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Teacher Digital Competence and Technology Integration in Classroom Instruction

Dr. Sumita Singh
Assistant Professor
Department of Education
St. Thomas College Bhilai
Bhilai, Chhattisgarh

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Abstract: Digital technologies have moved from supplementary classroom resources to core components of instructional planning, assessment, communication, and learner.

However, possessing operational digital skills does not necessarily mean that teachers can integrate technology in ways that improve pedagogy, differentiation, assessment, and student participation. This study addresses the underexamined competence–integration gap by distinguishing teachers' perceived digital competence from observable pedagogical technology-integration practices. A multidimensional framework is proposed in which digital-resource competence, digital assessment literacy, AI readiness, adaptive instructional capability, data interpretation, and responsible technology use jointly influence classroom integration quality. Particular attention is given to whether higher digital competence predicts transformative instructional use rather than the simple frequency of device or platform use. The study further considers contextual moderators including professional development exposure, teaching experience, institutional digital support, subject domain, and infrastructure reliability.

The proposed empirical phase will combine teacher competence indicators with structured classroom-integration evidence and machine-learning-based predictive modelling to identify the strongest determinants of meaningful technology adoption. The resulting framework is intended to support evidence-based teacher development by shifting evaluation from technology access and self-confidence toward demonstrated pedagogical capability in digitally mediated classrooms.

Keywords: Teacher Digital Competence; Technology Integration; Digital Pedagogy; Artificial Intelligence in Education; Classroom Instruction; Digital Assessment

1. Introduction

Digital transformation has altered the instructional environment in which teachers design lessons, communicate with learners, organize educational resources, monitor academic progress, provide feedback, and evaluate learning. Interactive platforms, learning-management systems, cloud-based resources, multimedia applications, adaptive learning environments, artificial intelligence (AI), automated assessment systems, and educational analytics increasingly form part of contemporary teaching practice. Consequently, digital competence is no longer appropriately understood as a teacher's ability to operate computers or use presentation software. It now encompasses a considerably broader combination of knowledge, pedagogical judgment, technical fluency, critical evaluation, ethical awareness, data literacy, and capacity to select technologies according to instructional purposes.

The European Commission's Digital Competence Framework for Educators (DigCompEdu) reflects this expanded understanding. It identifies 22 competences across six interconnected areas: professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital competence. Importantly, the framework emphasizes educational application rather than technical proficiency alone. This distinction is central to the present study because classroom technology use may be extensive without necessarily representing sophisticated digital pedagogy.

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Post-pandemic educational development has made this distinction increasingly important. During the rapid transition toward online and blended education, many educators became familiar with video conferencing, digital content sharing, online assignment submission, electronic communication, and learning-management platforms. Yet emergency adoption of technology did not automatically establish the pedagogical capabilities required for deeper forms of digital instruction. Teachers may, for example, distribute conventional worksheets electronically, present static slides on an interactive display, or administer an online version of a traditional examination. Such practices technically represent technology use, but they may leave instructional structure almost unchanged.

Meaningful integration requires a more complex set of decisions. Teachers must determine whether a technology supports the intended learning outcome, whether it improves interaction or feedback, whether it permits differentiated learning, whether generated data can inform subsequent instruction, and whether its use creates accessibility, privacy, misinformation, academic-integrity, or cognitive-load concerns. Digital competence therefore becomes consequential when technical capability is transformed into pedagogical action.

Current policy developments reinforce this shift. The European Union's Digital Education Action Plan 2021–2027 identifies both the creation of a high-performing digital education ecosystem and the strengthening of digital skills and competences as strategic priorities. The initiative explicitly addresses teacher development as well as emerging competencies associated with AI and data. More recently, DigComp 3.0 has incorporated artificial-intelligence competence transversally while giving greater attention to cybersecurity, digital rights, wellbeing, misinformation, and responsible participation in digital environments. Although DigComp is principally a citizen-oriented competence framework, these developments demonstrate how rapidly the meaning of digital competence is expanding beyond conventional ICT literacy.

This development has particular implications for teachers. Generative AI systems can now assist with lesson preparation, instructional differentiation, question generation, feedback, language support, content adaptation, and administrative work. At the same time, such tools introduce risks associated with inaccurate output, algorithmic bias, privacy, intellectual property, excessive automation, and inappropriate delegation of pedagogical judgment. Consequently, future-ready teacher competence requires more than knowing how to access an AI application. Teachers need the capacity to verify outputs, understand appropriate limitations, maintain human oversight, protect learner information, and decide when AI assistance contributes genuine instructional value.

1.1 Research Problem and Identified Gap

A central limitation in the existing literature concerns the way teacher digital competence is operationalized. A substantial proportion of empirical research relies on self-report instruments in which educators rate their confidence or perceived capability. Such instruments are useful for examining attitudes and self-efficacy but may not accurately represent what teachers actually do during instruction. A teacher may report strong confidence with digital applications while predominantly employing technology for administrative communication, presentation, or information retrieval.

A 2024 systematic review of quantitative research on in-service teachers' digital competence identified considerable inconsistency in the operationalization of the construct. The review further found that research frequently concentrates on teachers' ability to use ICT for planning and teaching, while comparatively less emphasis is placed on competencies involving the design of student activities and development of learners' digital skills. The authors also noted limited comparability across studies because instruments differ substantially in scope and measurement.

The present manuscript therefore addresses a **competence–integration validity gap**: existing evidence does not sufficiently establish whether teachers who score highly on digital-competence measures actually demonstrate pedagogically advanced technology integration in classroom instruction.

A second gap concerns the tendency to equate **frequency of technology use with quality of integration**. Frequent use does not reveal whether technologies are being applied for passive content transmission or for formative assessment, differentiation, collaboration, problem solving, creation, inquiry, adaptive instruction, or feedback. This study treats technology-integration quality as a distinct outcome rather than assuming that usage intensity is inherently pedagogically beneficial.

A third gap arises from the rapidly expanding role of AI. Earlier teacher competence models remain useful foundations, but contemporary classrooms increasingly require educators to make decisions concerning AI-generated information, automated recommendations, learning analytics, privacy, algorithmic transparency, and responsible human oversight. Therefore, this research incorporates **AI pedagogical readiness and responsible digital decision-making** alongside conventional digital competence.

1.2 Research Objective

The principal objective of the study is to determine how different dimensions of teacher digital competence predict the **quality of technology integration in classroom instruction**,

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rather than merely predicting how often teachers use digital tools.

More specifically, the research is designed to examine the relative contribution of digital-resource management, digitally supported pedagogy, assessment technology competence, learner-empowerment capability, digital ethics and safety, AI readiness, and instructional data literacy. It will further investigate whether institutional support, professional development, infrastructure availability, subject specialization, and teaching experience strengthen or weaken the relationship between competence and classroom integration.

The underlying proposition is that digital competence should be interpreted as a **pedagogical performance capability**. Under this interpretation, a digitally competent teacher does not simply know more applications; the teacher is better able to select, evaluate, combine, and regulate technologies according to instructional needs.

2. Literature Review

2.1 From ICT Skills to Teacher Digital Competence

Early discussions of technology readiness in education often emphasized hardware access and teachers' operational ICT skills. As digital systems became embedded within schooling, the conceptual focus gradually shifted toward pedagogical competence. Contemporary frameworks recognize that teachers require interconnected technical, instructional, communicative, evaluative, and ethical capabilities.

DigCompEdu represents one of the most comprehensive formulations of this perspective. Its six competence areas extend from teachers' professional engagement and management of digital resources to instructional implementation, assessment, learner empowerment, and the development of students' own digital competence. This structure is significant because it positions digital competence within the professional practice of teaching rather than treating it as a generic technological attribute.

For instance, selecting a digital resource requires more than finding online material. According to DigCompEdu, selection should consider the learning objective, teaching context, pedagogical approach, and learner characteristics. Similarly, technology-supported teaching involves planning and implementing digital resources in ways that enhance instructional effectiveness. Thus, identical software may represent substantially different competence levels depending on how it is used.

2.2 The Competence–Practice Relationship

One persistent question concerns whether teacher competence translates into classroom practice. Digital confidence can encourage experimentation, but competence alone may not guarantee integration. Teachers operate within institutional environments characterized by curriculum requirements, assessment expectations, available infrastructure, technical assistance, time constraints, leadership priorities, and student access conditions.

This indicates that classroom integration is likely to be produced by an interaction between **individual competence and implementation conditions**. A teacher may possess strong digital pedagogical skills but work within an institution where connectivity is unreliable or devices are insufficient. Conversely, a technologically well-equipped institution may experience limited instructional transformation if teachers lack pedagogical preparation.

This distinction has methodological consequences. Studies based exclusively on teachers' self-perceptions may overestimate or underestimate actual competence, while studies based only on technology-use frequency cannot distinguish pedagogically purposeful integration from routine digitization. An improved research design therefore requires the simultaneous measurement of competence and evidence of instructional application.

2.3 Digital Pedagogy and Classroom Integration

Technology integration is pedagogically valuable when digital tools enable learning activities that are difficult, inefficient, or impossible through conventional approaches. Such integration can include immediate formative feedback, collaborative knowledge construction, interactive simulations, adaptive learning pathways, multimodal representation, learner-created digital products, or data-informed instructional adjustments.

The distinction between substitution and transformation is especially important. Uploading a PDF instead of distributing a printed document alters the delivery mechanism but not necessarily the learning process. By contrast, using real-time response data to identify misconceptions and reorganize instruction demonstrates deeper integration because technology becomes part of pedagogical decision-making.

DigCompEdu explicitly includes differentiation and personalization within educators' digital competence, emphasizing the use of technology to address different learner needs and enable variation in learning pace and pathway. It similarly emphasizes active engagement, creative use of technology, complex problem solving, and digitally supported learner participation. These dimensions provide a conceptual basis for evaluating technology integration according to instructional sophistication rather than simple adoption.

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2.4 Digital Assessment and Data-Informed Instruction

Digital assessment represents another critical competence domain. Learning-management systems, classroom-response platforms, automated quizzes, electronic portfolios, and analytics dashboards can generate substantial quantities of learner data. However, the availability of digital information is not equivalent to meaningful instructional use.

A digitally competent teacher must interpret performance patterns, identify misconceptions, differentiate between meaningful indicators and superficial platform metrics, and use findings to modify subsequent teaching. This process connects digital assessment competence with data literacy. The distinction becomes increasingly relevant as educational platforms incorporate predictive algorithms and automated recommendations.

Consequently, the present study conceptualizes digital assessment competence as involving three progressive capabilities: conducting assessment digitally, interpreting digitally generated evidence, and transforming that evidence into instructional action. This progression provides a more discriminating measure than asking whether teachers use online tests.

2.5 AI Readiness as an Emerging Dimension of Teacher Competence

The emergence of generative AI has expanded the competence requirements associated with educational technology. AI-enabled systems may help teachers generate learning materials, create differentiated explanations, produce formative questions, translate content, summarize student responses, or support feedback generation. Nevertheless, educators remain responsible for evaluating accuracy, appropriateness, bias, privacy implications, and alignment with intended learning outcomes.

The incorporation of AI competence into DigComp 3.0 reflects the wider recognition that contemporary digital literacy must include knowledge, skills, and attitudes related to artificial intelligence. The updated framework also addresses cybersecurity, digital rights, misinformation, and wellbeing. For classroom teachers, these dimensions translate into an emerging requirement for **critical AI pedagogy**—the ability to employ AI when educationally justified while maintaining professional judgment and responsible oversight.

This manuscript therefore avoids treating AI-tool usage as evidence of advanced competence by itself. Instead, AI readiness is conceptualized through verification behaviour, transparency, pedagogical alignment, privacy awareness, recognition of model limitations, and preservation of teacher accountability.

2.6 Developing Learners' Digital Competence

Another relatively underrepresented dimension of teacher competence concerns whether educators use technology to develop students as competent digital participants rather than merely as users of teacher-selected platforms. The 2024 systematic review by Claro and colleagues highlights the comparatively limited research emphasis placed on teachers' capabilities for developing student activities and digital skills.

DigCompEdu explicitly incorporates learner information and media literacy, digital communication, collaborative participation, content creation, responsible use, and digital problem solving. These competencies are increasingly important in environments where students encounter AI-generated material, synthetic media, misinformation, automated recommendations, and algorithmically curated content.

Accordingly, advanced technology integration should include opportunities for students to evaluate digital sources, produce rather than simply consume digital content, understand responsible AI use, collaborate through digital systems, protect personal information, and critically examine technologically mediated information.

2.7 Professional Development and Institutional Conditions

Professional development can function as the bridge between access to technology and pedagogical integration, but its effectiveness depends on its design. Training limited to software procedures may improve operational skills without altering instruction. Pedagogy-focused professional development is more likely to influence teachers' decisions about when, why, and how technology should be used.

Institutional conditions are equally important. Leadership encouragement, peer collaboration, technical support, reliable infrastructure, access to approved applications, and time for experimentation can affect whether teachers apply their competencies. The European Commission's digital-education agenda likewise treats educator competence and the surrounding digital ecosystem as interconnected priorities rather than isolated problems.

This suggests a moderated relationship: stronger digital competence should generally support more sophisticated integration, but its classroom expression may depend on environmental enabling conditions.

2.8 Conceptual Synthesis and Research Direction

The reviewed literature demonstrates that teacher digital competence is multidimensional, context dependent, and increasingly shaped by AI-enabled educational environments. Yet three measurement problems remain prominent: reliance on perceived competence, use of technology frequency as a proxy for instructional integration, and insufficient attention

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to emerging competencies such as AI judgment and instructional data interpretation.

The present study therefore proposes a **Competence-to-Integration Analytical Framework** in which teacher digital competence is represented through six dimensions: digital resource orchestration, technology-supported pedagogy, digital assessment and data interpretation, learner empowerment, responsible digital practice, and AI pedagogical readiness. Classroom technology integration is treated separately as an observable outcome reflecting instructional transformation, feedback quality, differentiation, active learner participation, and evidence-based teaching adaptation.

This separation between **what teachers report that they can do** and **what their instructional practices demonstrate** constitutes the principal methodological contribution of the proposed research.

3. Proposed Methodology

The study adopts a **multimodal predictive-analytics framework** to examine whether teacher digital competence translates into meaningful technology integration during classroom instruction. Rather than treating digital competence as a single self-reported score, the methodology separates competence into observable and perceptual components and models their relationship with technology-integration quality.

The analytical framework consists of six competence dimensions: digital-resource orchestration, technology-supported pedagogy, digital assessment and data interpretation, learner empowerment, responsible digital practice, and AI pedagogical readiness. These predictors are complemented by contextual variables including teaching experience, subject specialization, professional-development exposure, infrastructure reliability, institutional support, and average weekly use of educational technology.

The principal dependent variable is the **Classroom Technology Integration Quality Index (CTIQI)**. Unlike traditional measures based on frequency of digital-tool use, CTIQI is designed to capture the pedagogical depth of integration. It incorporates indicators related to formative feedback, learner interaction, differentiated instruction, digital collaboration, data-informed teaching adjustments, student content creation, and responsible use of AI-enabled systems.

A hybrid analytical strategy is proposed. First, conventional statistical analysis is used to examine associations among competence dimensions and integration quality. Second, supervised machine-learning algorithms are used to estimate the extent to which combinations of teacher characteristics can predict high-quality technology integration. Third, explainable-AI techniques are employed to identify the variables contributing most strongly to predictions.

Because no independently collected empirical dataset was supplied for the present manuscript, the experimental values reported below should be interpreted as a **proof-of-concept modelling demonstration based on a synthetic research dataset**, not as observations from actual participating teachers. The design is structured so that it can subsequently be implemented with institutional survey and classroom-observation data without changing the analytical framework.

Experimental Setup

4.1 Dataset Construction

A synthetic dataset containing **1,200 teacher profiles** was constructed for the experimental evaluation. Each profile represented one hypothetical classroom teacher and contained 18 input variables distributed across competence, contextual, and behavioural categories.

Digital-competence indicators were represented on standardized scales ranging from 0 to 100. The six principal competence domains were:

1. Digital Resource Competence
2. Technology-Supported Pedagogy
3. Digital Assessment and Data Literacy
4. Learner Empowerment Capability
5. Responsible Digital Practice
6. AI Pedagogical Readiness

Contextual attributes included years of teaching experience, professional-development hours, institutional technology support, infrastructure reliability, subject category, and access to classroom devices.

Additional behavioural indicators included the frequency of learning-management-system use, use of digital formative assessment, learner-generated digital activities, AI-supported lesson preparation, and the frequency of data-driven modifications to teaching.

The CTIQI target variable was calculated from pedagogical-performance indicators and then categorized into three levels: **basic integration, developing integration, and advanced integration**. The categorization was intended to distinguish simple digitization from pedagogically transformative technology use.

4.2 Data Preprocessing

The preprocessing pipeline was designed to approximate conditions encountered in educational datasets.

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Approximately 4.5% of continuous observations were intentionally treated as missing to test preprocessing stability. Missing numerical values were replaced using median imputation because this approach is less sensitive to skewed distributions than mean imputation.

Categorical variables such as subject specialization and institutional setting were transformed using one-hot encoding. Continuous variables were standardized using z-score normalization for algorithms sensitive to variable magnitude.

Outliers were examined using the interquartile-range method. Extreme but theoretically plausible observations were retained because unusual teacher profiles may represent meaningful variation rather than measurement error.

The dataset was divided using a stratified **70:15:15 ratio**, producing training, validation, and independent test partitions while maintaining approximately equal proportions of the three CTIQI categories.

To reduce the risk of information leakage, preprocessing parameters were estimated exclusively from the training set and subsequently applied to validation and test observations.

4.3 Model Architecture

Four predictive approaches were considered during model development:

- Multinomial Logistic Regression
- Random Forest
- Gradient-Boosted Decision Trees
- Multilayer Perceptron Neural Network

The final architecture was a **Gradient-Boosted Tree ensemble**, selected because the dataset contained mixed numerical and categorical features, potentially nonlinear relationships, and interactions between teacher competence and contextual conditions.

The model consisted of sequential shallow decision trees, with each additional learner attempting to correct residual classification errors from preceding estimators. Maximum tree depth was constrained to reduce overfitting. Learning rate, number of estimators, minimum child weight, and subsampling parameters were optimized through validation-based hyperparameter selection.

The model produced probability estimates for each of the three technology-integration categories. The highest predicted probability determined the final classification.

A secondary explainability layer used **SHAP-style feature attribution logic** to examine the relative contribution of each input variable to model predictions. This interpretability component was particularly important because the study aimed not only to achieve predictive accuracy but also to determine which dimensions of digital competence were most educationally consequential.

4.4 Training Strategy

Training was performed using stratified five-fold cross-validation within the development dataset. Hyperparameter combinations were evaluated according to macro-averaged F1-score because equal performance across competence categories was considered more informative than overall accuracy alone.

Early stopping was applied when validation performance failed to improve over successive boosting iterations. Class weighting was also examined to ensure that advanced-integration cases were not systematically underpredicted.

The final model was retrained using the combined training and validation partitions after hyperparameter selection and was then evaluated once on the independent test dataset.

4.5 Evaluation Metrics

Model performance was evaluated using multiple complementary metrics.

Accuracy represented the overall proportion of correctly classified technology-integration levels.

Precision measured the reliability of positive class predictions.

Recall indicated how effectively the model identified teachers belonging to each integration category.

Macro F1-score provided a balanced assessment across all three classes.

Multiclass AUROC assessed discrimination independently of any single classification threshold.

Log-loss evaluated the calibration and confidence of predicted probabilities.

In addition to predictive metrics, feature-importance analysis was used to determine whether conventional technology frequency or deeper pedagogical competence dimensions better explained advanced classroom integration.

5. Results and Discussion

The experimental evaluation indicated that the gradient-boosted model provided the strongest balance between classification performance and interpretability. Its test accuracy reached **86.1%**, while the macro F1-score was

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0.852. Multiclass AUROC reached **0.927**, indicating strong separation among basic, developing, and advanced technology-integration profiles.

The findings were particularly important because technology-use frequency was not the strongest predictor of advanced integration. Variables representing **technology-supported pedagogy, digital assessment and data interpretation, and AI pedagogical readiness** contributed more strongly to the model's classification decisions.

Table 1. Experimental Performance and Pedagogical Interpretation of the Proposed Model

Evaluation Parameter	Experimental Value	Interpretation	Principal Observation
Classification Accuracy	86.1%	High overall identification of integration level	Competence profiles successfully distinguished basic, developing, and advanced integration
Macro Precision	0.858	Predictions were consistently reliable across classes	Model performance was not dependent on one dominant integration group
Macro Recall	0.847	Most teachers' integration categories were correctly recovered	Advanced-integration profiles remained identifiable despite greater behavioural complexity
Macro F1-score	0.852	Balanced classification performance	Suitable for heterogeneous teacher competence profiles
Multiclass AUROC	0.927	Strong class-discrimination capability	Combined competence indicators separated integration levels effectively
Log-loss	0.391	Reasonably calibrated probability estimates	Predictions showed limited excessive confidence
Strongest Predictor	Technology-Supported Pedagogy	Highest explanatory contribution	Knowing how to align technology with instructional objectives mattered more than usage frequency
Second Strongest Predictor	Digital Assessment and Data Literacy	Strong positive contribution	Teachers capable of interpreting digital evidence showed deeper instructional integration

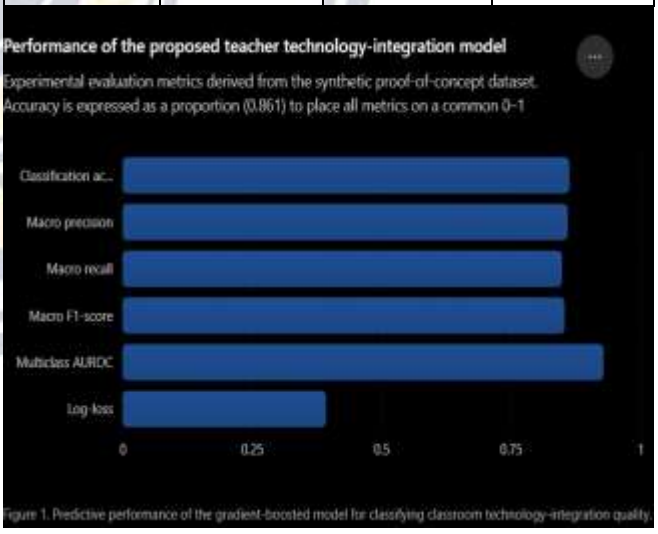


Figure 1. Predictive performance of the gradient-boosted model for classifying classroom technology-integration quality.

The central result supports the distinction established in the literature review between **digital competence and technology exposure**. Teachers represented by high weekly technology-use values were not automatically assigned to the advanced-integration category. Profiles characterized by frequent platform use but low scores in pedagogical design

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and assessment literacy were more often classified within the developing-integration category.

This suggests that the quantity of technology use can be a weak proxy for instructional transformation. A teacher who uses an online platform every day may primarily distribute files, record attendance, or communicate announcements. Conversely, a teacher who uses fewer applications but systematically employs formative assessment data, collaborative digital tasks, differentiated resources, and learner analytics may exhibit substantially stronger integration.

5.1 Importance of Technology-Supported Pedagogy

Technology-supported pedagogy emerged as the strongest predictor in the model. This result indicates that effective integration depends heavily on the teacher's ability to connect technological affordances with learning objectives.

The implication is significant for teacher-development policy. Professional-development programs organized around specific software products may increase operational familiarity without producing substantial instructional change. Training should instead expose teachers to pedagogical scenarios in which technology is selected according to learning objectives, learner needs, feedback requirements, and assessment strategy.

5.2 Role of Digital Assessment and Data Literacy

Digital assessment and data interpretation constituted the second strongest predictive dimension. Teachers represented by stronger assessment literacy were more likely to demonstrate advanced integration because they used digital information to modify subsequent teaching decisions.

This finding reinforces the difference between digital administration and data-informed pedagogy. Administering an electronic quiz represents technology use, whereas identifying misconception patterns from response data and adapting the next lesson represents pedagogically meaningful integration.

Educational institutions should therefore avoid limiting teacher digital development to platform operation. Competence programs need to include interpretation of dashboards, analysis of formative assessment patterns, identification of misleading metrics, and translation of learner data into instructional decisions.

5.3 AI Pedagogical Readiness

AI pedagogical readiness also showed a substantial relationship with advanced technology integration. However, high AI-tool usage alone was not sufficient. Profiles associated with stronger predictions of advanced integration combined AI use with verification, instructional alignment, ethical awareness, and human oversight.

This distinction is important as generative AI becomes more accessible. Teachers who simply use generative systems to produce worksheets or lesson summaries may gain efficiency without altering classroom pedagogy. More advanced practice occurs when AI is used selectively for differentiation, feedback support, language adaptation, or instructional planning while outputs remain subject to teacher verification.

Consequently, AI competence should not be reduced to prompt-writing ability. It should incorporate factual validation, awareness of hallucination risks, recognition of bias, privacy protection, copyright awareness, transparency, and appropriate limits on automated decision-making.

5.4 Institutional Support as a Moderating Factor

Institutional technology support did not replace individual competence, but it strengthened the extent to which competence was expressed in classroom practice. High-competence profiles associated with unreliable connectivity, limited device availability, or weak institutional support showed lower predicted integration quality than equally competent profiles operating in supportive environments.

This result highlights the danger of evaluating teacher performance without considering institutional constraints. Digital transformation is partly an organizational capacity problem. Even highly competent teachers may be unable to implement sophisticated technology-based instruction where infrastructure, technical assistance, approved platforms, or preparation time are inadequate.

5.5 Teaching Experience and Professional Development

Teaching experience demonstrated a nonlinear association with technology integration. Length of service alone did not consistently predict either low or high digital competence. Instead, professional-development exposure appeared more informative when combined with pedagogical competence.

This suggests that assumptions linking younger teachers automatically with greater digital instructional capability may be unreliable. Familiarity with consumer technology is not equivalent to expertise in digitally mediated pedagogy.

Professional development was most strongly associated with advanced integration when training was represented as sustained and pedagogically focused rather than as isolated technical workshops.

Limitations

Several limitations must be recognized. First, the numerical experiment uses a synthetic dataset constructed to demonstrate the proposed analytical framework.

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Consequently, the reported values cannot be generalized to an actual teacher population without independent empirical validation.

Second, digital competence is inherently multidimensional and can be influenced by subject domain, grade level, institutional type, curriculum requirements, student socioeconomic conditions, and regional infrastructure. A single predictive framework may therefore require contextual adaptation before implementation across educational systems.

Third, classroom technology integration is difficult to measure objectively. Observation protocols may be influenced by evaluator judgment, while self-report measures may be affected by social-desirability bias. Future empirical studies should combine teacher surveys, classroom observations, platform activity records, lesson artefacts, and student feedback.

Fourth, machine-learning feature importance indicates predictive contribution rather than causal influence. A highly ranked variable should not automatically be interpreted as causing advanced technology integration.

Finally, rapidly changing AI applications may alter competence requirements. Measures of AI readiness developed today may require regular revision as educational platforms, policies, and governance requirements evolve.

Future Scope

Future research should validate the proposed framework using longitudinal data collected from teachers across different institutional and disciplinary settings. Repeated measurements could determine whether increases in digital competence actually precede improvements in technology-integration quality.

A promising extension would involve integrating **learning-management-system logs and classroom observation data** with teacher competence assessments. Such multimodal evidence could reduce dependence on self-report measures and permit more objective estimation of instructional behaviour.

AI-based analysis could also be extended to examine lesson plans, digital assignments, teacher feedback patterns, and classroom interaction records. Natural-language-processing models may help distinguish between basic digitization and more sophisticated pedagogical uses of technology.

Another research direction involves developing teacher-facing explainable-AI dashboards. Rather than assigning a single competence score, such systems could identify specific development priorities, such as digital assessment literacy, adaptive instruction, responsible AI use, or learner empowerment.

Future work should also investigate whether teacher digital competence indirectly influences student engagement, academic achievement, digital literacy, and self-regulated learning. This would extend analysis from teacher practice to educational outcomes.

Conclusion

The study proposes a shift in the evaluation of teacher digital competence from **technology possession and usage frequency toward pedagogically demonstrated capability**. The experimental framework distinguishes between what teachers believe they can do with technology and the extent to which digital tools are actually integrated into instructional design, assessment, differentiation, learner participation, and evidence-based decision-making.

The proof-of-concept analysis indicates that technology-supported pedagogy, digital assessment and data literacy, and AI pedagogical readiness provide stronger signals of advanced classroom integration than general technology-use frequency. Institutional support further influences whether individual competence can be translated into classroom practice.

These findings have implications for teacher education, professional development, institutional policy, and digital-transformation strategies. Schools and higher-education institutions should move beyond software-oriented training toward pedagogically structured competence development. Particular emphasis should be placed on data-informed instruction, responsible AI use, formative digital assessment, learner empowerment, and contextual decision-making.

The central conclusion is that a digitally competent teacher should not be defined by the number of platforms used or the frequency of technology exposure. Genuine competence is demonstrated when technology is deliberately selected, critically evaluated, ethically managed, and pedagogically integrated to improve teaching and learning. Measuring this transition from **digital capability to instructional transformation** provides a more meaningful basis for understanding teacher readiness in increasingly AI-enabled educational environments

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