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AI Integration in Education: A Four-stage Cyclical Model Proposal

Ahmet Cançelik[1]*, Gamze Bilen[2]

[1]Department of Computer Technologies and Information Systems, Gölhisar School of Applied Sciences, Burdur Mehmet Akif Ersoy University, Burdur, Türkiye, [2]Department of Science Education, Faculty of Education, Kahramanmaraş Sütçü İmam University, Kahramanmaraş, Türkiye. *Corresponding Author's Email: acancelik@gmail.com

Abstract

Integrating AI into educational systems is often approached through either pedagogical or technological lenses, leaving governance and contextual dimensions insufficiently addressed. In this study, we address this need by proposing a four-stage cyclical framework for AI integration in education—assessment, design, implementation, and evaluation—that builds on a constructivist learning theory and socio-technical systems approach and incorporates a system of ongoing feedback and evaluation in the AI integration process to ensure that ethical considerations are taken into account at every stage. The proposed framework is informed by a narrative literature review of studies on AI integration in education from pedagogical, technological, and governance perspectives, based on a search of the literature databases Web of Science, Scopus, and ERIC. While our discussion is focused primarily on the Turkish context, where issues such as examination-centred education, infrastructure and digital literacy inequalities, legal and institutional barriers, and teacher digital literacy are obstacles to AI integration in education that have received relatively little attention in the literature on global AI integration frameworks, our proposed framework is designed as a context-sensitive model that may be adapted to different educational contexts, although its applicability across diverse systems requires further empirical examination. Empirical research using this framework to develop, implement, and evaluate AI-enhanced educational environments in a range of educational settings and cultural contexts will be needed to further test and refine the model proposed here.

Keywords: AI in Education, Edtech, Pedagogy, Turkish Education System.

Introduction

Education and its related contexts are being reshaped by the rapid growth of technology. Artificial intelligence (AI) technologies stand at the centre of this transformation, offering new possibilities for teaching, learning, assessment, and institutional decision-making through applications such as personalized learning experiences, learning analytics, and teacher support systems. While AI offers benefits such as individualised learning processes, automated administrative tasks, and strengthened data-driven decision-making mechanisms, it simultaneously brings some complex challenges at pedagogical, technological, and institutional levels, including ethical data governance, implementation costs, and the need to adapt domain-specific knowledge to AI-supported systems (1, 2).

These potential challenges are multidimensional. With respect to the technology, deficiency of infrastructure and differences in technical and technological competences of teachers are highly significant problems especially in areas with low income (3). Moreover, since educators have no experience of integrating teaching process and apprehend these new tools, they may bring obstruction (4). These difficulties are further intensified by socioeconomic inequalities, which shape access to digital tools, patterns of AI use, and the capacity of institutions to adopt innovation in equitable ways (5).

In the context of Türkiye, some major barriers such as its examination-based education system (6), the lack of a programmatic professional development for teachers (7, 8), regional infrastructure discrepancies (9) and social status disparities (10) can reduce chances of deeply integrating AI into education. For this reason, AI integration in Türkiye cannot be approached only as a matter of technological adoption; it must also be understood as an institutional, pedagogical, and governance issue shaped by local educational structures. This systematic style of education therefore requires a

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model that addresses not only technological opportunities but also implementation conditions, professional capacity, ethical oversight, and institutional compatibility within the legal and administrative realities of Turkish education.

The Turkish context is particularly relevant for this discussion because it combines growing policy attention with persistent implementation challenges. Recent national initiatives, including the Ministry of National Education's Artificial Intelligence in Education Policy Document and Action Plan (2025–2029) (11), reflect increasing institutional awareness of both the opportunities and risks associated with AI in education. However, this policy momentum coexists with structural constraints such as examination-centred schooling (6), regional inequalities in digital access, and variation in educator readiness (7, 8). The Turkish case therefore illustrates a broader tension between policy ambition and implementation capacity and strengthens the case for a context-sensitive integrated framework.

The existing literature on AI in education also reveals several recurring limitations: a lack of institutionalised standards for ethical AI use (12), insufficient teacher development programmes that fail to meet practitioners' needs (13), and pedagogical models that have not kept pace with the rapid evolution of AI technologies (14). As a result, educational institutions risk adopting AI in fragmented and unsystematic ways, limiting the potential of these technologies to improve learning outcomes.

Current methods presented in the literature are mostly one-dimensional, failing to offer systematic frameworks that allow pedagogical and technological aspects to be integrated concurrently. Although existing models such as Holmes's work on AI ethics (12) and Technological Pedagogical Content Knowledge (TPACK) provide important insights, they tend to focus on only one dimension of the problem (15, 16). Some frameworks foreground ethics and governance (17), whereas others emphasise teacher knowledge or technology use in instructional design (18). However, these approaches rarely explain how pedagogical transformation, institutional readiness, implementation processes, and ongoing evaluation can be brought together within a single operational model.

This study addresses that gap by proposing a four-stage cyclical framework for AI integration in education. The uniqueness of the proposed framework lies in three respects. First, it brings together pedagogical design, technological readiness, institutional governance, and implementation monitoring within one integrated structure. Second, it conceptualises AI integration as a cyclical and iterative process rather than a one-time or linear adoption sequence. Third, it embeds ethics, feedback, and continuous improvement as cross-cutting components of the model rather than treating them as external or secondary concerns. In this respect, the framework differs from existing educational technology or AI governance models by linking the pedagogical 'what' and 'why' with the institutional and technological 'how' of implementation.

This study aims to address the following three research questions: what are the essential elements that constitute the pedagogical aspects of AI integration and how these elements influence the integration process; how the requirements and challenges encountered by educational institutions in terms of the technological dimension of AI integration could be systematised; and what components an integrated model that simultaneously addresses pedagogical and technological dimensions of AI use in education should comprise and how the model implementation process should be designed.

Methodology

Aligned with the study's aim of developing an integrated conceptual model for the use of AI technology in education, this study adopts a qualitative methodology based on the conceptual analysis method. Guided by conceptual analysis, the study is designed as narrative review research to comprehensively analyse the existing literature and achieve the main aim. The adopted methodology and method are consistent with the approaches widely used in the field of educational technologies to develop conceptual frameworks and have been effective in the construction of new theoretical models (19).

The narrative review process was structured as five main stages, beginning with a literature review. First, the selection of studies involved defining the scope, focusing on academic publications in Turkish and English related to integration of artificial intelligence in education. The primary sources for this research were obtained from international academic databases (Web of Science, Scopus and Eric), and the Google Scholars platform. The search keywords were "artificial intelligence in education," "AI integration," "educational technology frameworks," and "pedagogy and AI". The stage of thematic coding and categorisation of the collected sources led to the establishment of three main themes that are pedagogical dimensions, technological requirements, and components of an integrated model. The coding process was conducted inductively, and repeated concepts in the literature formed the themes of this study. At the stage of theoretical integration and synthesis, comparative analysis was used to examine the thematically categorised sources. Finally, the conceptual model development stage involved formulating an integrated model proposal based on these findings.

The narrative synthesis method was adopted for the data analysis because it enables the integration of both qualitative and quantitative data or findings. This method also allows for the multidimensional analysis of complex educational phenomena and ensures that the findings gathered from various sources are systematically integrated. Thematically categorised findings from the existing literature were systematically analysed by grouping similar concepts and identifying the relationships between these concepts. Specifically, studies that separately examined the pedagogical and technological dimensions of AI technologies were comparatively analysed, and theoretical relationships between these dimensions were identified (20).

A literature-based theoretical comparison approach was adopted for the development and validation of the conceptual model, without the inclusion of any empirical data or expert opinions. At this stage, existing theoretical frameworks were comparatively analysed, leading to a synthesis of different model proposals (21). Additionally, an iterative approach was adopted that enables studying and drawing theoretical principles from the design-based research methodology, which is widely used in educational technologies. Thus, this approach ensures both the theoretical coherence of the model and its alignment with the existing literature.

The theoretical foundations of AI integration in educational contexts are built upon modern learning theories and methods that oppose technological determinism. Foundational theories are in study are grounded in socio-technical systems theory and constructivist learning theory. These two perspectives were selected because AI integration in education involves both technical and institutional arrangements and pedagogically meaningful learning processes. Accordingly, the proposed four-stage framework assumes that effective AI integration depends on aligning social and technical systems while also supporting active, learner-centred education.Socio-technical systems theory argues that successful implementation depends on the alignment of social elements (such as teachers, leadership, policies, and institutional roles) and technical elements (such as infrastructure, platforms, and data systems) (22). In education, this means that AI integration cannot be explained by technology alone (23). Its success depends on how tools, people, and institutional structures work together (24). In this study, socio-technical systems theory provides the systemic foundation

of the model by highlighting the importance of infrastructure, governance, professional readiness, and organisational coordination (25).

Constructivist learning theory emphasises that learners actively construct knowledge through interaction, reflection, and engagement with meaningful tasks (26, 27). In AI-enhanced education, this means that the value of AI lies not only in automation, but in its capacity to support feedback, scaffolding, personalisation, and active learning (28, 29). In this study, constructivist learning theory provides the pedagogical foundation of the model by ensuring that AI integration remains focused on learning quality, learner engagement, and meaningful instructional design (30).

Cognitive and social constructivist theories are crucial for designing AI-supported learning environments because these rely on interactions and experiences as the basis for processes of knowledge construction and learning (31). This theoretical standpoint supports the adoption of student-centred learning processes and the transformation of the traditional teacher-student hierarchy within the context of AI integration (32). The constructivist framework plays a crucial role for the use of AI tools as scaffolding mechanisms that support students' active participation and collaborative learning by creating optimal learning environments through analogies and supportive techniques that enhance students' engagement, especially in Science, Technology, Engineering, and Mathematic (STEM) fields. In addition to these theoretical foundations, from the perspective of Activity Theory, educational environments are sociocultural contexts and dynamic ecosystems where students and educators engage with AI tools in complex interactions (33). Thus, from this theoretical perspective, we emphasize that successful integration should mean a transition from the focus on only technological dimensions and implementations of AI towards a framework that may incorporate social and cultural considerations when discussing AI integration in education.

The proposed framework is mainly shaped by the combined contribution of these two theories. Socio-technical systems theory explains the need for alignment between institutional and technical conditions, while constructivist learning theory ensures that each stage remains centred on educational purpose and learning processes.

Stage 1: Pedagogical and Contextual Analysis

This stage focuses on identifying learner needs, teaching goals, and institutional conditions. It reflects constructivist learning theory through its focus on pedagogy and learner needs, and socio-technical systems theory through its attention to context, readiness, and institutional conditions.

Stage 2: Technological and Institutional Preparation

This stage includes infrastructure, professional development, governance, and ethical preparation. It is mainly informed by socio-technical systems theory, while constructivist learning theory guides the selection of tools that are pedagogically appropriate.

Stage 3: Pedagogical Implementation and Interaction

This stage concerns the use of AI in teaching and learning. It is mainly shaped by constructivist learning theory through its emphasis on active learning, feedback, and learner engagement, while socio-technical systems theory explains the interaction between teachers, tools, and institutional practices.

Stage 4: Monitoring, Evaluation, and Iterative Improvement

This stage focuses on reviewing outcomes, challenges, and improvement needs. It reflects socio-technical systems theory by treating AI integration as an evolving system, and constructivist learning theory by evaluating whether AI use genuinely improves learning.

In terms of the theoretical contribution of the model, the combination of socio-technical systems theory and constructivist learning theory enables the proposed framework to move beyond approaches that are either overly technological or purely pedagogical. Socio-technical systems theory explains why AI integration must be treated as an institutional and organisational process, while constructivist learning theory explains why that process must remain oriented toward meaningful learning. Together, these theories provide the conceptual rationale for a model that is cyclical, multidimensional, and implementation sensitive.

In addition, a strong theoretical foundation for ethical AI use in education has been established in the literature (6), though practical direction and operational solutions to the ethical dilemmas encountered in day-to-day educational practice remain limited. Although ethical issues such as privacy, bias, transparency, and accountability are widely discussed in the AI in education literature, ethical principles often remain at a general level unless they are translated into concrete institutional procedures. For this reason, the proposed framework treats ethics not as a separate or final consideration, but as a cross-cutting operational component that should be embedded throughout all stages of AI integration. Despite the aforementioned points regarding preparedness for AI technologies, when these approaches are integrated with the principles of sustainable education, meaningful learning experiences can be produced that foster new mechanisms for broader and more equitable access to quality education (34). The next significant concept to emphasize is AI literacy that further influences the use and interaction of technological tools by both students and teachers. Not only does this enhance learning outcomes, but it also leads to higher engagement rates. Furthermore, the new technological capabilities of artificial intelligence appear to be a significant focus on the learning process. It certainly should not be missed for its contributions to culture of lifelong learning and maximising use of technology.

This theoretical integration also clarifies the distinctiveness of the proposed framework. Rather than using theory only as general background, the study operationalises theory across the stages of the model. In doing so, it offers a clearer explanation of how pedagogical values, institutional structures, and technical systems interact in AI-enhanced education. On the other hand, in the absence of directing theoretical frameworks and institutions that are able to translate this need into support or investment, there is a danger of inconsistency and insufficiency with respect to practice with these technical and human resources requirements. Regardless, the lack of guide models to help develop the relationship between human factors, technology and organisation means that AI tools will likely see failures or just unconsidered implementation within education. It has been recommended that flexible ethical structures sensitive to the diversity of societal interpretations should be applied when addressing the complexities of AI tools in educational contexts (35). Moreover, within K-12 education, a framework built around five core AI concepts has been proposed to support the effective teaching of AI to young learners, aiming to increase educators' competence in delivering AI content while fostering skills such as creativity and critical thinking (36). Furthermore, the development of intelligent tutoring systems has proven the advantages of AI technologies in providing adaptable and personalised learning experiences, additionally, the AI technology systematically keeps records and track the needs of learners for delivering feedback and necessary assistance (37).

Although this study gives a strong conceptual foundation, the final model is constrained in several methodological aspects. Arguably, the most significant is that our validation is entirely theoretical; thus, we have not yet been able to assess the model's success in an actual school. The existing literature review criteria we mentioned above further narrowed this focus. Second, although our search was systematic, the literature review might not encompass all relevant studies due to selective choice of databases, language criteria, and sources, particularly from different domains or languages other than English. We also recognise the element of subjectivity therein; thematic analysis is inherently an interpretive process, and our own analytical lens necessarily shaped the synthesis.

In conclusion, while there is considerable analysis of the ethics of AI to date, there are still gaps in terms of practical implementation advice. Likewise, research oriented towards technological infrastructure ultimately lacks as a confluence point with pedagogical transformation. In summary, a broad survey of the literature demonstrates that studies in this area are impactful. However, a critical gap persists: the lack of comprehensive model that addresses the pedagogical and technological dimensions of AI tool use in education in an integrated manner. Current methods and present approaches tend to focus solely on either ethics-governance or technological infrastructure dimensions even though these axes do not work separately. Therefore, the absence of an integrated and context-sensitive model that simultaneously links pedagogical transformation with technological implementation persists. As a result, this situation leads educational institutions to adopt an unsystematic approach in AI integration processes, and these processes might end with inadequate applications and practices. Consequently, the outcome of this literature review demonstrates the necessity of the conceptual model proposed in the following section, which is structured around the triad of components, processes, and criteria. Accordingly, the proposed model has the potential to offer action-oriented guidance that educational institutions can benefit from the model step by step, while preserving theoretical coherence.

Results

The three research questions guiding this study are addressed through the findings of the narrative literature review and the conceptual model developed on that basis. With respect to the first research question, the essential pedagogical elements of AI integration include the transformation from teacher-centred to student-centred learning, the development of personalised and adaptive learning environments, and the enhancement of educator roles as facilitators supported by AI tools. These elements collectively shape the integration process by redefining instructional relationships and expanding the possibilities for learner engagement. With respect to the second research question, the technological requirements of AI integration can be systematised around four interrelated dimensions: infrastructure and connectivity, system design and scalability, data governance and cybersecurity, and institutional capacity-building. Addressing these dimensions in a coordinated manner reduces the risk of fragmented or unsustainable adoption. With respect to the third research question, the proposed four-stage cyclical framework — consisting of assessment, design, implementation, and evaluation — provides an integrated model that simultaneously addresses pedagogical and technological dimensions. The framework embeds ethics, feedback, and contextual adaptation as cross-cutting components, and is designed to guide institutions through a structured and iterative process of AI integration.

The results from the literature review reveals that the most noteworthy limitation is the unidimensional nature of existing approaches, which exhibit significant shortcomings in addressing the pedagogical and technological dimensions of AI tool implementation in an integrated manner in education. Moreover, although the models currently available such as Holmes's ethical framework and TPACK approach provide solid grounds for establishing pedagogical elements, they are either too vague to take action upon, do not sufficiently explain how implementation can reach practitioners, or are not iterative enough. As mentioned, clearly there is a need for a model to fill this gap. In this respect, the results of the literature review indicate the need for a framework that can systematically connect pedagogy, technology, ethics, and institutional decision-making. Accordingly, the review findings indicate the need for a framework that integrates these dimensions within a single implementation-oriented structure.

Accordingly, the findings of the review informed the development of the model proposed in this study. The proposed model is designed to serve both as a theoretical framework and a practical guide for educational institutions seeking to embed AI technologies in systematic and sustainable ways. The framework is built on the assumption that AI integration should address pedagogical and technological dimensions simultaneously, remain context-specific, support teacher competence development, and embed ethics and data security throughout the process.

Based on learning theories whose foundations are constructivist and on socio-technical systems perspectives, the conceptual basis of the model is presented. Within the constructivist paradigm, AI technologies are viewed as a tool that can assist students in constructing their own knowledge when current educational approaches have shifted from teacher-centred delivery of lessons to student-centred learning activities. Moreover, socio-technical systems perspective sheds light on this interaction complexity between technology and human factors and goes so far as to say that AI integration is more than a mere technical issue; it is a transformation that requires special consideration of the social, cultural and institutional axes. This proposed model moves beyond technological determinism by accounting for the human element in technology use in support of pedagogical aims, allowing consideration of ethical dimensions.

The first assumption is to address the simultaneous integration requirement regarding the pedagogical and technological dimensions. The second assumption is that the integration should be institution specific as standardised solutions may not adequately address the distinct needs of every educational context. A third assumption is that the success of AI integration depends largely on the development of teachers' competencies in technology usage and the support systems offered by institutions. Regarding the responsibility of educators and institutions, the adoption of adaptive assessment systems depends not only on technical and technological training but also on the integration of pedagogical expertise into the process. The fourth and the final assumption for the model is that ethical principles and data security represent essential determinants at every stage of AI technology integration in educational environments. Taken together, these assumptions define the core structure of the proposed framework.

While the pedagogical and technological components of the model will be discussed separately, the interaction between these components is the most relevant aspect of the proposed model. In other words, the dreams of transforming educational paradigms and learning objectives cannot be realised merely by implementing technology in schools; also, the latter will not exist without a pedagogical vision supported by the appropriate infrastructure. Thus, a progressive cycle-based approach has to be devised that is aligned with the co-evolving requirements of the two dimensions.

The first stage is the Assessment, which involves analysing the institution's existing state, defining needs, and evaluating readiness across pedagogical, technological, and ethical dimensions. In the Design stage, institution-specific implementation strategies are defined, objectives clarified and resource planning undertaken. The third stage, Implementation, covers the progressive development strategies starting with piloting. However, potential challenges in this stage, such as the difficulties of the piloting process, its non-generalisability, internal institutional resistance, and resource limitations, should not be overlooked. Therefore, to overcome these risks, iterative feedback loops and contributory participation strategies are crucial in this model. The last stage, Evaluation, entails observation of the model's implementation effectiveness through multidimensional criteria, such as of student achievement indicators, AI tool usage levels in the classroom, the satisfaction rates of educators and students, AI technology usability metrics, and data security audit results. Thus, the proposed model enables institutions to monitor not only technological implementation outcomes but also pedagogical quality and ethical compliance across all stages. These four stages together constitute the main operational cycle of the proposed framework.

In practical terms, this means that each stage of the framework should include defined ethical procedures, responsible actors, and observable indicators for monitoring implementation. Rather than limiting ethics to abstract principles, institutions should establish review mechanisms that examine whether AI systems are being used fairly, transparently, and in ways that protect learner rights and educational integrity.

At the first stage of proposed framework, ethics should be operationalised through context-sensitive needs assessment, including the identification of vulnerable learner groups, possible access inequalities, and potential bias risks associated with planned AI use. At the second stage, ethics should be translated into formal institutional arrangements, such as data governance procedures, approval mechanisms for AI tools, professional development on ethical use, and clarification of responsibility structures. At the third stage, ethical practice should be maintained through transparent implementation, including disclosure of AI use, human oversight of pedagogical decisions, and mechanisms for reporting misuse or unintended effects. At the fourth stage, ethics should be monitored through continuous review and audit, including feedback collection, bias review, incident reporting, and policy revision. Table 1 shows each stage's ethical focuses and their contribution during education. Accordingly, ethics in the proposed model is not limited to compliance; it is treated as an ongoing process of prevention, monitoring, reflection, and improvement.

Table 1: Ethics Monitoring Across the Four Stages

Stage	Ethical Focus	Operational Procedure	Monitoring Indicator
Stage 1: Pedagogical and Contextual Analysis	Fairness, inclusion, contextual suitability	Assess learner needs, identify access inequalities, review bias risks, consider vulnerable groups before AI adoption	Completed needs assessment; documented inclusion/bias review; evidence of stakeholder consideration
Stage 2: Technological and Institutional Preparation	Privacy, governance, accountability	Develop data protection procedures, define roles and responsibilities, approve tools, provide ethics-oriented staff training	Presence of privacy protocol; approved AI tool list; percentage of staff trained; documented governance procedures
Stage 3: Pedagogical Implementation and Interaction	Transparency, human oversight, responsible use	Inform students and teachers about AI use, ensure educator supervision, document AI-supported decisions, create reporting channels	Use of disclosure procedures; evidence of teacher oversight; number of reported issues or misuse cases
Stage 4: Monitoring, Evaluation, and Iterative Improvement	Audit, harm detection, continuous improvement	Review feedback, monitor bias and unintended consequences, evaluate complaints, revise policies and practices	Audit reports; incident logs; fairness review records; frequency of policy or practice updates

A key feature of the proposed framework is that feedback and assessment are not limited to the final evaluation stage but operate throughout the entire cycle of AI integration. At each stage, institutions generate information that can shape subsequent decisions. In the assessment stage, data on readiness, infrastructure, pedagogical needs, and ethical risks inform the priorities of the design process. In the design stage, decisions regarding tool selection, training needs, governance procedures, and pedagogical goals may be revised in response to stakeholder consultation or feasibility concerns. During the implementation stage, pilot results, user experiences, technical difficulties, and classroom observations provide feedback that may require immediate adaptation before broader institutional adoption. In the evaluation stage, evidence related to learning outcomes, usability, stakeholder satisfaction, ethical concerns, and operational sustainability is reviewed not only to judge success, but also to guide the next cycle of assessment and redesign.

In this sense, the framework is iterative because assessment generates design choices, implementation generates adjustment needs, and evaluation generates revised priorities for the next round of integration. Feedback therefore functions as a decision-making mechanism rather than merely a reporting tool. This makes the model responsive to context, capable of continuous improvement, and better aligned with the evolving nature of AI technologies and educational needs. Table 2 represents the core concepts regarding feedback and assessment functions during the implementation of the framework in educational processes.

Table 2: Feedback and Assessment Functions Across the Four Stages

Stage	Main feedback source	What is assessed	How it affects decision-making
Assessment	readiness analysis, stakeholder input, infrastructure review	institutional needs, access, teacher preparedness, ethical risks	shapes priorities, identifies gaps, determines whether and how AI integration should begin
Design	planning meetings, feasibility review, consultation feedback	pedagogical alignment, tool suitability, governance readiness, training needs	revises implementation plan, tool selection, support structures
Implementation	pilot observations, user feedback, usage data, technical reports	usability, classroom integration, resistance, technical performance, emerging ethical issues	supports real-time adjustment, scaling decisions, and targeted interventions
Evaluation	outcome data, satisfaction measures, audit results, incident reports	learning outcomes, effectiveness, fairness, sustainability, policy compliance	informs continuation, redesign, expansion, or restriction in the next cycle

Discussion

The core beliefs of the proposed model are aimed at preparing formal and non-formal educational institutions to address the multifaceted issues surrounding the introduction of artificial intelligence (AI) technology. Although the present study is primarily grounded in the Turkish educational context, the proposed framework is intended as a context-sensitive and adaptable conceptual model rather than a universally standardised solution. Its broader relevance lies in the fact that many education systems face similar challenges related to AI integration, even if these appear in different forms and intensities. For example, in centralised systems, governance, policy alignment, and institutional coordination may be particularly important, whereas in decentralised systems greater emphasis may be placed on local decision-making and school-level implementation capacity. Likewise, in high-resource contexts the main concerns may relate more strongly to ethics, transparency, and advanced pedagogical redesign, while in lower-resource contexts infrastructure, access, and professional readiness may be more urgent priorities. In this sense, the framework is not assumed to apply identically across all environments; rather, it offers a flexible structure whose stages and components can be adapted according to local institutional, pedagogical, and technological conditions.

Another contribution of the proposed framework is that it offers a comprehensive and task-oriented structure compatible with the operational needs of educational institutions. Specifically, institutions are guided to re-evaluate existing conditions, identify suitable entry points, and coordinate pedagogical and technological objectives. A clear implementation risk assessment is also encouraged to enable preventive action. Given that AI integration decisions are often made at an early stage when few concrete outcomes are yet observable, it is important that success is not judged solely through technical performance. Broader indicators — including pedagogical achievements, stakeholder satisfaction, and adherence to an ethical framework — should be taken into account throughout the implementation process.

These points indicate that the value of the framework lies not in universal standardisation, but in its structured adaptability. The model therefore contributes to the literature by offering a conceptual structure that can be interpreted according to different governance traditions, resource conditions, and institutional capacities. The model development process pursued integration by drawing on key elements of design-based research methodology, reflecting the interdisciplinary nature of the proposed framework (38). This interdisciplinary lens is further supported by recent literature, which emphasises the importance of frameworks that bring together pedagogical and technological dimensions in education (39).

Accordingly, the proposed model focuses on being action-oriented within this scope whilst remaining theoretically consistent and practically relevant. Another important point emerging from the results is that the proposed framework responds directly to a gap in the existing literature. While many current approaches address ethics, pedagogy, or technological capacity separately, the present model brings these dimensions together within a cyclical and implementation-oriented structure. This makes the framework not only conceptually integrative but also more useful for institutional planning and staged decision-making. The framework conceptualises AI integration as an iterative process consisting of assessment, design, implementation, and evaluation. The cyclical structure emphasises that evaluation informs renewed assessment and redesign, thereby supporting continuous institutional learning and improvement. As shown in Figure 1, the proposed framework conceptualises AI integration as a cyclical and iterative process. To allow the model to meet the needs of integrating pedagogical goals and technological requirements, the proposed integrated model is designed based on constructivist learning theory and the socio-technical systems approach. The unique feature of the model is its direct linkage of instructional processes such as personalised learning, adaptive assessment systems, and interactive learning environments with data security, infrastructure supporting adaptive expansion, and institutional control mechanisms. The iteratively designed stages of assessment, design, implementation, and evaluation are supported by continuous feedback mechanisms and embed ethical sensitivity at every stage. Thus, the model is theoretically coherent with the existing literature while it offers institutions step-by-step adaptable guidance.

From the pedagogical perspective, the focus of AI-integration is the transformation from teacher-centred roles (e.g., information transmitter) to strengthening student-centred learning experiences. The transformation from the traditional teaching methods to collaborative learning environments is both a reason and a result of educators' enhanced roles as facilitators and guides. Furthermore, the pedagogical dimension of AI use fosters student engagement through the personalised learning experiences, the development of adaptive assessment systems, and the creation of interactive learning environments. While nationwide investment in AI integration is becoming increasingly significant (30, 40), the pedagogical perspective remains critical for the successful adoption of AI in the Turkish educational context. Although the importance and implementation of AI have been studied across various groups, including students, teachers, and academics, there is still a pressing need for studies focused on pedagogical adaptation within a practical, multidimensional framework.

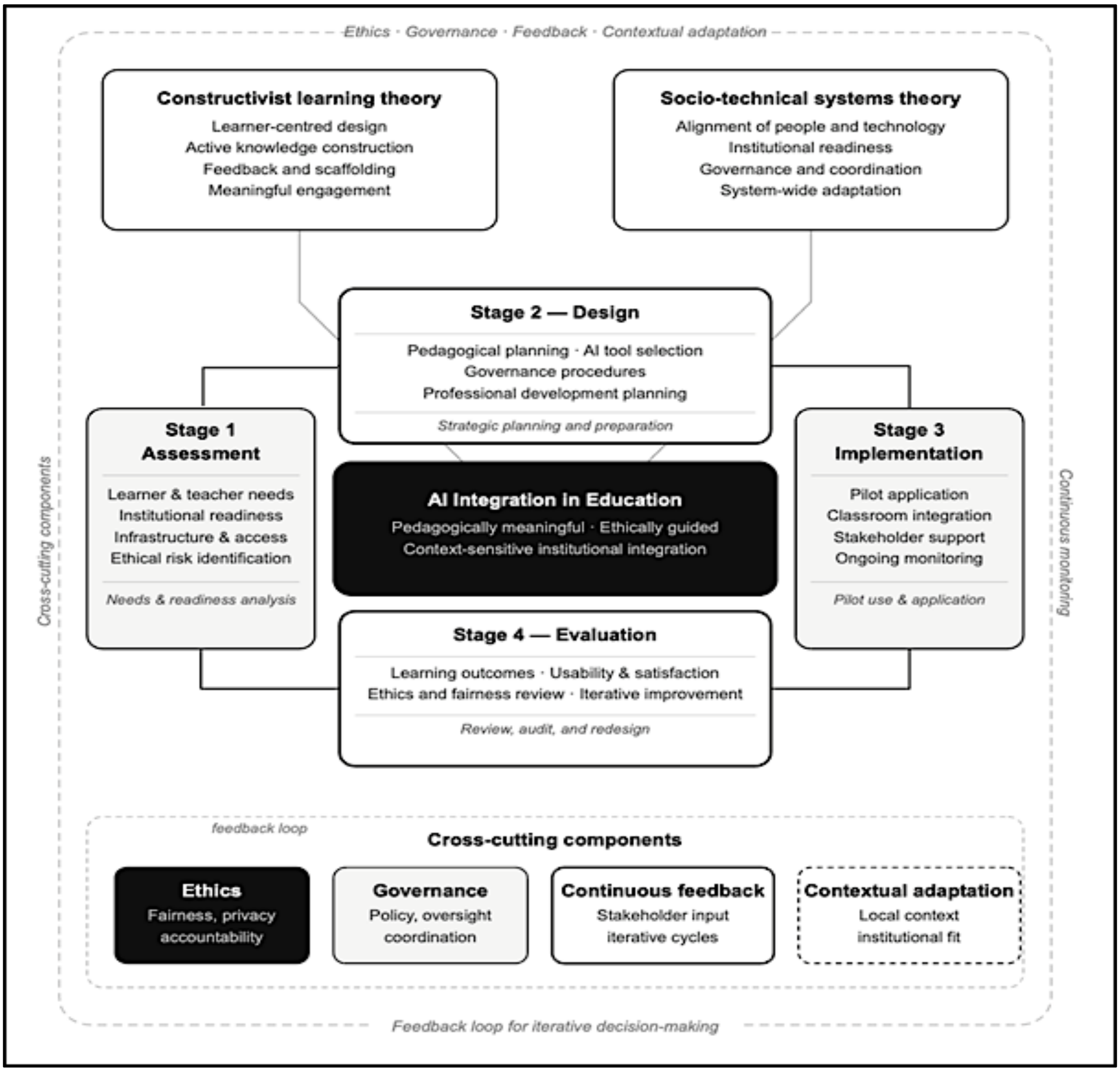

Figure 1: Four-Stage Cyclical Framework for AI Integration in Education

While ethical principles focus on defining and shaping the safe and responsible use of AI technologies across educational systems, the pedagogical dimension shapes how those principles manifest in actions taken during teaching and learning processes. Ethical governance can help strengthen institutional adoption by ensuring that growth in technical capacity aligns with pedagogical needs. These AI technologies are bringing significant changes to education methods and techniques. The changes fall into three categories: technologies that support educators, student-team learning experiences and radical changes to conventional pedagogy. The AI technologies, particularly intelligent teaching systems and adaptable learning platforms, can assist educators in automating time-consuming administrative tasks (41); hence educators are in an important position to discover more opportunities to facilitate theoretical and practical focus of their teaching quality and student's engagement. In this sense, it enormously benefits classroom settings in relation to teaching effectiveness and promoting access to inclusive learning environments (42). Explaining how the use of explainable AI technologies through teacher education and technology acceptance processes can improve interpretability and trust leading to higher educational technologies adoption. By using AI applications like Talk Moves and Classroom Discourse Analyzer, teachers can develop supportive learning environments that increase teacher engagement in the integration of technological innovation into educational processes (43). When it comes to supporting personalised learning, AI-supported tools can collect information on the students' learning behaviours and preferences, allowing more tailored suggestions and programmes. Such a capability allows teachers to do more than just respond to students' individual need, it also gives them opportunities to manage their own professional development more effectively (44).

In practical terms, one form of pedagogical paradigm shift in the classroom is a flipped classroom model. The flipped classroom model and implementation with AI technologies have gained considerable interest in particular to facilitate transformation processes toward more student-centred educational environments. The flipped classroom model is another format consisting of classroom sessions where students can interactively learn in a self-paced manner, while also incorporating teaching-learning applications for advanced research studies or explorations. With the support of AI technology, flipped classrooms allow students to learn more independently and by themselves, and also transform teachers from being the main transmitters of knowledge into student facilitators (45, 46), which can lead to better learning outcomes. Furthermore, the implementation of AI-regulated feedback loops and measures to ensure compliance with academic integrity policies like AI content detectors can enhance this model. While technological advancement comes with its own set of advantages, there are serious challenges that come with the successful implementation of AI applications in education. The technological dimension of the model covers the infrastructural requirements, system designs and installations, and development of the capacity processes to support AI technology integration (47). It comprises cloud-based systems, data analytics platforms, AI algorithms, and scalable user interfaces. Yet factors such as cost, scalability, and cybersecurity risks must not be overlooked (48, 49). Therefore, the investment in technology needs to be decided not just at the level of hardware and software but also the level of risk management and long-term sustainability. User interfaces should also be accessible, intuitive, and easy to use. In the context of data management, reducing algorithmic bias, ensuring transparency, and producing fair algorithms should also be treated as essential prerequisites.

Successful AI integration in education depends on stable and reliable technological infrastructure. Adequate hardware, software, and network connectivity are fundamental prerequisites, particularly for closing the access gap in disadvantaged regions. It has been found that inequalities in access to the internet and hardware deepen the opportunity gap in lower-resourced settings (50). AI infrastructure therefore requires a continuous cycle of installation, periodic updates, maintenance, and competence-building alongside robust institutional governance. In this regard, the sustainability of infrastructure critical for AI systems will rely on the iterative processes of installation, periodic upgrades, maintenance and competence-building along with tight institutional governance. In short, access to hardware, software and the internet matters but sustainability — true sustainability, which goes far beyond installation — is a decisive factor. Technological systems quickly become obsolete without timely updates, regular maintenance, and qualified human resources, which underscores the need for transformational leadership and targeted teacher training (51).

Moreover, the ethical dimensions of AI use in higher education could provide a site for raising critical questions about the principles and frameworks that underpin the implementation of technology. These frameworks are essential to guide responsible implementation of AI in any form that minimizes harm and protects students and educators (52, 53). Alongside their natural role as guide and inspiration, these ethical frameworks also function to shape the development of institutional policy, teacher training, and technical protocols. Important ethical considerations in the field of education – privacy, bias-fairness, explainability of models, and data management (collection-storage-deletion) – play a significant role in different types of activities behind teaching and learning processes and stand as both a leading principle for implementation and how they are adopted.

The Technological Pedagogical Content Knowledge (TPACK) framework is a helpful and effective model contributing to the readiness to integrate AI technologies into pedagogical practice, especially for pre-service teachers (54). While TPACK makes intersections visible, the framework does not sufficiently address the dimensions of dynamic adaptation, data-driven decision-making, explainability, and contextual sensitivity due to the rapid evolution of AI. Therefore, although TPACK makes significant contributions to teacher training, this framework also needs to be updated because of the dynamic nature of AI technologies. The role of educational technologies in supporting human intelligence has been conceptualised as requiring human-technology collaboration rather than technological determinism (30). While this emphasis reveals the limitations of existing technology-oriented approaches, it also draws attention to the need for balancing pedagogical priorities with technological implementations.

Furthermore, the government level of AI integration in Turkey could be currently characterised through a 'readiness paradox', where an ambitious national strategies (such as National AI Strategy 2024-2025 Action Plan) arise to promote high-level institutional awareness, while these initiatives encounter with a significant backlash from existing structural deficiencies, social and ethical complexities (55). The factors that affect educators' attitudes toward AI technologies in the Turkish educational context are culturally unique and differ from those found in Western settings. Research results based on Turkish pre-service teachers indicate that they have moderate level of both positive and negative attitudes toward AI, in addition to moderate to high levels of anxiety about the potential impact of AI (56-58). These challenges underscore the necessity of developing contextually adapted frameworks rather than directly transferring global AI integration models. Turkey's examination-oriented education system restricts the scalability of AI applications built for supporting students' personalisation and self-regulated learning. High-stakes standardised testing creates the pressure for fewer opportunities for open-ended, technologically mediated pedagogies. Moreover, students in rural areas still face the challenge of structural inequalities between cities and towns that lead to discrepancies in access to technology for educational purposes; meanwhile, teachers also struggle with a lack of trainings offered or attended (59, 60). These challenges highlight the need to establish contextually fit frameworks instead of just replicating global integration models on AI. Even though empirical studies within the Turkish educational context are not documented, case exploratory works demonstrate that sensitive understanding of institutional structure's impact on local assessment strategies and teachers situated beliefs aligning to pedagogical use institutes aware content when found in the act. Therefore, it emphasizes the significance of a sensing framework and adaptive efforts rather than an instant reproduction of the latest frameworks and methodologies in Turkey.

In the Turkish context, there might be some challenges during this model implementation. The exam-based structure of the education system may restrict the effectiveness and potential of AI tools for personalisation. Moreover, infrastructural disparities in rural areas may increase the inequality of access to and use of AI technology in education. Therefore, it is crucial to take the principles of contextual adaptation into account for applying the model. Instead of directly adopting the global frameworks, specific attention should be paid to developing a strategic model within the necessary adaptability to account for Turkish socio-cultural conditions.

From this perspective, the Turkish case illustrates a broader policy and practice tension: while interest in AI integration is increasing, implementation remains constrained by structural, pedagogical, and institutional limitations. For this reason, the model should be understood as a guide for context-aware adaptation rather than direct replication of international approaches.

Another important impact of the research is that it offers a comprehensive, task-oriented model compatible with educational organizations. More specifically, educational institutions need to perform several tasks, including the re-evaluation of existing conditions in order to detect possible entry points, the coordination of pedagogical and technological objectives, and the establishment of clear implementation risk assessments that enable preventive action. Because AI integration decisions are often made in the initiation phase, and because there are initially few concrete outcomes to observe, it is not appropriate to judge the success of AI integration solely through technical outcomes. Instead, broader indicators such as pedagogical achievements, stakeholder satisfaction, and commitment to an ethical framework should also be considered throughout the implementation process.

Evidence from the literature suggests that successful AI implementation in education is shaped less by technological infrastructure alone and more by teacher competence, institutional preparedness, and contextual factors. In the Turkish educational context, characteristics such as exam-centredness, uneven availability of technological resources, and variation in educators' digital literacy underscore the importance of developing adaptable strategies that respond to local needs and socio-cultural conditions, rather than directly replicating international frameworks.

Although the proposed framework has not yet been empirically tested, its practical applicability can be illustrated through a hypothetical implementation scenario. Consider a mid-sized public university in Türkiye seeking to integrate AI-supported tools into its undergraduate programmes. At the first stage, the institution would conduct a needs assessment examining existing infrastructure, educator readiness, and learner characteristics, while also identifying potential ethical risks such as unequal access or algorithmic bias. At the second stage, institutional governance structures would be established, appropriate AI tools selected, and targeted professional development programmes designed for academic staff. At the third stage, a pilot implementation would be initiated in selected courses, with human oversight maintained and feedback channels established for both educators and students. At the fourth stage, outcomes would be evaluated against pedagogical, ethical, and operational indicators, and the findings would inform the next cycle of assessment and redesign. This scenario illustrates how the four stages of the framework can function as an actionable and iterative guide for institutions navigating the complexities of AI integration.

In conclusion, the presented model presents a context-sensitive approach that negotiates pedagogical and technological dimensions, operationalises ethics in practice, balances risks and proposes progressive and action-oriented guidance. Its main contribution is to conceptualise AI integration as an iterative institutional process rather than a one-time technological adoption decision. At the same time, its practical value will ultimately depend on future empirical studies, pilot applications, and comparative implementations across different educational settings.

Conclusion

This study contributes a critical overview of recent literature on the integration of AI technologies in education and proposes a conceptual framework that encompasses both pedagogical and technological dimensions. The findings show that most current frameworks exhibit unidimensional approaches, particularly due to the lack of a design that supports the adequate pedagogical transformation processes and incorporates these transformations into technological infrastructure requirements. Despite the significant contributions of studies such as the TPACK model and Holmes's ethical framework, these remain limited in terms of practice-oriented guidance, contextual sensitivity, and dynamic adaptability. Therefore, these limitations increase the risks that institutions may face regarding the disconnected or incoherent application of AI integration in education and an unsuccessful attempt to achieve sustainability in the long term.

In response to these limitations, the present study proposes a four-stage cyclical framework consisting of assessment, design, implementation, and evaluation. The framework integrates constructivist learning theory and socio-technical systems theory, while also embedding ethics, governance, feedback, and contextual adaptation as cross-cutting components throughout the model. In this way, the study contributes not only a conceptual structure for understanding AI integration, but also a staged and iterative logic for institutional decision-making.

The proposed model suggests that successful AI integration depends not only on technological infrastructure, but also on teacher competence, institutional preparedness, pedagogical alignment, and ethical oversight. In summary, this study presents an integrated framework that addresses both pedagogical and technological dimensions of AI integration simultaneously, moving beyond fragmented approaches. The framework contributes to theoretical discourse in the field while also offering practical guidance that educational institutions can draw upon to adopt AI technologies in a more meaningful, structured, and responsible manner.

At the same time, the framework remains conceptual, and its practical applicability still requires empirical validation. While these decisions are required to arrive at a baseline structure of the model, they also highlight an evident gap in empirical work assessing its usefulness in practice settings. Therefore, the main contribution of the study should be understood as the proposal of an integrated, context-sensitive, and theoretically grounded framework that can guide future implementation and research rather than as a fully validated implementation model.

Recommendations

Based on the findings of the study, several recommendations can be made for future research, educational institutions, policymakers, and educational technology developers.

First, future research should focus on empirically testing the proposed framework in different educational settings. The model should be piloted across K-12, higher education, and adult education to test its efficacy and limitations. Such studies may also help clarify which dimensions of AI literacy should be prioritised, what kinds of evidence should be used to assess learning and institutional outcomes, and which professional development models are most effective for supporting educators. In addition, comparative studies across different sociocultural and socioeconomic contexts would strengthen the international relevance and transferability of the proposed framework.

Second, educational institutions should approach AI integration as a staged and strategic process rather than as a purely technical adoption decision. This includes the re-evaluation of existing conditions, the identification of suitable entry points, the coordination of pedagogical and technological objectives, and the implementation of clear risk assessment procedures. Institutions should also avoid judging AI integration solely through technical performance and instead evaluate it through broader indicators such as pedagogical achievement, stakeholder satisfaction, usability, and ethical compliance.

Third, policymakers should treat AI integration not only as a technological investment but also as an institutional and educational transformation process. Curriculum frameworks should include AI-specific and ethics-related content, teacher training programmes should be expanded to include AI-focused professional development, and governments should invest in infrastructure that supports equality of opportunity across regions and institutions.

Finally, educational technology developers should design AI systems that are more sensitive to pedagogical needs, teacher-student interaction, and personalised learning processes. For academics and practitioners alike, the long-term goal should be to support institutional learning and sustainable educational change rather than simply increasing the presence of AI tools in educational environments.

Limitations

This study has several limitations that should be acknowledged. First, the proposed framework is conceptual in nature and has not yet been empirically tested in real educational settings. This is consistent with the nature and purpose of model development studies, which aim to establish a theoretically coherent and literature-informed foundation prior to empirical validation. Nevertheless, the practical feasibility, effectiveness, and scalability of the framework remain to be examined through implementation-based research, including pilot studies, expert validation exercises, and comparative applications across different institutional contexts.

Second, the study is based on a narrative review and conceptual synthesis rather than a systematic review or meta-analysis. While this approach is appropriate for theory building and model development, it also involves interpretive judgement in the selection, categorisation, and synthesis of the literature. As a result, other researchers may identify different emphases or relationships among the same body of work.

Third, the literature search was limited to selected databases and to sources accessible in Turkish and English. Although major international databases were used, relevant studies published in other languages, regional outlets, or interdisciplinary venues may not have been captured. This limitation may have affected the breadth of the conceptual synthesis.

Fourth, although the framework is intended to be adaptable across contexts, the discussion in this study is shaped primarily by the educational conditions of Türkiye. Issues such as examination-centred schooling, regional infrastructure disparities, legal-administrative structures, and teacher readiness significantly influenced the interpretation of the literature and the design logic of the model. Therefore, the framework should be transferred to other national contexts with appropriate contextual adaptation rather than direct replication.

Finally, the study proposes an integrative framework, but it does not yet provide empirical evidence regarding its effects on student learning, teacher practice, institutional governance, or long-term sustainability. This limitation is inherent to conceptual model development research, where the primary contribution lies in theoretical integration and structured guidance rather than empirical measurement. Future studies should therefore pilot and evaluate the model across different educational levels and sociocultural settings. Such studies might include, for example, structured expert panel reviews of the framework's components, small-scale pilot implementations in higher education or K-12 settings, or simulation-based scenario analyses examining how the framework would operate under different institutional conditions. These approaches would provide the empirical grounding necessary to assess the model's applicability, identify its limitations, and guide any necessary refinement.

Abbreviations

AI: Artificial Intelligence, EdTech: Educational Technology, EFL: English as a Foreign Language, ERIC: Educational Resources Information Center, ICT: Information and Communication Technologies, JEL: Journal of Economic Literature, STEAM: Science, Technology, Engineering, Art, and Mathematics, STEM: Science, Technology, Engineering, and Mathematics, TPACK: Technological Pedagogical Content Knowledge, UNESCO: United Nations Educational, Scientific and Cultural Organization.

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Author Contributions

Ahmet Cançelik: conceptualisation, literature review, methodology, writing – original draft, writing – review, editing, Gamze Bilen: literature review, methodology, writing – review, editing, validation.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability

This study is based on a narrative literature review and does not involve the collection or analysis of primary data. No datasets were generated or analysed during the current study.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) and Claude (Anthropic) for language editing and proofreading purposes only. The authors reviewed and edited all AI-assisted content and take full responsibility for the final manuscript.

Ethics Approval

This study is a conceptual and narrative review study and does not involve human participants, animal subjects, or personal data collection. Therefore, ethics committee approval was not required.

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