016) found that initial enthusiasm sometimes declined. *Second*, teacher training increased confidence and reported use but did not consistently produce student-centered practice. Wu et al. (2015) and Esteve-Mon et al. (2016) reported positive competence-related outcomes, but Uslu (2017) found limited movement beyond teacher-centered applications. Self-reported competence may also exceed demonstrated competence, as shown by Esteve-Mon et al. (2016).

Third, infrastructure was necessary but insufficient. High-resource settings did not automatically produce positive student outcomes, and low-resource contexts did not uniformly prevent innovation. The quality of implementation, pedagogical support, leadership, and learner access mediated how resources were used. The contrast between settings should therefore not be reduced to a simple high-resource versus low-resource distinction. *Fourth*, positive attitudes toward technology did not always correspond to sustained use. Issa and Jaaron (2017) found high perceived usefulness but weaker training, content availability, and ease of use. Selim and Chiravuri (2015) similarly showed that perceived learner benefits and self-efficacy were strongly associated with acceptance, but the study did not establish actual classroom effects.

Finally, sustainability remained uncertain. Several studies involved preliminary models, short-term interventions, pandemic-related emergency arrangements, or limited follow-up. Claims that DIVAYANA or the TPACK-extended program generated lasting improvement would therefore be premature. Divayana et al. (2021) conducted only preliminary model development and used simulated data for part of the evaluation, while Wu et al. (2015) relied on limited follow-up responses and stakeholder perceptions. Issa and Jaaron (2017) further

demonstrated that initiatives remain vulnerable when funding, training, policy, and technical support are not maintained.

5.8 Theoretical and Practical Implications

Theoretically, the findings support an integrated model in which learning-related outcomes emerge from interactions among technology acceptance, teacher competence, pedagogical alignment, institutional capacity, and evaluation quality. This model avoids treating technology as an independent causal intervention and instead conceptualizes ICT integration as a multilevel educational process. It also explains why the same digital tool may support meaningful learning in one context but result in superficial or inconsistent use in another.

Figure 10 shows how meaningful ICT-supported learning is shaped by interconnected learner, teacher, pedagogical, institutional, and policy conditions. At the learner level, access, digital competence, motivation, self-regulation, prior knowledge, accessibility needs, and home support influence participation. Teacher-level factors include TPACK, digital self-efficacy, pedagogical beliefs, professional development, mentoring, workload, and willingness to redesign instruction. The pedagogical layer emphasizes curriculum alignment, active learning, formative assessment, collaboration, feedback, cognitive-load management, and evaluation. Institutional conditions include leadership, devices, connectivity, technical support, maintenance, professional-learning communities, data governance, and community partnerships, while the wider policy environment encompasses funding, national digital strategies, inclusive-access policies, regulation, and socio-economic disparities. Alignment across these layers can support equitable access, sustained participation, improved teaching quality, digital competence, collaboration, critical thinking, and academic learning. Conversely, misalignment may produce superficial use, digital inequality, teacher overload, inconsistent implementation, distraction, and weak learning effects. The figure therefore integrates the section's theoretical and practical implications by showing that sustainable ICT integration depends on coordinated support across the entire educational ecosystem.

The review hypothesis is therefore conditionally supported. ICT integration was more likely to produce positive learning-related outcomes when teachers possessed relevant digital and pedagogical competence, institutions provided reliable infrastructure and sustained support, and learning activities were aligned with curriculum and assessment. Conversely, weak training, fragmented implementation, inadequate technical support, unequal access, and teacher-centered substitution were associated with more limited or inconsistent outcomes. These findings indicate that the effects of ICT depend less on the technology itself than on the quality of the surrounding educational system.

For educators, technology selection should begin with the intended learning competency rather than the novelty or availability of a particular tool. When collaboration is the objective, the digital environment should require interdependent work and provide mechanisms for contribution, feedback, shared responsibility, and accountability. When the objective is critical thinking or problem-solving, learners should analyze evidence, compare alternatives, test solutions, make decisions, and justify conclusions. When the objective is digital literacy, assessment should examine information evaluation, digital creation, communication, safety, privacy, and ethical participation rather than familiarity with devices alone.

For institutions, implementation plans should integrate infrastructure, professional development, curriculum, assessment, technical support, accessibility, data governance, maintenance, and continuous evaluation. Initial enthusiasm, high acceptance, or device distribution should not be treated as evidence of successful integration. Institutions should monitor how technologies are used, which learners participate, whether barriers persist, how teachers redesign instruction, and whether the intended competencies are demonstrated through appropriate measures.

For policymakers, the findings support targeted and coordinated investment rather than technology-first procurement. Policy should combine broadband and device access with teacher development, local technical capacity, maintenance, inclusive content, accessibility support, data protection, and mechanisms for evaluating educational outcomes. Such an approach can improve implementation sustainability and reduce the risk that ICT investments reproduce or intensify existing educational inequalities.

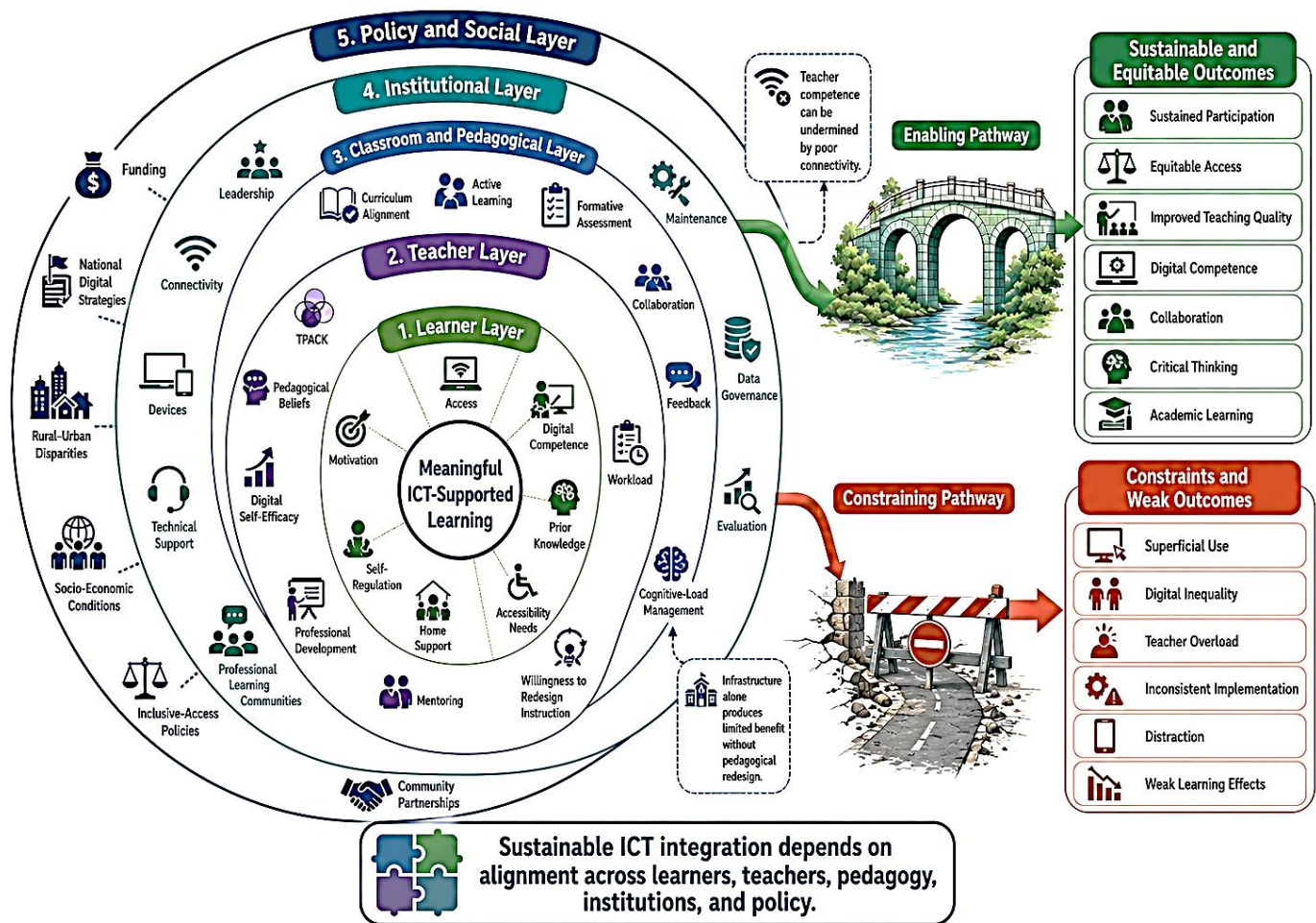


Figure 10. Multilevel ecosystem for sustainable and equitable ICT integration across learner, teacher, pedagogical, institutional, and policy layers.

5.9 Limitations of the Review

This review has several limitations. *First*, the search was restricted to Scopus, which may have excluded relevant studies indexed only in ERIC, Web of Science, PsycINFO, regional databases, or specialist repositories. *Second*, the inclusion of only English-language journal articles published from 2014 through 2024 may have excluded relevant evidence from other languages, earlier periods, and publication formats. *Third*, the search strategy required explicit references to ICT integration, models or assessment, and learning-related outcomes. Studies using different terminology may therefore have been missed. *Fourth*, the 19 included studies were highly heterogeneous in educational level, technology, framework, design, duration, participant group, and outcome measurement. This heterogeneity prevented statistical meta-analysis and required narrative synthesis.

Fifth, the evidence base was dominated by cross-sectional surveys, self-report measures, qualitative perceptions, preliminary development studies, and uncontrolled evaluations. Direct student competency measures, classroom observations, comparison groups, implementation-fidelity measures, and longitudinal follow-up were relatively uncommon. Findings based on acceptance, satisfaction, readiness, or feasibility were therefore not treated as equivalent to demonstrated learning effects. *Sixth*, several studies were conducted in single institutions, provinces, or national contexts, limiting transferability. The literature also contained unequal representation across educational levels and socio-economic settings. Concerns about contextual homogeneity and limited representation of rural or under-resourced institutions have also been identified in related research (Fikriyatii et al., 2022; Lamb, 2015; Saeed & Ramdane, 2022; Yulianti, 2024).

Finally, the bibliometric analysis used a relatively small corpus of 117 records and a minimum author-keyword occurrence threshold of two. This choice preserved thematic diversity but may have produced clusters

influenced by low-frequency terms. The visualization describes co-occurrence patterns and average publication years; it does not establish thematic importance, causal relationships, research quality, or intervention effectiveness.

5.10 *Directions for Future Research*

Future studies should prioritize longitudinal and comparative designs that examine whether changes in technology use, teacher practice, and student competencies persist beyond initial implementation. Longer follow-up periods would help determine whether improvements in critical thinking, collaboration, problem-solving, and digital literacy are sustained across courses or educational stages (Kwangmuang et al., 2021; Rosidin et al., 2019).

Researchers should also use direct and validated competency measures. Studies should distinguish academic achievement from engagement, satisfaction, self-efficacy, technology acceptance, and perceived improvement. Competencies such as critical thinking, collaboration, creativity, communication, problem-solving, digital literacy, and information literacy should be assessed through performance tasks, observation protocols, digital artifacts, learning analytics, or validated instruments. Integrated digital assessments may be particularly useful for examining teamwork and authentic problem-solving (Chamba & Chikusvura, 2024).

More research is needed in diverse educational contexts, including rural schools, low-connectivity environments, vocational institutions, special education, and culturally distinct settings. Comparative studies should examine how infrastructure, language, socio-economic conditions, accessibility, policy, and organizational culture moderate implementation (Rossi et al., 2021; Suciati et al., 2022).

Professional-development research should compare one-off workshops with sustained coaching, mentoring, professional learning communities, collaborative design, and action-research models. Studies should measure not only changes in teacher confidence or TPACK scores but also classroom practice, implementation fidelity, student participation, and direct learning outcomes (Nong et al., 2022; Zlatkin-Troitschanskaia & Schlax, 2020).

Emerging technologies require similarly rigorous and context-sensitive evaluation. Research on generative AI, intelligent tutoring systems, adaptive learning, virtual and augmented reality, chatbots, and learning analytics should examine pedagogical alignment, accessibility, privacy, bias, teacher oversight, assessment validity, and direct competency development. Recent studies demonstrate increasing interest in both students' acceptance of AI applications and AI-supported educational approaches across different educational levels (Aravatinos et al., 2024; Lavidas et al., 2024). Nevertheless, behavioral intention, satisfaction, novelty, or frequency of use should not substitute for evidence of sustained learning, equitable participation, responsible implementation, and directly measured competency development.

Finally, policy studies should investigate how funding, infrastructure, digital-literacy initiatives, teacher-development systems, and equity measures interact over time. Rather than evaluating policies only through device provision or platform adoption, future research should assess who benefits, which inequalities remain, how technologies are used, and whether improvements in learning and participation are sustained.

6. Conclusion

This systematic review shows that ICT integration can support teaching, learning, assessment, and educational management, but its effects on learning competencies are neither automatic nor uniform. Across the 19 studies included in the systematic evidence synthesis, positive outcomes were more likely when technology use was aligned with instructional objectives, supported by teacher competence, embedded in student-centered learning activities, and reinforced by reliable infrastructure and institutional commitment. However, direct evidence of improved student competencies was limited. Many studies assessed technology acceptance, readiness, feasibility, teacher self-efficacy, administrative effectiveness, satisfaction, or perceived learning rather than objectively measured academic performance or transferable competencies.

The findings therefore do not support an unqualified conclusion that ICT integration, Problem-Based Learning, or blended learning consistently produces substantial improvements in critical thinking, collaboration, and problem-solving. Instead, the review indicates that active, collaborative, and inquiry-oriented uses of technology are more educationally promising than applications that merely substitute digital tools for conventional teacher-centered practices. Their effectiveness depends on instructional design, learner support, assessment quality, implementation fidelity, and the conditions under which they are introduced.

The review also demonstrates that ICT integration is a multilevel process that cannot be explained by a single framework. TPACK helps explain the knowledge teachers require to align technology, pedagogy, and disciplinary content; SAMR describes the extent to which technology transforms learning tasks; TAM and UTAUT explain acceptance and use; instructional-design models guide the development of technology-supported learning; and leadership, readiness, and evaluation frameworks address organizational capacity and implementation quality. These frameworks are complementary, but none independently establishes that technology improves learning.

The hypothesis guiding this review is therefore conditionally supported. ICT integration was more likely to produce positive learning-related outcomes when teachers possessed relevant digital and pedagogical competence, institutions provided sustained professional development and technical support, infrastructure was reliable and accessible, and technology-supported activities were aligned with curricula and assessment. In contrast, limited training, weak leadership, inadequate connectivity, fragmented implementation, and the replication of conventional instruction through digital media were associated with weaker or inconsistent outcomes.

The principal contribution of this review lies in distinguishing the broader thematic prominence of ICT-related topics from the strength of empirical evidence concerning learning competencies. Bibliometric mapping of the 117 Scopus records showed that the literature is organized around higher education, e-learning, blended learning, learning outcomes, technology adoption, instructional design, digital transformation, and institutional management. The detailed synthesis of the 19 eligible studies, however, revealed that thematic prominence should not be interpreted as proof of effectiveness. This distinction provides a more cautious and methodologically defensible account of what is currently known about ICT integration in education.

7. Recommendation

Educators should begin ICT integration by defining the competencies learners are expected to develop and then selecting technologies that directly support those goals. Digital activities should align with curriculum, pedagogy, accessibility, and assessment. Active approaches such as problem-, project-, inquiry-, collaborative-, and blended learning may be useful when they promote analysis, participation, feedback, and authentic problem-solving rather than merely reproducing conventional instruction in digital form. Learning evaluation should combine engagement and satisfaction measures with direct evidence such as performance tasks, achievement data, observations, and student work. Teacher professional development should move beyond short technical workshops. Institutions should provide sustained, subject-specific support through coaching, mentoring, collaborative lesson design, professional learning communities, and classroom-based follow-up. Teacher competence should be assessed through lesson plans, teaching portfolios, observations, and evidence of technology-supported student learning rather than self-report alone.

Institutions and policymakers should integrate infrastructure, technical support, curriculum, assessment, accessibility, data governance, maintenance, and long-term evaluation within a coherent ICT strategy. Rural, low-income, and underserved settings require targeted investment in connectivity, devices, digital content, teacher support, and local technical capacity. Leadership should monitor how technologies are used and whether they improve participation, instructional quality, and learning opportunities. Future research should use longitudinal and comparative designs, include diverse educational settings, and prioritize direct measures of critical thinking, collaboration, communication, problem-solving, creativity, and digital literacy. Studies should compare one-off training with sustained professional-development models and rigorously evaluate emerging technologies, including artificial intelligence, adaptive systems, chatbots, virtual and augmented reality, and learning analytics. Future reviews should also search multiple databases and report sensitivity analyses for bibliometric thresholds and keyword-cleaning decisions.

Author contribution

Binar Kurnia Prahani: conceptualization, methodology, software, supervision, validation, and writing review and editing.
Hanandita Veda Saphira: conceptualization, investigation, methodology, data curation, formal analysis, visualization, and writing the original draft.

Conflict of Interest

There are no competing interests.

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Ethical statement

All included studies were derived from publicly available, peer-reviewed publications, and no primary data collection involving human participants was undertaken. Thus, no ethical approval or informed consent was required for this research.

Data availability

Not applicable.

Utilization of AI statement

During the preparation of this work, the authors used ChatGPT to enhance the clarity of the writing. After using the ChatGPT, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

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