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Bridging the Technology Integration Gap: Investigating How Professional Development Shapes Teachers' Digital Teaching Practices

MD Shahadat Hossain Shishir[1], Md Rasel Ul Alam [2], Shahedul Islam[3]

[1]*World University of Bangladesh, Dhaka-1230, Bangladesh*

[2] *University of the Cumberlands, Kentucky, USA*

[3] *United International University, Dhaka, Bangladesh*

**Corresponding author:* shahadatdaf20@gmail.com

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Abstract

The integration of digital technologies into teaching has expanded substantially, yet meaningful and pedagogically effective use remains inconsistent across educational contexts. This study investigates how professional development shapes teachers' digital teaching practices and identifies the mechanisms that influence the transition from technology awareness to meaningful classroom integration. The analysis focuses on the relationship among professional development, technological-pedagogical knowledge, digital competence, teacher self-efficacy, pedagogical beliefs, and institutional support. The findings indicate that effective professional development is characterized by sustained learning opportunities, practical classroom application, collaboration, reflection, feedback, and context-specific support rather than isolated technical training. Professional development strengthens teachers' technological and pedagogical capabilities while also influencing confidence and beliefs about the instructional value of digital technologies. However, the translation of these capabilities into sustained classroom practice is dependent on contextual conditions such as leadership, peer support, infrastructure, time, and technical assistance. The study proposes an integrated framework in which professional development influences digital teaching practices through competence development and psychological readiness, while organizational conditions moderate the effectiveness and sustainability of technology integration. The findings suggest that bridging the technology integration gap requires a shift from tool-focused training toward continuous, pedagogically grounded professional learning that connects technology, subject knowledge, instructional design, and classroom practice.

1. Introduction

1.1 Digital transformation and the persistent integration problem

Digital technologies have altered the material conditions of teaching. Learning management systems, multimedia resources, interactive applications, collaborative platforms, digital assessment systems, and discipline-specific software have widened the range of activities that teachers can design and learners can experience. Yet the pedagogical value of a technology is not determined by its presence. The same tool can be used to reproduce a traditional lecture, support a more interactive activity, or enable forms of inquiry and collaboration that were previously difficult to organize. This distinction is central to understanding the technology integration problem. Parker et al. (2019), for example, developed an observation protocol specifically because merely documenting the presence of technology could not adequately capture the quality of integration. Their framework emphasized technology use in relation to science practices, student-centered teaching, and contextualization rather than technology use in isolation.

The implication is that a school, university, or teacher may appear highly digital while still exhibiting a relatively low level of pedagogical integration. Access, adoption, routine use, and transformative use represent different stages of technological maturity. Teachers may have devices and connectivity yet use them primarily for presentation, information display, administrative communication, or other low-interactivity functions. A more substantive form of integration requires teachers to make deliberate decisions about when technology adds pedagogical value, how the technology aligns with content and learning goals, and how the activity changes what teachers and learners can do. This paper uses the term technology integration gap to refer to the space between the availability or adoption of technology and its sustained, pedagogically meaningful use.

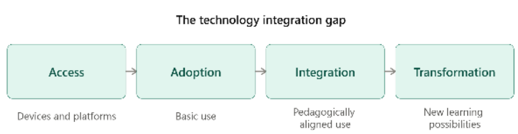

Figure 1. The technology integration gap: moving from access and adoption toward pedagogically meaningful and transformative digital practice.

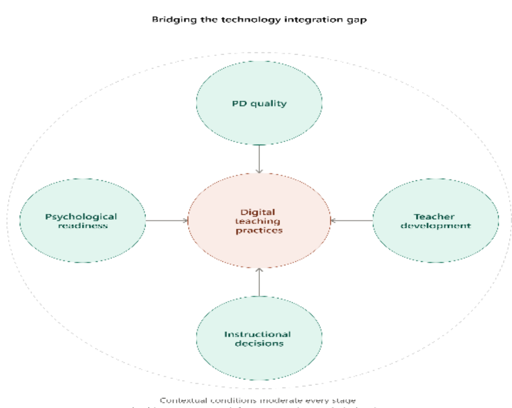

Figure 2. Conceptual framework for explaining how professional development can bridge the technology integration gap.

1.2 Professional development as a bridge between technology and practice

Professional development is a plausible bridge because technology integration is not simply a matter of learning software features. It requires teachers to combine technological knowledge with pedagogical strategies and subject matter understanding. The TPACK perspective is especially useful here because it treats effective technology integration as a form of situated knowledge rather than an additive collection of technical skills (Mishra & Koehler, 2006). Evidence from technology-focused professional development supports this view. Alemdag et al. (2020) designed a professional-development programme around TPACK and learning by design for teachers in a public education centre and reported improvements in teachers' TPACK as well as changes in teaching practices. Koh (2020) likewise showed, through an action-research study of instructional consultation, that technology modelling, pedagogical realignment, and deepening practice can support TPACK development for faculty with different levels of prior experience.

The quality of professional development therefore matters. One-off workshops may increase familiarity with tools but provide limited opportunity for teachers to test, receive feedback on, redesign, and embed new practices. Reviews and design studies have repeatedly emphasized content focus, active learning, coherence, duration, collective participation, relevance, reflection, and follow-up as important characteristics of effective professional learning for technology integration (Yurtseven Avci et al., 2020). Liao et al. (2017) similarly found a growing preference among K–12 teachers for personalized, sustained, and situated professional development, including in-class support and teacher-led learning. Paulus et al. (2020) framed professional learning communities as a teacher-centered alternative to the conventional workshop model and linked collaborative professional learning to more transformative forms of technology integration.

1.3 From digital literacy to digital competence

A second reason professional development matters is that contemporary technology integration requires a broader conception of digital competence. Falloon (2020) argued that teacher capability extends beyond basic digital literacy to a broader competency framework that includes the knowledge and dispositions needed to select, use, evaluate, and pedagogically integrate digital resources. Reisoğlu and Çebi (2020) similarly examined how pre-service teachers' digital competences can be developed through activities aligned with DigComp and DigCompEdu. Their work highlights the value of moving between theory, collaborative activity, and practical application rather than treating digital competence as a technical checklist.

Digital competence is particularly relevant to the present paper because it provides a link between professional development and classroom practice. Professional development may increase the teacher's repertoire of technological strategies, but practice improves when the teacher can judge the appropriateness of a digital resource, anticipate how learners may use it, design tasks around it, evaluate evidence of student learning, and adapt the activity. In other words, competence provides the decision-making infrastructure through which technology becomes part of pedagogy.

1.4 Self-efficacy, beliefs, and contextual conditions

The technology integration literature also shows that knowledge is not sufficient on its own. Ertmer and Ottenbreit-Leftwich (2010) conceptualized teacher technology change as an interaction among knowledge, confidence, beliefs, and culture. Ertmer et al. (2012) further demonstrated that teacher beliefs and technology integration practices are closely related. Kim et al. (2013) likewise emphasized the importance of teachers' beliefs in understanding their technology integration. These findings suggest that professional development can have indirect effects on practice by changing teachers' confidence and beliefs about what technology is for, what counts as effective teaching, and whether experimentation is worthwhile.

At the same time, teachers work within organizational systems. Thannimalai and Raman (2018), studying secondary schools in Malaysia, found a significant relationship between principals' technology leadership and teachers' technology integration and reported a significant moderating effect of professional development. Kafyulilo et al. (2016) showed that teachers who had participated in a professional development programme did not all continue using technology at the same level; encouragement from school management and practical conditions such as time, electricity, classroom size, and access to tools were important. These findings caution against attributing the entire technology integration gap to individual teachers. Classroom practice is embedded in institutional structures.

1.5 Research gap and purpose

Although substantial research has examined professional development, TPACK, digital competence, beliefs, and school-level conditions, these streams are often discussed separately. The resulting picture can become fragmented: one literature evaluates professional-development models, another measures digital competence, another examines teacher beliefs, and another studies leadership or infrastructure. The present paper brings these strands together to explain a more complete pathway from professional learning to digital teaching practice. The central proposition is that professional development affects technology integration through at least three interconnected mechanisms: capability development, psychological readiness, and contextual enablement. This leads to the following research questions.

2. Literature Review

2.1 Technology integration as a multi-dimensional construct

The concept of technology integration has evolved from a simple focus on frequency of use toward a concern with quality, purpose, and pedagogical alignment. Early technology-integration research often measured whether teachers used computers or other ICT tools. Later work emphasized the nature of the activity, the role of the learner, and the relationship between technology, pedagogy, and content. Parker et al. (2019) demonstrated this shift by designing an observation protocol that combined quantitative coding with contextual evidence about teacher intentions, actions, and reflections. Similarly, Spiteri and Chang Rundgren (2020) reviewed factors affecting primary teachers' use of digital technology and demonstrated that technology use is shaped by a combination of teacher-level and contextual conditions.

This broader definition matters for the present study because a professional development programme can produce different forms of change. A teacher may learn to operate a digital presentation tool without changing pedagogy; another teacher may adopt collaborative digital tasks that shift classroom participation; and a third may use technology to create learning opportunities that would otherwise be difficult to implement. Therefore, the outcome of professional development should be evaluated at the level of teaching practice rather than tool adoption alone.

2.2 Professional development models for technology integration

The evidence base contains several professional-development formats. Workshop-based models provide access to new tools and can be efficient for broad dissemination, but they risk separating technical instruction from teachers' immediate pedagogical needs. Collaborative models, including professional learning communities, provide a social structure through which teachers can discuss classroom problems, observe peers, share resources, and negotiate meaning. Coaching and consultation models provide individualized support and are especially suitable when teachers have different starting points. Course- and design-based models focus on lesson planning, microteaching, authentic tasks, and classroom implementation. The strongest pattern across the reviewed literature is not that one format is universally superior; rather, PD becomes more useful when it is active, relevant, sustained, collaborative, and connected to classroom practice (Yurtseven Avci et al., 2020).

Alemdag et al. (2020) provide a concrete example of a design-based programme. Their programme used a TPACK framework and learning-by-design approach and involved teacher reflections, lesson plans, and focus-group data. The programme enhanced TPACK and influenced teaching practice, illustrating how learning can be embedded in the process of designing and implementing instruction. Koh et al. (2017) likewise examined TPACK-focused professional development and its implications for teacher ICT integration and student outcomes. Together, these studies reinforce the idea that professional development is most consequential when teachers are asked to convert new knowledge into instructional design.

2.3 TPACK as a mechanism of change

TPACK offers one of the clearest conceptual explanations for why technology integration can be difficult. Teachers do not simply add technological knowledge to existing pedagogical and content knowledge; they must determine how specific technologies can represent, sequence, explain, assess, and support a particular subject. This is why TPACK is useful as a mediating or enabling mechanism between professional development and practice. Aktaş and Özmen (2020), for example, investigated a TPACK development course for pre-service science teachers that included training, lesson planning with microteaching, and school application. The structure of the course illustrates a movement from conceptual learning to enactment.

Koh (2020) provides additional insight by identifying three consultation approaches: technology modelling, pedagogical realignment, and deepening practice. Their sequencing is relevant to the technology integration gap. Teachers with limited technology experience may first need models and examples, while teachers with more experience may benefit more from reconsidering pedagogy and reflecting on existing practice. This suggests that professional development should be differentiated according to teacher readiness rather than treating all participants as if they have identical needs.

2.4 Digital competence and professional digital capacity

Digital competence extends the TPACK discussion by emphasizing broader professional capability. Falloon (2020) proposed the Teacher Digital Competency framework as a way to move beyond generic digital literacy. In the teacher-education literature, Brevik et al. (2019) examined professional digital competence and transformative agency, arguing that teachers need opportunities to use digital resources as part of professional learning and practice. Lázaro Cantabrana et al. (2019) focused on measuring teacher digital competence and contributed an instrument intended to assess knowledge among pre-service teachers. These studies suggest that professional digital capability should be treated as a developmental construct that includes knowledge, professional judgment, and the ability to use technology purposefully.

2.5 Beliefs and self-efficacy

Teacher beliefs influence whether newly learned technologies are interpreted as useful, compatible with effective teaching, and worth investing time in. Ertmer and Ottenbreit-Leftwich (2010) positioned confidence and beliefs alongside knowledge and culture as central to technology change. Ertmer et al. (2012) characterized teacher beliefs as a critical relationship with technology integration practices, while Liu (2011) examined the relationship between pedagogical beliefs and technology integration. Kim et al. (2013) further emphasized teachers' belief systems in explaining technology integration. The collective implication is that professional development that ignores beliefs and confidence may produce shallow adoption because teachers may not revise the assumptions that guide instructional decisions.

2.6 School leadership, peer learning, and contextual support

Contextual factors explain why a professional development experience may transfer differently across schools. Leadership can create or constrain opportunities for experimentation. Thannimalai and Raman (2018) explicitly examined the moderating role of professional development in the relationship between principals' technology leadership and teachers' technology integration. Kafyulilo et al. (2016) found that continued technology use varied across teachers and that encouragement from school management was critical. Tondeur et al. (2019) examined teacher educators as gatekeepers and highlighted strategies such as modelling, collaboration, authentic technology experiences, and continuous feedback.

Infrastructure and time are equally relevant. Even where teachers have acquired technological and pedagogical competence, unreliable electricity, limited equipment, crowded classrooms, lack of technical assistance, or insufficient planning time can restrict implementation. This is a critical point for research because the technology integration gap can arise from a mismatch between teacher capability and organizational opportunity. Professional development therefore cannot be evaluated independently of the conditions under which teachers are expected to apply what they learn.

2.7 Sustainability and continuation

Sustained technology integration is a more demanding outcome than immediate post-training adoption. Kafyulilo et al. (2016) provide a useful longitudinal perspective: teachers who had participated in professional development did not all maintain technology use at the same level. Continuation depended on institutional, technological, and personal conditions. Gurevich et al. (2017) similarly tracked novice mathematics teachers across stages of professional development and early teaching practice, finding that practical experience changed how teachers perceived the benefits of technology. These findings suggest that professional development may produce a learning trajectory rather than a one-time treatment effect.

2.8 Evidence synthesis of the 30-paper corpus

Study	**Year**	**Evidence type**	**Primary focus**	**Contribution to framework**
Alemdag et al.	2020	Case study	TPACK + learning by design	PD -> TPACK -> practice
Aktaş & Özmen	2020	Intervention	TPACK development course	Course -> competence
Falloon	2020	Framework	Teacher digital competency	Digital competence model
Fernández-Batanero et al.	2020	Systematic review	Digital competence + PD	Training gap
Koh	2020	Action research	Instructional consultation	Consultation -> TPACK
Paulus et al.	2020	Conceptual / PLC	Professional learning communities	Collaborative PD
Reisoğlu & Çebi	2020	Case study	DigComp/DigCompEdu	Digital competence development
Yurtseven Avci et al.	2020	Design/ review	Effective PD design	Core PD features
Blanchard et al.	2016	Mixed/ longitudinal	Technology-enhanced PD	Use + confidence
Kafyulilo et al.	2016	Qualitative	Continuation after PD	Sustainability
Koh et al.	2017	Professional development study	TPACK-21CL	ICT integration
Liao et al.	2017	Survey	PD preferences	Personalized/situated PD
Gurevich et al.	2017	Longitudinal qualitative	Novice teacher PD	Practice + attitudes
Thannimalai & Raman	2018	Quantitative survey	Leadership + PD	Moderation / integration
Spiteri & Chang Rundgren	2020	Literature review	Factors affecting teacher use	Teacher + context
Tyler-Wood et al.	2018	Case study	Technology implementation	Rural context
Çoklar & Kabakçı Yurdakul	2017	Qualitative	Teacher integration experiences	Teacher practice

Study	Year	Evidence type	Primary focus	Contribution to framework
Tondeur et al.	2019	Qualitative synthesis	Teacher educator strategies	Modelling/collaboration
Brevik et al.	2019	Open-access study	Professional digital competence	Transformative agency
Lázaro Cantabrana et al.	2019	Instrument development	Teacher digital competence	Measurement
Parker et al.	2019	Instrument / observation	Quality integration	Meaningful use
Ertmer & Ottenbreit-Leftwich	2010	Conceptual synthesis	Knowledge/confidence/beliefs/culture	Change mechanisms
Liu	2011	Empirical	Pedagogical beliefs	Beliefs -> integration
Tondeur et al.	2012	Synthesis	Pre-service technology integration	Qualitative evidence
Hutchison	2012	Empirical	Technology-focused PD	Teacher perceptions
Ertmer et al.	2012	Empirical / synthesis	Beliefs + integration	Critical relationship
Kim et al.	2013	Empirical	Teacher beliefs	Beliefs -> use
Mishra & Koehler	2006	Framework	TPACK	Foundational theory
Inan & Lowther	2010	Quantitative path model	Teacher readiness + school support	Readiness, support -> integration
Dogan et al.	2020	Quantitative path models	Teacher skills + technology use	Skills -> technology integration

1.6 Research questions

I. RQ1. What characteristics of professional development are most consistently associated with stronger teacher technology integration?

II. RQ2. How does professional development influence teachers' TPACK, digital competence, and related capabilities?

III. RQ3. What role do self-efficacy, pedagogical beliefs, and contextual support play in translating professional development into classroom practice?

IV. RQ4. What conceptual pathway best explains how professional development can bridge the technology integration gap and support sustained digital teaching practices?

3. Methodology

3.1 Review design

A structured literature-review and evidence-synthesis design was used. The aim was not to pool statistically comparable effect sizes but to integrate heterogeneous evidence about how professional development shapes teacher technology integration. This design is appropriate because the evidence set includes quantitative surveys, qualitative studies, intervention or case studies, systematic reviews, conceptual models, framework papers, and measurement studies. Treating these studies as if they were interchangeable would obscure rather than clarify the mechanisms of change.

The review was bounded to literature published in 2020 or earlier, consistent with the study objective of constructing a pre-2021 evidence baseline. Where articles had an online publication date in 2020 but an issue assignment in 2021, the online publication year was used only when the work was demonstrably available in 2020; this boundary rule should be applied consistently in any final database audit. Open-access journal articles, institutional repositories, ERIC records, and author manuscripts were prioritized so that the evidence could be independently accessed.

3.2 Search strategy and eligibility

The search concept combined terms for teacher professional development with terms for technology integration and teacher digital capability. Core strings included combinations of "teacher professional development," "technology integration," "digital teaching," "ICT integration," "TPACK," "digital competence," "technology professional development," and "teacher technology use." Candidate studies were screened for date, relevance to teachers or teacher educators, and direct relevance to the mechanisms linking professional learning with digital teaching practice.

3.3 Inclusion criteria

I. Published in 2020 or earlier;
II. Focused on teachers, teacher educators, pre-service teachers, or faculty where the findings illuminate teacher digital practice;
III. Examined professional development, technology integration, digital competence, TPACK, technology-related beliefs, or contextual conditions affecting teacher practice;
IV. Provided empirical, systematic-review, framework, or conceptual evidence directly relevant to the research questions;
V. Had an openly accessible full-text version or a credible public scholarly record.

VI. 3.4 Exclusion criteria

VII. Studies published after 2020;
VIII. Studies focused exclusively on student outcomes without a teacher-practice component;
IX. Purely technical papers that did not examine teacher learning or pedagogy;
X. Duplicate records or papers for which the full text did not permit meaningful thematic coding.

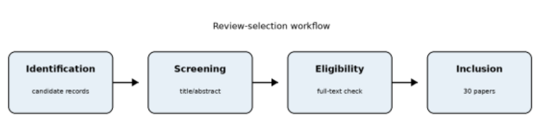

Figure 3. Review-selection workflow used to define the 30-paper evidence corpus. Exact database-level record counts should be inserted from the final search log before journal submission.

Stage	**Decision rule**	**Output**
Identification	Search across scholarly sources using technology integration + PD terms	Candidate records
Screening	Remove duplicates; screen title/abstract for topic and date	Potentially relevant studies
Eligibility	Check full text, teacher focus, and evidence relevance	Eligible studies
Inclusion	Apply final date/open-access/relevance criteria	30-paper evidence corpus

3.5 Coding framework

Each study was coded against a common analytic frame: publication year, educational context, evidence type, professional-development format, competence construct, psychological mechanism, contextual condition, technology-integration outcome, and sustainability. Coding was used descriptively to build the thematic figures and tables. Importantly, the resulting frequencies should be interpreted as evidence-presence counts rather than effect sizes. A study that discusses a construct extensively and a study that measures it with a specific scale are both coded as evidence for that construct, but they do not receive equal causal weight.

4. Results

4.1 Profile of the evidence corpus

The 30-paper evidence set spans 2006–2020, with a visible concentration of studies in the later part of the period. The most recent studies increasingly frame technology integration as a competence, design, or professional-learning problem rather than simply an access problem. Figure 4 illustrates the cumulative growth of the evidence set used in this paper. The pattern is descriptive rather than bibliometric: it shows the distribution of the selected corpus rather than the complete publication history of the field.

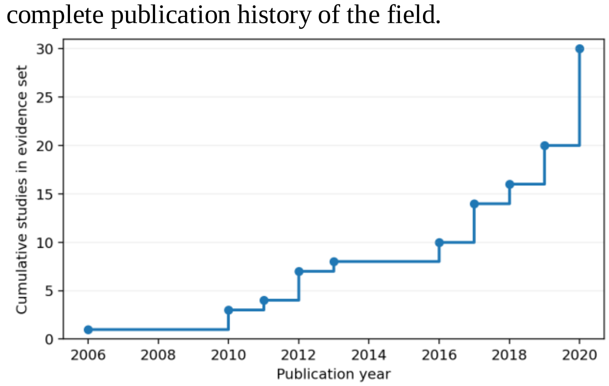

Figure 4. Cumulative distribution of the selected evidence set by publication year.

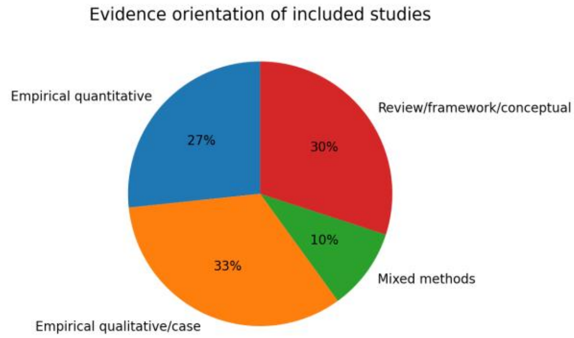

Figure 5. Descriptive distribution of evidence orientations in the 30-paper corpus.

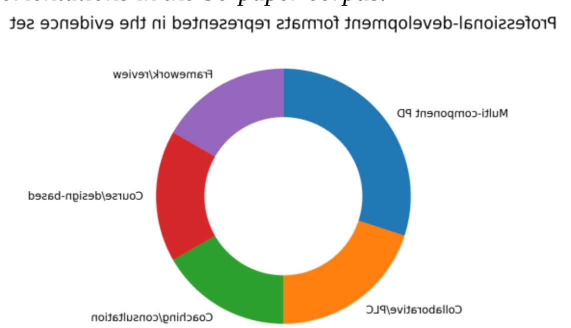

Figure 6. Professional-development formats represented across the evidence corpus.

4.2 The strongest characteristics of effective professional development

The thematic coding shows a consistent emphasis on active and classroom-connected professional learning. Content focus and classroom practice are prominent because effective technology integration depends on the relationship between a tool, a pedagogical purpose, and subject-specific learning. Active learning is also repeatedly emphasized: teachers need opportunities to design, implement, observe, discuss, and revise digital teaching activities. Collaboration appears as another recurring feature, particularly in PLC and teacher-educator studies. Follow-up, reflection, and coaching are present less consistently, but when they occur they address the transfer problem directly by extending professional learning into practice.

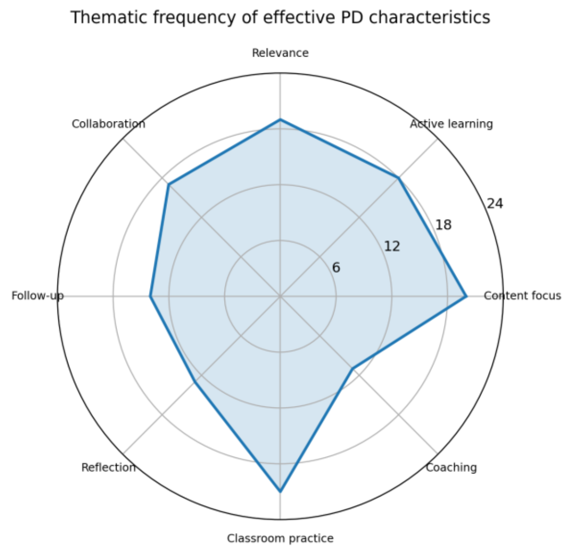

Figure 7. Thematic frequency of professional-development characteristics across the evidence set. Frequencies are descriptive study-coding counts, not effect sizes.

4.3 Professional development and teacher capability

The evidence indicates that professional development most directly changes what teachers know and can do. TPACK development appears repeatedly as a mechanism linking professional learning to instructional design. Alemdag et al. (2020) documented enhancement in TPACK together with changes in teaching practice. Aktaş and Özmen (2020) used a staged TPACK development course that moved from training to microteaching and school application. Koh (2020) demonstrated how consultation can create TPACK through modelling, pedagogical realignment, and deepening practice. The convergence across these studies supports the proposition that technology integration improves when professional development targets technology-related pedagogical reasoning rather than generic technical skill.

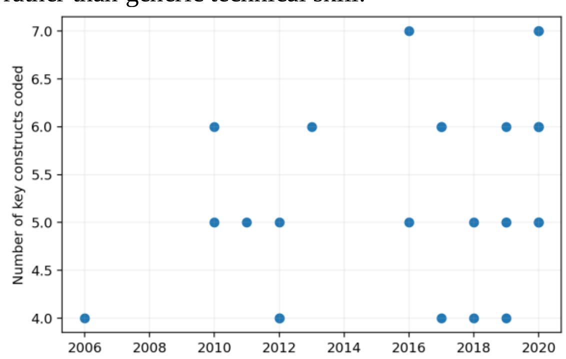

Figure 8. Scatterplot of publication year against the number of key constructs represented in each study, used to illustrate increasing conceptual breadth in the selected corpus.

4.4 Psychological readiness and teacher beliefs

The review also indicates that confidence and beliefs are not peripheral variables. Ertmer and Ottenbreit-Leftwich (2010) place confidence and beliefs alongside knowledge and culture as core components of technology change, while Ertmer et al. (2012) and Kim et al. (2013) link teacher beliefs to actual integration practice. In professional-learning studies, confidence is often improved when teachers can experience technology in manageable, authentic instructional settings. Blanchard et al. (2016), for example, followed technology-enhanced teacher professional development over multiple years and reported increases in teachers' comfort with technology and technology use in instruction. The result is a mechanism in which professional development does more than transmit knowledge: it changes perceived capability and reduces uncertainty around classroom implementation.

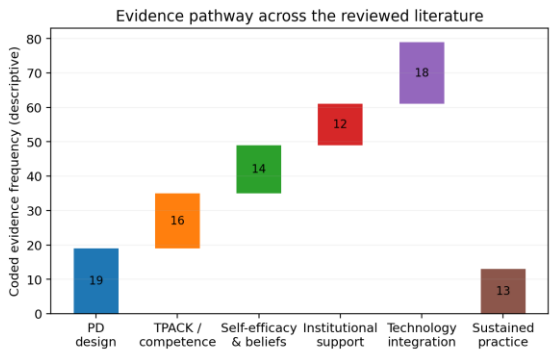

Figure 9. Evidence pathway: professional-development features and intermediate mechanisms that recur across the reviewed literature. The values are descriptive coding frequencies.

4.5 Institutional support and the transfer problem

A central result is that professional development cannot fully explain sustained integration without contextual conditions. Thannimalai and Raman (2018) found that professional development significantly affected the relationship between principals' technology leadership and teachers' technology integration. Kafyulilo et al. (2016) reported that school-management encouragement was critical to continuation of technology use after professional development. These findings indicate that transfer from professional learning to classroom practice is conditional. Teachers may understand a technology and believe in its value while still failing to use it when time, infrastructure, support, or organizational expectations are misaligned.

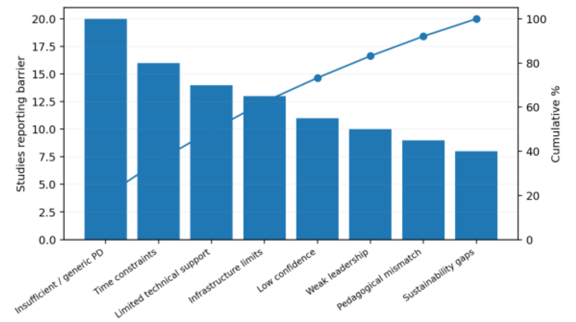

Figure 10. Pareto-style visualization of recurring barriers identified or emphasized across the evidence corpus. Descriptive frequencies show how often barriers were represented in the coded studies.

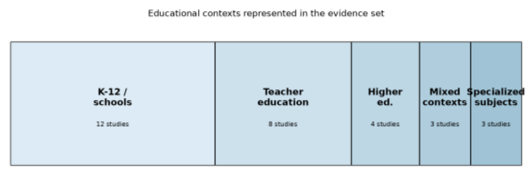

Figure 11. Educational contexts represented in the evidence corpus.

4.6 From training to sustained practice

The evidence supports a staged process rather than an event model. Teachers are first exposed to a tool, framework, or teaching strategy. They then need opportunities to apply the learning to a classroom problem, receive feedback, reflect on evidence of student learning, and redesign the activity. Over time, this cycle can consolidate digital practice. Yurtseven Avci et al. (2020) explicitly emphasized duration, active learning, relevance, reflection, evidence of student learning, support, and follow-up as design considerations. Tondeur et al. (2019) highlighted modelling, authentic experiences, collaboration, and feedback. Together, these findings suggest that the most important PD outcome is not "attendance" or immediate tool use, but a growing capacity for instructional decision-making.

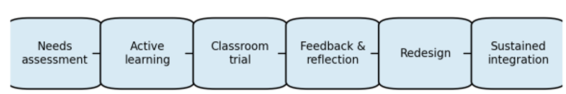

Figure 12. Proposed implementation pathway from needs assessment through active learning, classroom trial, feedback, redesign, and sustained integration.

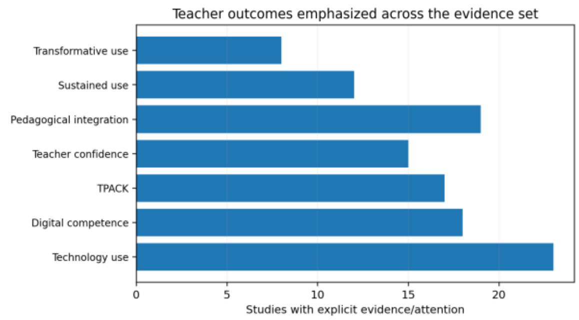

Figure 13. Teacher outcomes emphasized across the evidence corpus.

4.7 Cross-construct evidence pattern

Figure 14 summarizes the conceptual linkages identified by the coding. Professional development is most strongly connected to knowledge and practice outcomes, while self-efficacy and beliefs form a psychological bridge. Leadership, peer support, infrastructure, and time represent contextual conditions. Sustainability receives a distinct place because continuation depends on whether classroom use becomes compatible with the teacher's working environment. This pattern is consistent with the literature's movement from simple technology-adoption models toward multi-factor explanations of digital teaching.

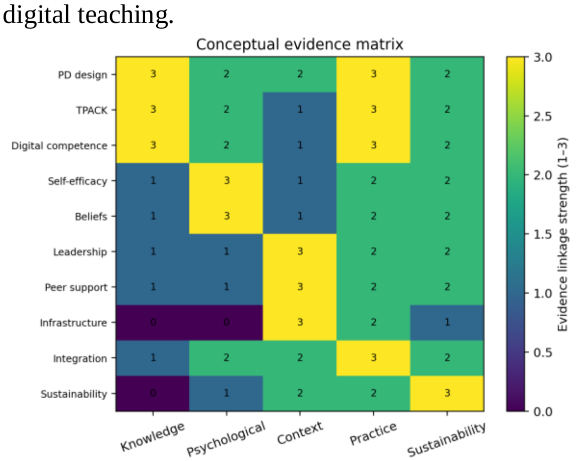

Figure 14. Cross-construct evidence matrix. Higher values indicate stronger recurring linkage in the reviewed studies; the matrix is a thematic synthesis, not a correlation matrix.

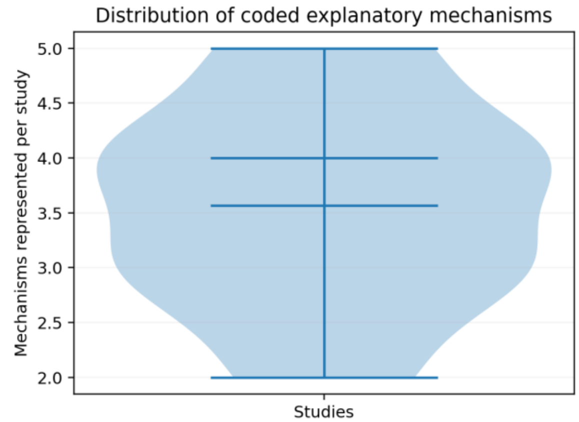

Figure 15. Distribution of the number of explanatory mechanisms represented within individual studies in the evidence corpus.

4.8 Thematic synthesis table

Theme	Recurring evidence	Interpretation
PD design	Active learning, relevance, duration, coherence, classroom practice, collaboration, follow-up	Design quality matters more than exposure alone
TPACK / competence	Technology-pedagogy-content alignment, lesson design, digital judgment	Capability is a key bridge from learning to action
Self-efficacy / beliefs	Confidence, usefulness, pedagogical beliefs, willingness to experiment	Psychological readiness influences enactment
Context	Leadership, peer support, time, infrastructure, technical assistance	Organizational opportunity enables or constrains transfer
Integration quality	Purposeful, student-centered, contextualized, discipline-specific use	Technology presence is not equivalent to meaningful integration

5. Discussion

5.1 Professional development is a mechanism, not a binary treatment

The results support a more differentiated understanding of professional development. The question is not simply whether a teacher received technology training. The more informative questions are how the learning was organized, how long it lasted, whether the content was connected to instructional goals, and whether teachers had opportunities to test and revise new practices. Yurtseven Avci et al. (2020) synthesized six core characteristics of effective teacher professional development—content focus, active learning, coherence, duration, collective participation, and context—and then identified additional technology-integration features such as relevance, reflection, evidence of student learning, support, follow-up, and teacher leadership. This aligns closely with the present synthesis.

The practical implication is that PD evaluation should report design characteristics, not only participation counts. A 90-minute workshop and a semester-long collaborative design programme are both "professional development," but their potential to affect classroom practice is very different. The current literature supports a move toward design-sensitive evaluation in which professional-learning experiences are treated as systems with inputs, mechanisms, and outputs.

5.2 The central bridge is pedagogical competence

A recurring finding is that meaningful technology integration depends on teachers' ability to coordinate technology with pedagogy and content. This explains why TPACK appears so prominently across intervention, consultation, and teacher-education studies. Mishra and Koehler's (2006) framework provides the theoretical foundation, while Alemdag et al. (2020), Aktaş and Özmen (2020), and Koh (2020) show ways professional learning can operationalize the framework. Rather than learning technologies as detached tools, teachers learn to make design decisions: when a digital resource improves representation, when a collaborative platform changes participation, when a simulation supports conceptual understanding, or when technology adds little value and should not be used.

Digital competence complements rather than replaces TPACK. TPACK emphasizes the integrated knowledge needed to teach with technology; digital competence captures a broader professional repertoire that includes digital resources, professional engagement, assessment, and learner empowerment. Falloon (2020) and Reisoğlu and Çebi (2020) support this broader conception. Together, the constructs explain why a teacher can be technically confident yet pedagogically limited, or pedagogically innovative yet constrained by low technological fluency.

5.3 Psychological readiness explains part of the transfer pathway

The review also shows why competence does not automatically become practice. Teachers interpret new digital practices through beliefs about teaching and learning. A technology-enhanced strategy may be rejected because it appears incompatible with classroom management, assessment routines, curriculum pacing, or established conceptions of effective teaching. Ertmer and Ottenbreit-Leftwich (2010) and Ertmer et al. (2012) provide a strong theoretical basis for this argument, while Kim et al. (2013) and Liu (2011) show that beliefs are associated with technology integration. Professional development that includes authentic teaching experiences can change beliefs because teachers generate their own evidence about what works rather than merely hearing that a tool is effective.

5.4 Institutional context determines whether learning can be enacted

The findings on leadership and continuation are especially important for understanding the technology integration gap. Kafyulilo et al. (2016) showed that even after professional development, continuation varied and was influenced by school-management encouragement and practical conditions. Thannimalai and Raman (2018) similarly connected professional development, principal technology leadership, and teacher integration. These findings point to a simple principle: professional learning changes teachers' capacity, but organizational conditions determine whether capacity can be exercised.

This principle shifts responsibility away from blaming individual teachers for weak adoption. A teacher may have strong TPACK but insufficient planning time; a school may have strong leadership but poor connectivity; a district may provide high-quality PD but little follow-up. The most effective systems therefore align teacher learning with organizational support. In practical terms, PD should be paired with scheduling, technical assistance, access to devices and digital resources, peer collaboration, and leadership that rewards experimentation and reflection.

5.5 Why technology presence is not the same as integration quality

Parker et al. (2019) make an important contribution by distinguishing technology that supports, enhances, or transforms instruction from technology that is ineffective or poorly integrated. This distinction helps sharpen the outcome variable in the present study. A teacher can use technology every day without substantially changing learner agency, inquiry, collaboration, or disciplinary practice. Conversely, a teacher may use a small number of tools in highly purposeful ways that produce deeper changes. Professional development should therefore target the quality of instructional use rather than maximizing the number of technologies adopted.

5.6 A revised model for bridging the gap

The integrated evidence supports the following pathway: professional-development quality influences teacher capability; capability interacts with self-efficacy and beliefs; those factors shape instructional decisions; and instructional decisions become digital teaching practices when contextual conditions permit. The relationship is iterative rather than purely linear. Classroom implementation generates evidence that feeds back into teacher beliefs, competence, and subsequent professional learning. The final conceptual model therefore treats professional development as a learning cycle embedded within a context, not a one-directional intervention.

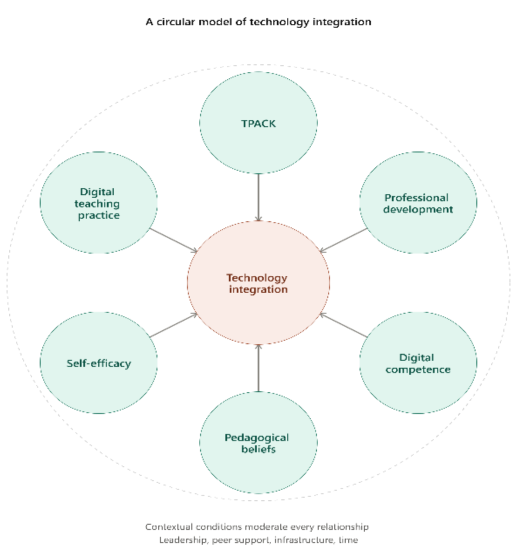

Figure 16. Network view of the main explanatory constructs linking professional development to digital teaching practice.

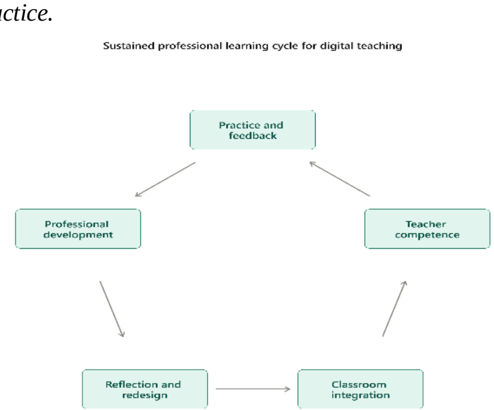

Figure 17. Sustained professional learning cycle: professional development, practice, feedback, competence, classroom integration, and reflection reinforce one another.

6. Implications for Research and Practice

6.1 Implications for professional-development designers

Professional development should begin with teachers' instructional problems rather than with a catalogue of tools. Designers should identify what learners need to understand or do, then examine whether technology adds pedagogical value. This problem-first sequence naturally creates opportunities for TPACK development. PD should include active design, classroom trials, peer discussion, reflection, and feedback, and it should be extended over time. Differentiation is also important: teachers with low digital confidence may need modelling and structured practice, whereas more experienced teachers may benefit more from design critique and pedagogical realignment (Koh, 2020).

6.2 Implications for school and institutional leaders

Leaders should treat technology integration as an organizational change process. Time for collaborative planning, access to technical support, stable infrastructure, and opportunities to share classroom evidence are not optional add-ons; they are part of the conditions that make professional learning usable. Kafyulilo et al. (2016) and Thannimalai and Raman (2018) suggest that management encouragement and leadership are important to continuation. Leaders should also evaluate technology use based on instructional quality rather than the visibility of devices or frequency of software use.

6.3 Implications for teacher-education programmes

Teacher education should integrate technology into subject pedagogy rather than isolate it in a single technology course. Modelling, learning by design, authentic school experiences, collaborative problem solving, and continuous feedback can create the conditions for professional digital competence and transformative agency (Brevik et al., 2019; Tondeur et al., 2019). Pre-service teachers should be assessed on their ability to justify technology choices in relation to content and pedagogy, not only on their technical fluency.

6.4 Implications for future research

Future studies should move beyond self-reported technology use and include classroom observations, lesson artifacts, student work, and longitudinal follow-up. Researchers should also report professional-development dosage, design features, implementation fidelity, and the institutional conditions under which PD occurred. This would make cross-study synthesis more precise and could eventually support meta-analytic estimation where outcome measures are sufficiently comparable.

7. Limitations

This paper has several limitations. First, the evidence boundary ends in 2020 by design. The resulting framework should therefore be understood as a pre-2021 synthesis rather than a current review of the entire field. Second, the 30 studies differ in design, participant group, educational level, and outcome measure. The thematic frequencies shown in the figures are descriptive coding counts and should not be interpreted as causal effect estimates. Third, the evidence set combines empirical studies with systematic reviews, conceptual papers, and framework studies because the research questions concern mechanisms as well as measured outcomes. Fourth, the final database-level screening totals should be reproduced from a saved search log before journal submission. Finally, open-access availability can influence which studies are easy to retrieve and may introduce selection bias relative to the full scholarly literature.

8. Conclusion

The technology integration gap is fundamentally a gap between technological possibility and pedagogical enactment. The reviewed literature indicates that professional development can narrow this gap when it develops more than technical familiarity. Effective professional learning builds TPACK and digital competence, increases confidence, supports productive beliefs about technology, and gives teachers opportunities to design, implement, evaluate, and revise digital teaching practices. The influence of professional development is nevertheless conditional: leadership, peer support, time, infrastructure, and technical assistance determine whether teachers can transfer learning into sustained classroom use.

The central contribution of this paper is therefore a process-oriented explanation of technology integration. Professional development should be viewed as the upstream driver; teacher competence and psychological readiness as the main mechanisms; contextual support as the enabling environment; and digital teaching practice as the observable outcome. This model shifts the conversation away from device provision and short training events toward a systems perspective on professional learning. Bridging the technology integration gap requires not simply more technology, but more coherent and sustained opportunities for teachers to learn how, when, and why technology should be used to improve teaching and learning.

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