International Journal of Advanced Education and Research
www.alleducationjournal.com
E-ISSN: 2455-5746
Received: 12-09-2026, Accepted: 12-10-2026, Published: 27-10-2026
Volume 11, Issue 4, 2026, Page No. 28-31

Reconceptualizing teacher effectiveness in the age of artificial intelligence: Emerging dimensions and implications

Dr. Archana Yadav[1], Sonika Yadav[2]
[1] Assistant Professor, Department of Teacher Education, Central University of Haryana, Haryana, India
[2] Research Scholar, Department of Teacher Education, Central University of Haryana, Haryana, India
DOI: https://doi.org/10.66856/ijaer.2026.11.4.11048

Abstract
Artificial intelligence (AI) is steadily reshaping classroom practice and with it, the criteria by which teaching quality is judged. Traditional models of teacher effectiveness were built around subject mastery, pedagogical skill, classroom management and measurable student outcomes. The diffusion of adaptive learning systems, generative AI tools and automated assessment platforms into everyday teaching is now placing new demands on teachers that these traditional models do not fully capture. This conceptual paper draws on existing research to examine on teacher effectiveness, AI competence frameworks, teacher role transformation and AI ethics in education to argue for a reconceptualization of teacher effectiveness for the AI era. Drawing on frameworks such as TPACK and its AI-oriented extensions, studies on generative-AI-era teacher roles and scholarship on algorithmic bias and the digital divide, the paper proposes six emergent dimensions of teacher effectiveness: AI-pedagogical integration competence, critical AI literacy and ethical judgment, human-AI collaborative facilitation, socio-emotional stewardship, adaptive professional learning and equity-oriented practice. The paper concludes by discussing implications for teacher education, professional development and educational policy and by outlining directions for future empirical validation of the proposed dimensions.

Keywords: Teacher effectiveness, artificial intelligence in education, teacher competence, TPACK, AI literacy, teacher professional development

Introduction

For decades, teacher effectiveness has been treated as one of the strongest in-school predictors of student achievement and researchers have paid considerable attention towards defining and measuring it. Yet even after decades of research, scholars note that the field has struggled to arrive at a single, stable definition of what makes a teacher effective, in part because effectiveness has been operationalized differently across observational protocols, student evaluations, peer assessment and value-added measures of achievement (Fauzi & Johan, 2024) [6]. Historically, effectiveness has been anchored in classroom-observable behaviors such as instructional clarity, content mastery, classroom management and the capacity to raise measurable student outcomes (Aaronson *et al*., 2007; Akiba *et al*., 2007) [1, 2].

The emergence of artificial intelligence in classrooms is unsettling these long-standing conceptions. Generative AI tools, adaptive tutoring systems and AI-based assessment platforms are increasingly taking on tasks that were once considered core markers of teaching skill, including explaining content, generating practice material, giving feedback and even flagging students at risk (VanLehn, 2011; Kulik & Fletcher, 2016) [10]. At the same time, new empirical work shows teachers taking on roles as curators, facilitators and co-designers of AI-supported learning experiences rather than sole sources of knowledge (Zhai, 2024) [19]. This shift raises a foundational question for the field: if AI can now perform many of the functions once used to define an effective teacher, what does teacher effectiveness mean today and what new competencies must be foregrounded?

This paper responds to that question conceptually. Rather than proposing a new measurement instrument, it synthesizes recent literature across three streams - traditional teacher effectiveness research, AI-in-education scholarship and teacher competence frameworks such as TPACK and its AI-oriented extensions to propose a reconceptualized, multidimensional model of teacher effectiveness suited to AI-permeated classrooms.

Objectives of the Study

The present conceptual paper is guided by the following objectives:

1. To critically examine traditional conceptualizations and models of teacher effectiveness and explore their relevance and limitations in AI-integrated classroom contexts.
2. To review the existing literature on artificial intelligence in education, with particular emphasis on how AI is transforming the instructional, assessment, and relational roles of teachers.
3. To examine established teacher competence frameworks, including TPACK and i-TPACK, along with emerging AI competence frameworks, to know the changing knowledge and skills required of teachers in AI-integrated educational settings.
4. To identify and conceptually explore the emerging dimensions of teacher effectiveness in light of the growing use of AI in classrooms.
5. To examine the implications of this evolving understanding of teacher effectiveness for teacher education, professional development, and educational policy.

Literature Review

1. Traditional Conceptualizations of Teacher Effectiveness

Early conceptions of teacher quality were tied to observable compliance behaviors - following a prescribed curriculum, maintaining classroom discipline, and keeping orderly physical premises -well before empirical achievement data became central to the discussion (Fauzi & Johan, 2024) [6]. Later work shifted toward outcome-based definitions, associating effectiveness with teacher experience, professional/content knowledge and the provision of adequate opportunity to learn, measured through instructional time and content coverage (Fauzi & Johan, 2024) [6]. Cross-national and large-scale studies such as those built on TIMSS data, have used these same indicators - experience, education and opportunity to learn, to compare teacher contribution to achievement internationally while noting that the evidence for simple background characteristics remains comparatively weak relative to observed instructional behavior.

A parallel strand of research has focused on evaluation methodology itself cautioning that definitions of effectiveness have frequently been influenced by whatever instruments happen to be available rather than by a prior theoretical account of what effectiveness is. Campbell *et al*. (2003) [3] described this as a case of the measurement "cart" leading the conceptual "horse," warning that reliance on convenient metrics risks distorting the very construct being measured. Multidimensional observational frameworks for example protocols assessing classroom emotional climate, instructional support and classroom organization along with student perception surveys and value-added achievement models have each captured different, only moderately overlapping facets of practice, underscoring that teacher effectiveness is inherently multidimensional rather than reducible to a single index. More recent syntheses have extended this multidimensionality into teacher education itself, framing teachers' professional competence as an outcome of teacher education and in turn a predictor of effective classroom teaching (Kaiser & König, 2019) [8]. Collectively, this literature establishes teacher effectiveness as a multidimensional, context-dependent and historically contested construct - one that predate and was not designed with AI-mediated instruction in mind.

2. The Rise of Artificial Intelligence in Education

Artificial intelligence has shifted from a peripheral instructional aid to a substantive presence in classrooms through adaptive learning platforms, automated grading and feedback tools and since the wide availability of generative AI -conversational tools capable of producing lesson materials, explanations and formative feedback on demand (Luckin *et al*., 2016) [11]. Empirical work on intelligent tutoring systems predates the generative AI moment: meta-analytic reviews indicated that intelligent tutoring systems could produce learning gains approaching those of expert human tutors under certain conditions (VanLehn, 2011; Kulik & Fletcher, 2016) [10], foreshadowing debates about which instructional functions could be delegated to machines. With the arrival of generative AI, these debates intensified: AI systems have been developed for automated essay scoring, simplifying instructional text and generating customized quizzes and case material aligned with curricular objectives (Luckin *et al*., 2016) [11], while also enabling real-time, adaptive learning environments that respond dynamically to student interaction (Ali *et al*., 2023; Goldberg & Robson, 2023, as cited in Zhai, 2024) [19].

3. Competence Frameworks for AI-Integrated Teaching

Several scholars have sought to extend existing frameworks of teacher knowledge to address the growing role of artificial intelligence in education, rather than treating AI as a completely separate area of expertise. Among these efforts, the Technological Pedagogical Content Knowledge (TPACK) framework has provided an important foundation. Originally developed to explain the interplay between technological, pedagogical, and content knowledge, TPACK has increasingly been used as a starting point for understanding the knowledge and skills that teachers require when dealing with emerging technologies, including AI. In a related move, Ng *et al*. (2021) proposed a foundational AI literacy framework built around four aspects- knowing and understanding AI, using and applying AI, evaluating and creating with AI and engaging with its ethical issues which subsequent researchers have drawn on when adapting TPACK-style models for teacher AI competence and Kim *et al*. (2021) [9] used a TPACK-based analysis of AI curricula to identify the most critical teacher competencies for teaching AI content in K–12 settings. Building on this, Celik (2023) [4] proposed an "Intelligent-TPACK" (i-TPACK) framework that explicitly foregrounds AI-specific ethical knowledge as a distinct component of teacher competence, and subsequent professional development research has operationalized i-TPACK across five interacting domains - intelligent technological knowledge, intelligent content knowledge, intelligent pedagogical knowledge, their intersection and AI ethics aligned with evidence-based teacher learning pathways.

Beyond TPACK-derived models, a broader family of AI competence frameworks for teachers has emerged. A critical review of these frameworks identified at least five distinct conceptual approaches, noting that frameworks grounded in empirical data tend to produce detailed, granular competency descriptions while conceptually derived frameworks offer broader, more abstract overviews (Mikeladze, 2024) [12]. Within this literature, Molenaar (2022) [13] proposed an "automation model" of teacher adaptivity, borrowed conceptually from automation research in the automotive and medical fields, describing six levels along which control over instructional decisions can shift between teacher, learner and AI system; the model emphasizes that teachers retain agency in deciding which tasks to hand over to AI and which to keep within human judgment (as discussed in Mikeladze, 2024) [12]. Overall, this literature suggests an emerging consensus that AI-related teacher competence cannot be reduced to technical proficiency alone; it must integrate pedagogical judgment, content expertise and increasingly ethical reasoning about when and how to delegate instructional functions to AI.

4. Reconceptualization of Teacher Roles in AI-Mediated Classrooms

A distinct but related strand of literature examines how teachers' day-to-day roles are shifting as generative AI becomes embedded in classroom practice. Zhai (2024) [19] proposed a conceptual framework identifying four roles teachers may occupy as generative AI adoption deepens-

Observer, Adopter, Collaborator and Innovator corresponding to increasing depth of engagement with the technology. This framework suggests that as teachers move along this continuum their instructional focus shifts from direct content delivery toward curating, guiding and refining AI-generated material to match specific learning objectives and student needs, effectively repositioning the teacher as a facilitator of an AI-enhanced learning environment rather than the primary source of content knowledge. Complementary qualitative work on English-language teaching found that instructors adopting AI took on roles as "evolving facilitators," "blended role practitioners," "flexible material designers" and "creative prompters," reflecting how AI's capacity for personalization, automated feedback and adaptive material generation is redistributing instructional labor (as reported in a qualitative study of AI-powered English language teaching, PMC12121750, 2025). Sentiment-analysis research on teacher discourse showed that teachers who framed generative AI as transformative of their professional role responded with greater enthusiasm than those who viewed it narrowly as an efficiency tool, linking teachers' affective response to how they interpret AI's implications for their own agency (extending Moorhouse & Kohnke's 2024 argument, as discussed in recent topic-modeling research on teacher GenAI discourse). Research on teacher–AI co-design further suggests that productive integration depends on both cognitive interactions using AI to sharpen the clarity and structure of learning tasks and socio-emotional dimensions of interaction that shape the emotional climate of AI-supported lessons (Liu *et al*., 2025; Sethi *et al*., 2024; Robert *et al*., 2024, as synthesized in recent work on teacher-AI co-design of learning tasks).

Towards a Reconceptualized Model: Emerging Dimensions of Teacher Effectiveness in the AI Era

Synthesizing the literature reviewed above, this paper proposes that teacher effectiveness in AI-integrated educational settings can be conceptually reorganized around six interdependent dimensions. These dimensions are not intended to replace traditional indicators of effectiveness such as content knowledge or instructional clarity but to sit alongside and in several cases reweight them.

Dimension 1: AI-Pedagogical Integration Competence

AI-Pedagogical Integration Competence refers to the capability of teachers to select and use AI tools in ways that support lesson planning, teaching, and learning. It involves choosing appropriate AI tools, deciding when and how to use them, and ensuring that their use is connected to the intended learning objectives rather than using AI simply because it is available (Celik, 2023 [4]; Ng *et al*., 2021).

Dimension 2: Critical AI Literacy and Ethical Judgment

Critical AI Literacy and Ethical Judgment refers to the capability of teachers to critically examine AI-generated information and recommendations for accuracy, bias, reliability, and suitability for learners. It also involves making informed and ethical decisions about when AI can be used appropriately and when human judgment should take priority (Idowu *et al*., 2024 [7]; U.S. Department of Education, 2023) [15].

Dimension 3: Human–AI Collaborative Facilitation

Human–AI Collaborative Facilitation refers to the capability of teachers to use AI as a supportive partner in teaching and learning while retaining their professional and instructional responsibility. It involves guiding students in working with AI, using AI to develop learning experiences, and balancing the capabilities of AI with teachers' own knowledge, judgment, and interaction with students (Zhai, 2024) [19].

Dimension 4: Socio-Emotional Stewardship.

Socio-Emotional Stewardship is the sustained capacity to build relational trust, model empathy, and support students' social-emotional development in ways that AI systems cannot substitute for, positioning relational skill as a distinguishing rather than peripheral marker of effectiveness (Chan & Tsi, 2024) [5].

Dimension 5: Adaptive, Continuous Professional Learning

Given the rapid pace of AI development, effectiveness increasingly depends on teachers' disposition and capacity for ongoing, iterative professional learning about emerging tools, rather than a fixed, front-loaded competence acquired once during initial training (Sun *et al*., 2023; Molenaar, 2022) [13, 15].

Dimension 6: Equity-Oriented Practice

Equity-Oriented Practice is the commitment and capability to recognize and actively counteract unequal access to AI tools and algorithmic bias in AI-mediated instruction and assessment, so that AI adoption narrows rather than widens existing achievement and opportunity gaps (Van Dijk, 2017; Idowu *et al*., 2024) [7, 17].

These six dimensions can be understood as layered around the traditional core of teacher effectiveness (content knowledge, pedagogical skill, classroom management) rather than replacing it: AI reshapes how that core knowledge is applied, evaluated and supplemented while adding entirely new competency demands particularly around ethics, equity and human-AI collaboration that traditional models did not anticipate.

Discussion and Implications

The reconceptualization proposed here carries several implications. For **teacher education**, programs will need to move beyond treating AI as an add-on module and instead integrate AI-related competencies across content-methods coursework consistent with calls to embed AI-specific ethical and pedagogical knowledge within existing frameworks like TPACK rather than teaching it in isolation (Celik, 2023; Ng *et al*., 2021) [4].

For professional development, the literature on i-TPACK-based training and AI teaching-competency programs suggests that effective preparation requires active, scenario-based and reflective learning experiences rather than one-off workshops (Sun *et al*., 2023) [15].

For teacher evaluation systems, the multidimensionality already recognized in classical effectiveness research (Kaiser & König, 2019; Fauzi & Johan, 2024) [6, 8] suggests that appraisal instruments will need new indicators capturing ethical AI use, equity-oriented practice and human-AI collaborative facilitation alongside existing observational and outcome-based measures rather than assuming that instruments built for a pre-AI classroom

remain valid unchanged. For policy, the equity and bias concerns raised in the literature (Idowu *et al*., 2024 [7]; U.S. Department of Education, 2023) [15] imply that AI adoption in schools cannot be treated as a purely technical or infrastructural decision; it requires explicit safeguards and support so that the reconceptualized competencies this paper describes are attainable for teachers across resource contexts not only in well-resourced schools.

Suggestions

As a conceptual paper, this work synthesizes existing literature to propose a dimensional model rather than empirically testing it. The dimensions proposed here should be treated as propositions for further inquiry rather than validated constructs. Future research could usefully (a) develop and psychometrically validate instruments to measure the six proposed dimensions, (b) examine how the relative weighting of these dimensions varies across educational levels, subjects and national contexts and (c) conduct longitudinal studies tracking how teacher effectiveness indicators shift as AI tools become further embedded in everyday practice.

Conclusion

The diffusion of artificial intelligence into classrooms is not simply adding a new tool to teachers' repertoires; it is altering the very functions on which teacher effectiveness has traditionally been judged. This paper has argued that a reconceptualized model of teacher effectiveness for the AI era must retain core traditional elements- content mastery, pedagogical skill, classroom management while foregrounding six emerging dimensions: AI-pedagogical integration competence, critical AI literacy and ethical judgment, human-AI collaborative facilitation, socio-emotional stewardship, adaptive professional learning and equity-oriented practice. As AI systems continue to take on functions once considered core markers of good teaching, it is precisely the dimensions that resist automation - ethical judgment, relational trust and equity-mindedness that are likely to become the most distinctive markers of teacher effectiveness going forward.

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