A Conceptual Model of Institutional Adaptation: Developmental Trajectories of AI Integration in Medical Education

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Abstract

Artificial intelligence (AI) is increasingly reshaping how biomedical knowledge is accessed, synthesized, and applied, raising important questions about the competencies that medical education seeks to cultivate. Although often framed as unprecedented, these developments can be situated within a broader history of technological change in education, in which new tools have reconfigured relationships among knowledge, expertise, and learning. This study adopts a historical conceptual analyses approach to examine how medical education may respond to AI by drawing insights from an earlier technological transition: the introduction of handheld calculators in mathematics education. Using a structured comparative analysis informed by institutional adaptation theory, the study traces how educational systems have engaged with technological disruption over time, including patterns of institutional resistance, pedagogical repositioning, gatekeeping practices, curricular reconsideration, assessment debates, and governance responses. The calculator transition is considered not as a direct analogue to AI, but as a historical case that illuminates recurring dynamics of institutional change. The analysis informs the articulation of a developmental trajectory model that characterizes how medical education systems may adapt as AI becomes integrated into medical training and clinical learning environments. The model is presented as an interpretive framework for understanding institutional adaptation rather than as a predictive schema. Situating contemporary debates within broader historical patterns, the study offers a theoretically informed perspective on how medical education engages with technological change. It underscores the value of integrating historical insight with conceptual analysis to better understand ongoing transformations in professional education.

Keywords: Curriculum Transformation, Pedagogical Change, Faculty Preparedness, AI, Medical Education, Cognitive Offloading.

Introduction

Artificial intelligence (AI) rapidly transforms how biomedical knowledge is accessed, synthesized, and applied in clinical practice. These developments have prompted growing discussion about the implications of AI for medical education, particularly regarding the cognitive competencies that medical training seeks to cultivate. As AI systems increasingly retrieve information, generate diagnostic suggestions, and assist with clinical documentation, educators are beginning to reconsider how physicians should be trained to practice effectively in technologically mediated clinical environments (Wartman & Combs, 2018).

Although current debates surrounding AI may appear unprecedented, educational institutions have historically encountered similar tensions when emerging technologies altered the relationship between knowledge, expertise, and learning. Innovations that change how information is produced or accessed often provoke concerns about the erosion of foundational skills, the role of educators, and the nature of professional competence. At the same time, historical experience suggests that educational systems rarely transform immediately in response to technological change. Instead, institutions typically adapt gradually as educators, regulators, and professional communities renegotiate how new tools should be integrated into established pedagogical structures.

One historical example that illustrates these dynamics is the introduction of handheld calculators into mathematics education during the late twentieth century. Early debates surrounding calculators centered on fears that automated computation might undermine students' arithmetic competence and weaken foundational cognitive skills (Hembree & Dessart, 1986; Schielack & Dockweiler, 1992; Monaghan, 2016). Over time, however, calculators were gradually incorporated into mathematics curricula and came to be viewed as tools that could support deeper conceptual engagement when used appropriately.

While this historical episode offers useful insights into how educational systems respond to technological disruption, the comparison between calculators and contemporary AI must be interpreted cautiously. Calculators primarily automated procedural computation, whereas AI technologies influence a far broader range of intellectual activities, including information synthesis, authorship, reasoning, and clinical decision support. The purpose of invoking the calculator transition is, therefore, not to suggest technological equivalence but to illuminate recurring institutional dynamics that may emerge when new technologies challenge existing educational practices.

Within medical education, discussions about AI often focus on whether technological assistance may diminish learners' cognitive engagement. However, an alternative perspective suggests that the presence of AI may increase the importance of strong conceptual understanding, as clinicians must critically evaluate algorithmic outputs, recognize potential errors or biases, and integrate technological insights with contextual clinical judgment. These debates highlight the broader challenge facing medical education: determining how professional expertise should be cultivated in an environment where both human reasoning and algorithmic systems increasingly contribute to clinical decision-making.

This article contributes to these discussions by proposing a conceptual framework for understanding how educational institutions adapt to technological disruption. Drawing on historical insights from the calculator era alongside contemporary developments in AI-enabled medical education, the paper identifies recurring institutional dynamics that shape how new technologies are integrated into professional training systems. Building on these observations, the article introduces a developmental trajectory model that conceptualizes how institutional responses to technological innovation may evolve over time.

Rather than predicting a specific future for medical education, the framework presented here is intended as an interpretive tool that helps situate current developments within broader patterns of institutional adaptation. Through an examination of how educational systems have previously responded to technological change, the analysis seeks to provide a structured perspective for understanding the evolving relationship between AI and medical education.

Institutional Adaptation as a Theoretical Lens

Understanding the debates surrounding artificial intelligence in medical education requires a broader institutional perspective. This study therefore draws on institutional adaptation theory, which conceptualizes educational systems as dynamic institutions that evolve in response to social change. From this perspective, technological innovations rarely produce immediate transformation within professional education. Instead, institutional change typically unfolds gradually through processes of resistance, negotiation, reinterpretation, and incremental modification of established practices and norms (Thelen, 2002; Mahoney & Rueschemeyer, 2003). Within educational contexts, these processes are shaped by interactions among professional norms, faculty attitudes, governance structures, and pedagogical traditions that influence how new technologies are interpreted and incorporated into training systems.

Methodology

This article presents a conceptual analysis informed by historical examples to examine how educational institutions respond to technological disruption. Guided by institutional adaptation theory, the analysis draws on historical scholarship and contemporary literature to develop an interpretive framework for understanding how education systems adapt to emerging technology.

To illuminate these processes, the analysis incorporates insights from the introduction of handheld calculators into elementary mathematics education alongside the contemporary emergence of AI in medical education. The calculator transition provides a historically documented example of how educational institutions negotiated the pedagogical implications of a new technology over time. As reiterated earlier, the comparison is not intended to imply direct equivalence between calculators and AI. Calculators primarily automated procedural computation, whereas contemporary AI technologies influence a broader range of cognitive activities including information synthesis, reasoning, and decision support. Instead, the historical example functions as an interpretive reference point that helps illuminate recurring institutional dynamics that may also arise when educational systems encounter new technologies.

Conceptual comparisons of this kind are frequently used in the social sciences to explore how institutions respond to analogous structural challenges across historical contexts (Skocpol & Somers, 1980; Collier, 1993). Historical reference is particularly valuable because it reveals recurring patterns of institutional adaptation that might otherwise remain obscured when contemporary developments are treated as entirely unprecedented (Thelen, 2002; Pierson, 2004). In this study, the historical lens serves primarily as an analytic heuristic for identifying institutional dynamics such as resistance, policy lag, debates over cognitive implications, and gradual pedagogical adaptation. The goal is, therefore, interpretive rather than predictive. Historical patterns cannot determine the future trajectory of AI in medical education, but they can help contextualize current debates and illuminate possible pathways of institutional response.

Data Sources

The analysis draws upon multiple sources to inform the conceptual examination of technological adaptation in education. Historical materials include scholarly research examining the adoption of calculators in mathematics education, particularly studies investigating the cognitive and pedagogical implications of calculator use (Hembree & Dessart, 1986; McCauliff, 2004; McNamara, 1995; Monaghan, 2016). These works provide insight into the debates, institutional responses, and instructional adjustments that accompanied calculator integration. In addition, policy documents and guidance issued by professional organizations such as the National Council of Teachers of Mathematics provide further perspective on how governing bodies responded to technological change and attempted to standardize pedagogical practice.

For the contemporary case, the analysis draws on a growing body of scholarship examining AI in medical education, including research exploring pedagogical applications, ethical considerations, and faculty perceptions associated with AI-assisted learning (Masters, 2019; Roveta et al., 2025; Topol, 2019; Tolentino et al., 2024). The study also considers policy statements and guidance issued by medical schools (Morales et al., 2026) and professional organizations, including the American Medical Association (AMA). Together, these sources provide insight into how medical educators, institutions, and governing bodies are beginning to interpret and respond to the integration of AI within educational and clinical training environments.

Rather than serving as empirical datasets for formal comparison, these sources are used to identify emerging institutional responses and interpret evolving debates surrounding technological integration. In this way, the literature functions as an interpretive foundation that supports the conceptual analysis of institutional adaptation in medical education.

Analytical Framework

To structure the conceptual analysis, the study examines both the historical and contemporary cases through six analytical dimensions that capture key aspects of how educational institutions respond to technological innovation. These dimensions function as interpretive lenses that help illuminate how emerging technologies are debated, negotiated, and gradually integrated into existing pedagogical systems. By examining these dimensions across both the calculator transition and the contemporary emergence of AI in medical education, the analysis highlights recurring institutional dynamics that often accompany technological disruption. Each dimension reflects a different facet of institutional adaptation. Some dimensions capture early responses to innovation, such as skepticism, resistance, and the role of educators as gatekeepers of pedagogical change. Others reflect later stages of institutional adjustment, including shifts in teaching practices, modifications to curricula, changes in assessment systems, and concerns about equitable access to technological resources.

Table 1. Analytical Dimensions of Institutional Adaptation to Technological Innovation

Analytical Dimension	Description
Institutional Resistance	Forms of skepticism or opposition during the early stages of technological adoption.
Pedagogical Positioning	Ways in which new technologies are conceptualized within instructional practice and learning processes.
The Gatekeeper Phenomenon	The role of educators as institutional mediators who either facilitate or impede the integration of new technologies.
Curricular Reform	Modifications in curriculum design that occur as educational systems adjust to new technological capabilities.
Assessment Reform	The evolution of assessment practices as technologies reshape the competencies that educational institutions seek to measure.
Equity of Access	Disparities in access to technological resources and their implications for educational equity.

Examining these dimensions across historical and contemporary contexts enables the identification of patterns that characterize institutional responses to technological disruption. Rather than serving as variables for direct comparison or predictive stages of technological change, the dimensions function as conceptual categories that organize the analysis and illuminate recurring institutional dynamics through which educational systems interpret and adapt to emerging technologies over time. Consistent with interpretive historical inquiry, the framework is intended not to establish causal prediction but to provide an analytic lens for situating current developments in AI within broader patterns of institutional adaptation documented in prior technological transitions.

The sections that follow apply this framework to two contexts. First, the calculator transition in mathematics education is examined as a historically documented example of technological integration in education. The analysis then considers how similar institutional dynamics are emerging as AI technologies begin to reshape medical education and professional training.

Institutional Resistance

The introduction of handheld calculators into elementary mathematics education during the 1970s generated substantial resistance among educators and policymakers. For many critics, manual computation was not merely a procedural task but a core component of mathematical reasoning and intellectual development. As a result, the prospect of students relying on calculators prompted concerns that automated computation would weaken arithmetic competence and erode foundational cognitive skills (McNamara, 1995). These debates reflected broader anxieties about whether technological assistance might undermine the cognitive processes that educational systems were designed to cultivate.

Although concerns surrounding AI echo earlier debates about educational technologies, the issues raised are considerably more complex. Calculators primarily automated procedural computation, whereas contemporary AI systems influence a much broader range of cognitive activities, including information synthesis, reasoning, and clinical documentation. As a result, debates about AI adoption extend beyond questions of skill erosion to include issues such as authorship, professional accountability, and the role of human judgment in decision-making.

Critics argue that excessive reliance on AI could weaken the diagnostic "muscle memory" traditionally developed through repeated engagement with complex clinical problem-solving scenarios (Preiksaitis & Rose, 2023; Topol, 2019).

Despite differences in scope and intensity, concerns in both eras extend beyond technological capabilities to broader questions about preserving professional expertise and intellectual autonomy in technologically mediated learning environments. Viewed through the lens of institutional adaptation, these debates illustrate a recurring pattern in the early stages of technological integration. Innovations that appear to automate tasks traditionally associated with professional expertise frequently provoke skepticism and regulatory caution. Such reactions do not necessarily prevent technological adoption; rather, they represent an initial phase through which educational institutions negotiate the boundaries between technological assistance and the preservation of disciplinary competence.

Pedagogical Repositioning

Following the initial period of resistance, research examining calculator use gradually reshaped how educators understood the pedagogical role of computational technology. Early debates about calculators were often framed in terms of potential cognitive harm, yet subsequent research found little evidence that calculator access diminished conceptual understanding of mathematics. Instead, studies suggested that calculators could enhance problem-solving performance by reducing the cognitive burden associated with repetitive arithmetic tasks (Hembree & Dessart, 1986). When routine calculations no longer monopolized students' cognitive resources, educators were able to place greater emphasis on conceptual reasoning and problem formulation.

These findings contributed to a gradual repositioning of calculators within math education. Rather than being viewed as threats to intellectual development, calculators increasingly came to be understood as tools that could support deeper engagement with mathematical concepts when used appropriately. This shift encouraged educators to reconsider the balance between procedural skill development and higher-order reasoning within mathematics curricula.

A related pedagogical reconsideration is beginning to emerge in discussions of AI in medical education. As AI systems become capable of retrieving biomedical information, generating diagnostics, and assisting with clinical documentation, educators are increasingly questioning how these tools should be positioned within teaching and learning environments (Chan & Zary, 2019). In some respects, AI allows learners to offload certain routine cognitive tasks associated with information retrieval or pattern recognition. This shift may redirect attention toward how learners interpret, evaluate, and apply technologically mediated (Masters, 2023; Topol, 2019). Consequently, debates about the pedagogical role of AI extend beyond questions of efficiency to deeper concerns about how clinical reasoning, professional judgment, and professional expertise should be cultivated when knowledge work is increasingly mediated by intelligent systems.

Viewed through the institutional adaptation framework guiding this study, such ongoing debates represent an important phase in the negotiation of new technologies within educational systems. As educators experiment with different pedagogical uses of emerging tools, instructional practices often evolve in ways that gradually redefine the relationship between technological assistance and disciplinary learning.

The Gatekeeper Phenomenon

Historical experiences with technological change in education suggest that the adoption of new tools is rarely determined by technological capabilities alone. Instead, educators often function as institutional gatekeepers whose interpretations and pedagogical decisions significantly influence whether and how technologies are integrated into instructional practice. During the early years of calculator adoption, implementation varied considerably across classrooms. Some teachers incorporated calculators, while others resisted their use and continued to emphasize manual computation. McCauliff (2004) suggests that these differences were partly shaped by educators' professional identities and pedagogical traditions. Teachers whose instructional practices were closely tied to mastery of computational procedures were often more skeptical of technologies that appeared to automate those tasks.

A comparable dynamic is visible in contemporary discussions surrounding AI in medical education. Faculty responses to AI learning tools currently range from cautious experimentation to pronounced skepticism (Salih, 2024). Recent research indicates that many educators remain uncertain about the pedagogical implications of AI and the appropriate boundaries between technological assistance and independent intellectual work (Masters, 2023; Topol, 2019). Blanco et al. (2025), for example, report that some medical educators perceive themselves as being "technologically eclipsed" by students who are more comfortable experimenting with AI tools.

Concerns about academic integrity have been particularly prominent. Some faculty members worry that AI systems could enable students to generate assignments, clinical notes, or examination responses with limited intellectual engagement (Preiksaitis & Rose, 2023). Others have expressed concern that AI-generated explanations may challenge traditional instructional roles by providing learners with automated guidance that appears to replicate or supplement faculty expertise (Roveta et al., 2025; Tolentino et al., 2024). At the same time, some educators view these developments as opportunities to rethink instructional strategies and explore new forms of AI-supported learning.

From the perspective of institutional adaptation, these gatekeeping dynamics play a central role in shaping how technologies become incorporated into educational systems. Consequently, the integration of AI in medical education will likely depend not only on technological capabilities but also on how educators interpret and negotiate the role of AI within professional training.

Curriculum Restructuring

Within the analytical framework guiding this study, curricular reform represents a central mechanism through which educational institutions adapt to technological innovation. As the use of calculators became widely used, mathematics curricula gradually shifted from an exclusive emphasis on manual computation towards conceptual reasoning, problem-solving strategies, and analytical thinking (Monaghan, 2016). This evolution reflected a broader recognition that technologies can reshape the cognitive competencies that disciplines prioritize.

Medical education now appears to be approaching a comparable moment in which curricular restructuring may become increasingly important. While the preclinical phase has traditionally emphasized foundational scientific knowledge, including biochemical pathways, anatomical structures, and physiological mechanisms; advances in AI-assisted information retrieval challenge the pedagogical rationale for devoting extensive instructional time to memorizing large volumes of factual information. These developments raise broader questions about how medical knowledge should be organized and emphasized within medical training, a topic that will be explored in greater depth in the discussion of medical education reform later in the article.

Assessment Reform

Technological innovation also requires reconsideration of how educational systems evaluate learning outcomes. During the calculator era, educators recognized that traditional examinations centered on manual computation were becoming increasingly misaligned with classroom practice. When calculators could perform arithmetic operations instantaneously, assessing students primarily on procedural calculations no longer provided a meaningful indicator of mathematical competence (Schielack & Dockweiler, 1992). In response, mathematics assessments evolved to emphasize problem formulation, interpretation of results, and conceptual understanding. Students were increasingly expected not only to produce correct answers but also to demonstrate the reasoning underlying their solutions (Monaghan, 2016). This shift reflected the broader principle that assessment systems must evolve when technologies alter the nature of cognitive work within a discipline.

A comparable challenge is emerging in medical education. Generative AI systems have demonstrated the capacity to perform well on standardized medical examinations, including components of the United States Medical Licensing Examination. These developments raise important questions about whether conventional assessment formats adequately capture the forms of reasoning that characterize authentic clinical expertise, an issue that will be revisited later when considering the implications of AI for medical education reform.

Equity and Access

In the framework adopted for this analysis, equity of access represents a critical dimension through which technological innovations reshape educational systems. During the calculator era, disparities in school funding meant that some students gained early exposure to computational tools, while others continued to rely exclusively on manual calculation methods. These differences contributed to what some scholars described as a “cognitive gap” between learners trained in technology-supported problem solving and those whose education remained focused on procedural computation (Monaghan, 2016).

In the emerging AI era, such disparities manifest in new and potentially more consequential ways. Access to advanced AI tools, computational infrastructure, and specialized training resources is likely to be concentrated within well-resourced institutions and high-income countries. Without deliberate strategies to ensure equitable access, the integration of AI risks reinforcing existing structural inequalities within global medical education.

A related concern involves algorithmic sovereignty. Many contemporary AI systems are trained on datasets derived predominantly from high-income healthcare environments. When these systems are used without appropriate adaptation, they may reproduce biases that do not accurately reflect the epidemiological realities, health priorities, or resource constraints of low-resource settings (Amann et al., 2020; Topol, 2019).

Towards a Transformation of Medical Education in the AI Era

Building on the institutional patterns identified across the preceding analytical dimensions, the historical comparison between the calculator era and the emerging AI era suggests that educational responses to technological disruption often follow recognizable trajectories. Early phases characterized by significant resistance, concerns about cognitive erosion, uneven institutional adoption, and debates about pedagogical use have historically accompanied the introduction of new educational technologies. Over time, however, these tensions may give way to productive integration as educators develop new pedagogical frameworks and institutions establish supportive policies, governance structures, and professional development systems.

Evidence suggests that medical education may now be entering a similar transitional phase. Educators are increasingly experimenting with AI-supported learning tools, new instructional approaches are beginning to emerge, and scholarly discourse is gradually shifting from questioning whether AI should be used in medical education to examining how it can be integrated responsibly and effectively (Masters, 2023; Topol, 2019; Wartman & Combs, 2018). At the same time, these developments remain preliminary. Many institutions continue to operate within curricular, assessment, and governance frameworks designed for a pre-AI educational environment. Meaningful integration of AI into medical education will, therefore, require coordinated institutional reform that extends beyond technological adoption. Effective adaptation must encompass curriculum design, assessment systems, faculty development, and governance structures capable of supporting the responsible use of AI across both educational and clinical training contexts.

Curricular Reconfiguration for an AI-Augmented Knowledge Environment

One instructive insight from earlier technological transitions concerns the relationship between technological innovation and curricular adaptation. As handheld calculators became widely available in mathematics education, instructional priorities gradually shifted from a dominant emphasis on manual computation toward greater attention to conceptual reasoning, analytical thinking, and problem solving (Monaghan, 2016).

Medical education may now be encountering a comparable moment of curricular reflection. While generative AI has rapidly entered educational and clinical environments, the overall structure of medical curricula has changed far less dramatically than the technological context in which learning occurs. Traditional medical education continues to devote substantial instructional time to the acquisition and memorization of foundational biomedical knowledge. This structure reflects an educational model developed when clinicians had limited access to rapid information retrieval and, therefore, relied heavily on internalized knowledge for safe medical practice. Recent advances in AI-assisted information systems are reshaping this informational environment. These developments have prompted growing discussion about whether existing curricular structures remain optimally aligned with the competencies required for AI-mediated clinical practice.

To date, many medical education programs have responded by introducing new competencies, such as AI literacy, digital health awareness, and data-informed decision-making into already dense curricula. While these additions represent important steps, they often expand existing programs without substantially reconsidering the broader structure of medical training. As a result, some scholars have begun to explore whether technological advances may invite deeper reflection about how instructional time is allocated across different phases of medical education (Manguvo & Mafuvadze, 2026). From this perspective, the integration of AI may not reduce the importance of foundational knowledge but rather alter how that knowledge is applied within technologically mediated clinical environments.

Against this backdrop, Figure 1 presents a conceptual model illustrating one possible direction for curricular adaptation in AI-enabled learning environments. In this model, advances in AI-supported learning tools may allow certain aspects of foundational knowledge acquisition to occur more efficiently through adaptive and interactive educational platforms. Such tools could potentially support greater emphasis on conceptual integration rather than prolonged memorization-based instruction. This shift might enable earlier and more sustained clinical immersion during training, alongside increased attention to complex clinical reasoning, ethical decision-making, patient communication, and collaborative decision-making within AI-assisted clinical environments.

Importantly, this model should be interpreted as an exploratory conceptual framework rather than a prediction of future educational structures. While discussions about potential changes to the duration or sequencing of training remain speculative, examining these possibilities helps illuminate how evolving technological environments may prompt broader reconsideration of the organization, priorities, and temporal structure of medical education.

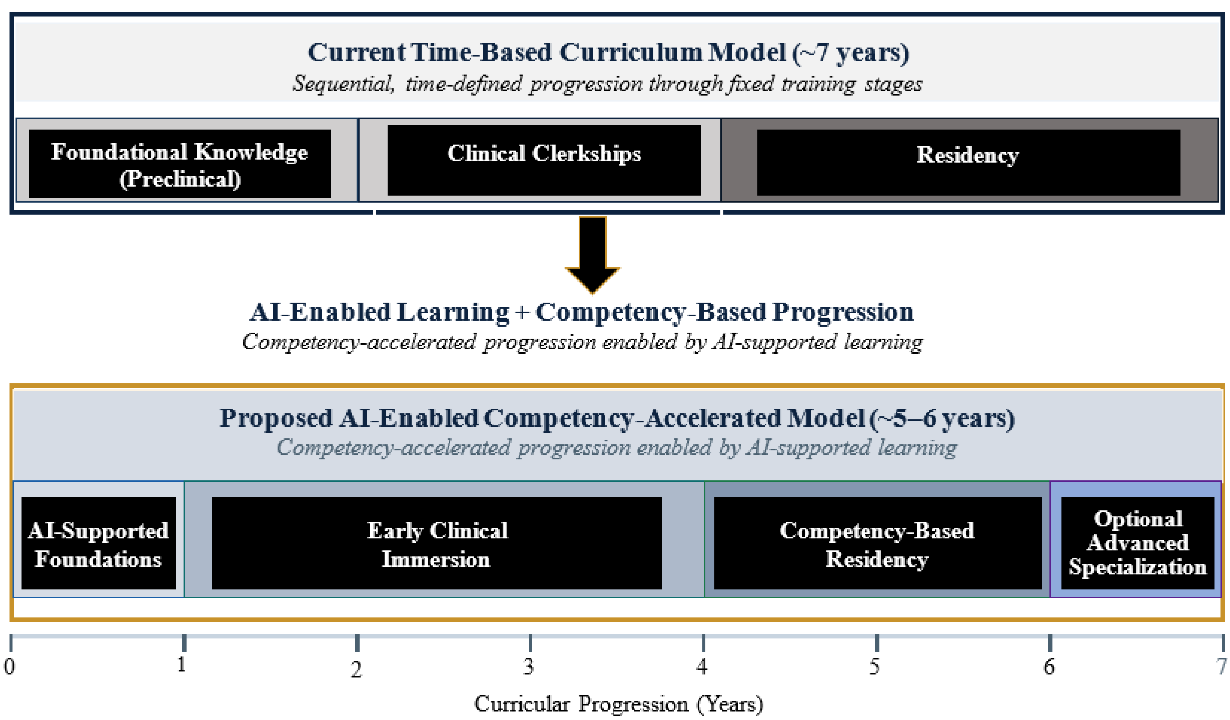

Figure 1
Exploratory conceptual comparison of a traditional time-based curriculum and a hypothetical AI-enabled competency-accelerated model.

Reimagining Assessment in AI-Mediated Clinical Training

Curricular priorities are often accompanied by corresponding shifts in assessment practices. During the calculator transition in mathematics education, evaluation methods that focused exclusively on manual computation became less aligned with emerging instructional goals. Over time, test items were redesigned to place greater emphasis on conceptual understanding, problem solving, and analytical reasoning rather than routine arithmetic procedures to ensure that assessment practices continued to measure the competencies that educators sought to cultivate (McCauliff, 2004).

The growing capabilities of AI systems raise broader questions about how professional competence should be evaluated in contexts where clinicians increasingly interact with algorithmic decision-support tools. If AI systems can assist with tasks traditionally associated with medical expertise, educators may need to reconsider which cognitive processes assessments should prioritize. In addition to factual knowledge and pattern recognition, assessment systems may increasingly need to evaluate a learner's ability to interpret algorithmic outputs, recognize potential errors or biases in AI-generated recommendations, and integrate these insights into patient-centered clinical reasoning. While such formats have long served as efficient tools for evaluating large cohorts of students, recent advances in generative AI raise questions about whether these approaches remain aligned with the evolving informational environment of clinical practice (Rezaei-Zadeh et al., 2025).

In response to these discussions, several alternative assessment approaches have begun to appear in the literature. Scenario-based simulations, for example, could ask students to evaluate or refine AI-generated diagnostic suggestions, thereby assessing learners' ability to critically engage with algorithmic outputs and apply clinical reasoning (Rezaei-Zadeh et al., 2025). Other proposals include open-resource examinations that incorporate structured AI use, reflecting real-world clinical settings where physicians routinely interact with digital decision-support systems (Bakthavatchaalam & Sivasankar, 2025). Hybrid formats combining traditional clinical reasoning tasks with exercises that involve interaction with AI systems have also been suggested as possible ways to capture emerging competencies in technologically mediated healthcare environments (Preiksaitis & Rose, 2023). These discussions suggest that assessment practices may gradually evolve as AI becomes more embedded in clinical practice and medical training. Determining how assessment systems should adapt will likely require continued experimentation, empirical evaluation, and dialogue among educators, licensing bodies, and professional organizations, as will be discussed later.

Preparing Educators and Learners for AI-Augmented Practice

The calculator era demonstrated that meaningful integration occurred only after targeted professional development initiatives cultivated what some scholars described as "calculator literacy" among educators (McCauliff, 2004). A comparable process of professional adaptation is necessary for the responsible integration of AI in medical education. Emerging research suggests that many medical educators possess limited familiarity with AI technologies and express uncertainty regarding their pedagogical integration (Blanco et al., 2025; Masters, 2023). Without adequate support, faculty may struggle to guide students in the responsible use of AI tools or to design learning activities that incorporate AI in pedagogically meaningful ways. Faculty development must, therefore, extend beyond basic technical literacy to address the broader pedagogical implications of AI-mediated learning. Educators will need preparation in critically evaluating AI outputs, designing AI-supported learning environments, and helping students interpret algorithmically generated information within clinical contexts.

Students likewise require structured preparation to function effectively in AI-augmented educational and clinical environments. This preparation includes developing algorithmic literacy, ethical awareness, and the capacity to critically evaluate machine-generated outputs (Manguvo & Mafuvadze, 2026; Roveta et al., 2025; Topol, 2019). In addition, examination boards and licensing authorities must engage in parallel professional development efforts to adapt assessment practices accordingly. Such efforts may include preparing examiners to establish clear guidelines regarding the appropriate role of AI in examination and assessment contexts.

Governance and Policy Frameworks for Responsible AI Integration

Technological transitions in education are shaped not only by classroom practices but also by institutional governance structures that guide how new tools are adopted and regulated. Historical experience from the calculator era illustrates how policy guidance can influence the trajectory of technological integration. During the early years, calculator adoption varied widely across schools and classrooms. Over time, professional organizations such as the National Council of Teachers of Mathematics issued policy guidance clarifying when and how calculators could be used in instruction and assessment. These frameworks helped standardize pedagogical practices and provided educators with clearer expectations regarding appropriate technological use (McCauliff, 2004; Monaghan, 2016).

Although the scope and complexity of AI technologies extend far beyond those associated calculators, the integration of AI into medical education raises comparable governance considerations. Without clear institutional policies, educators and training programs may adopt inconsistent approaches to AI use in coursework, clinical training, and assessment practices. Such variability can create uncertainty among learners and faculty regarding acceptable uses of AI, expectations for academic integrity, and the role of algorithmic systems within clinical reasoning processes.

Research has shown that institutional policies addressing AI in medical education remain uneven. A recent cross-sectional analysis of U.S. medical schools by Morales et al. (2026) found that fewer than half had established formal institutional guidelines governing the use of AI within educational contexts. Where policies do exist, they often focus primarily on academic integrity concerns rather than providing broader guidance on pedagogical integration. This pattern is not uncommon during the early phases of technological adoption, where institutions frequently develop policies incrementally as practical challenges become more visible.

Beyond individual institutions, national and professional organizations also play an important role in shaping the governance landscape of medical education. Bodies such as the AMA, Association of American Medical Colleges (AAMC), and accrediting organizations such as the

Liaison Committee on Medical Education (LCME) influence curricular expectations, and professional standards across training programs. As AI tools become increasingly embedded in healthcare systems, these organizations are beginning to explore how guidance on AI literacy, ethical use, and responsible clinical decision-support may be incorporated into educational standards and professional competencies (Topol, 2019).

From the perspective of institutional adaptation theory, governance frameworks often evolve alongside technological experimentation rather than preceding it. Early policy responses may focus on mitigating potential risks, such as academic misconduct or data privacy concerns. Over time, as educators gain experience with new tools, governance structures may gradually expand to address broader pedagogical and professional considerations. The development of coherent governance frameworks will likely involve ongoing coordination among educational institutions, professional organizations, and regulatory bodies. As the discussion in the following section suggests, understanding these institutional dynamics helps illuminate the broader trajectory through which educational systems adapt to technological change.

Developmental Trajectory of Medical Education Reform in the AI Era

Technological innovations rarely produce immediate or uniform transformation within professional education systems. Instead, institutional responses often unfold gradually as educators, regulators, and professional communities interpret the implications of new technologies and renegotiate their role within established training structures. The preceding analysis of institutional resistance, pedagogical repositioning, gatekeeping by educators, curricular change, assessment practices, and governance frameworks suggests that the integration of emerging technologies tends to involve recurring institutional dynamics rather than instantaneous systemic reform.

To synthesize these observations, the authors propose a developmental trajectory model that conceptualizes how educational institutions may adapt to disruptive technologies over time. The trajectory draws on patterns observed during earlier technological transitions, including the calculator era, while also incorporating insights from contemporary discussions of AI in medical education. Importantly, the comparison between these contexts is intended to illuminate institutional dynamics rather than to suggest direct equivalence between the technologies themselves. Nevertheless, examining historical responses to technological change can help reveal recurring institutional patterns that may inform how educational systems respond to emerging innovations.

Within this conceptual framework, technological adoption often begins with the emergence of a new capability that challenges existing assumptions about knowledge, expertise, and professional training. Early institutional responses frequently involve skepticism, regulatory caution, and debate regarding the potential cognitive and professional implications of the technology. As educators experiment with new tools, technologies may gradually become incorporated as supplemental resources within existing pedagogical structures. Over time, continued experimentation and institutional negotiation may lead to shifts in teaching practices, curricular priorities, and assessment models. In some cases, these adjustments may eventually contribute to broader structural changes in how professional training is organized. Table 2 presents the proposed developmental trajectory as a conceptual model of institutional adaptation to technological innovation in education.

Table 2. Developmental Trajectory of Institutional Adaptation to AI in Medical Education

Stage	*Name*	*Description*	*Key Characteristics*
Stage 0	**Technological Emergence**	*Introduction of Generative AI*	• Early experimentation with AI tools • Limited evidence regarding educational impact • Curiosity, uncertainty, and exploratory use
Stage 1	**Institutional Resistance**	*Initial threat response to AI technologies*	• Concerns about academic integrity • Fear of erosion knowledge and clinical reasoning • Institutional restrictions or bans on AI use • Professional skepticism about AI reliability
Stage 2	**Supplemental Integration**	*AI used primarily as an optional efficiency tool*	• AI tools used for retrieval, summarization, • AI permitted but peripheral to formal instruction • Existing curriculum largely unchanged • AI improves efficiency without altering pedagogy
Stage 3	**Pedagogical Reorientation**	*Teaching emphasis shifts in response to AI capabilities*	• Emphasis on clinical reasoning and judgment • Critical evaluation of AI-generated outputs • Normalization of AI tools in learning environments • Emergence of AI-supported instructional approaches
Stage 4	**Curricular Redesign**	*Structural curricular adaptation to AI-mediated practice*	• Algorithmic literacy and AI ethics introduced • Interpretation and oversight of AI outputs • AI-supported simulations and assessment formats • Technology literacy integrated into training
Stage 5	**Structural Transformation**	*Systems-level transformation of professional training*	• Training pathways reorganized for AI-based practice • Expanded competency-based progression • Earlier clinical immersion enabled by AI • Reconsideration of training duration and sequencing

Viewed through this lens, the current integration of AI in medical education appears to occupy an early and still-evolving position along this trajectory. AI tools are increasingly incorporated into learning environments and clinical workflows, yet many medical educators continue to operate within curricular structures, assessment practices, and governance frameworks developed prior to the widespread availability of AI-assisted knowledge systems. As institutions continue to experiment with these technologies, the extent to which deeper structural adaptations will occur remains an open empirical question. While the table above outlines the hypothesized developmental stages of institutional adaptation, Figure 2 presents a conceptual visual model that synthesizes this trajectory, illustrating how medical education systems may evolve as AI becomes progressively integrated into professional training.

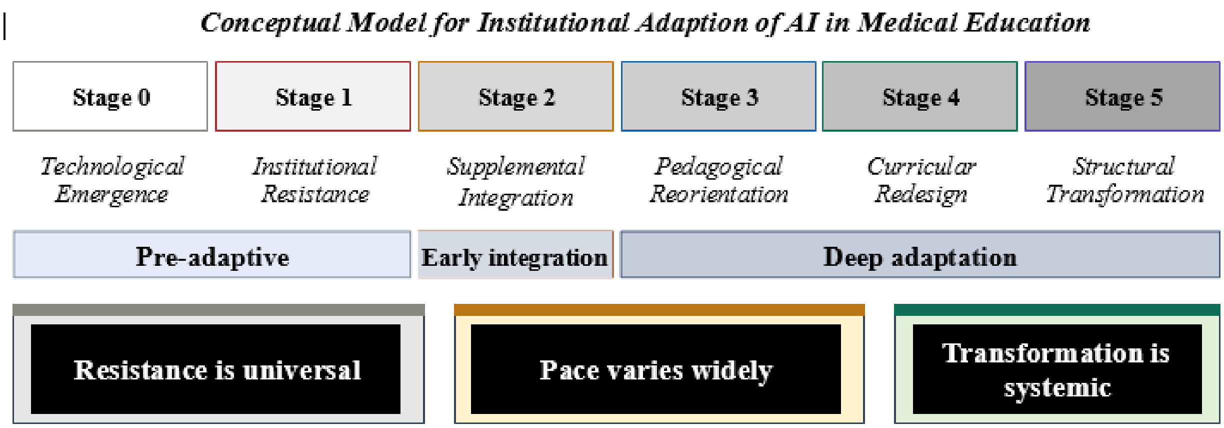

Figure 2.
Conceptual visual model of AI integration in medical education.

Scope and Interpretive Limits of the Conceptual Model

The value of the trajectory model lies not in predicting a single future for medical education but in providing a conceptual framework for interpreting how educational systems respond to technological innovations. Although developed in the context of medical education, the model may also offer interpretive insights for other professional training environments, including law, engineering, and business education, where emerging technologies are similarly reshaping knowledge work and professional preparation. By situating current developments within broader patterns of institutional adaptation, the model offers a structured lens through which educators and policymakers may better understand the evolving relationship between technological innovation and professional training.

At the same time, the model should be interpreted as a conceptual heuristic rather than a deterministic sequence of stages. It is not intended to predict a universal pathway of technological adoption or to imply that all educational systems will progress through identical phases. Rather, it provides an interpretive framework for understanding how institutional responses to technological change often evolve as educators, institutions, and professional organizations negotiate the role of emerging technologies within educational practice.

Importantly, the model does not assume that technological integration will necessarily lead to structural transformation in medical education. In some contexts, new technologies may remain confined to supplemental roles within existing educational structures rather than prompting substantial systemic change. Notably, institutional responses are shaped by numerous contextual factors, including professional norms, regulatory environments, and organizational incentives.

Conclusion

Artificial intelligence is rapidly transforming the informational environment in which clinical knowledge is accessed, synthesized, and applied. These developments have generated widespread discussion about how medical education should respond to the growing presence of AI in both clinical and learning environments. Yet technological innovation alone does not determine how professional education evolves. Drawing on insights from earlier technological transitions, this article proposed a conceptual framework for examining how educational institutions respond to disruptive technologies. The analysis highlights how technological integration often unfolds through gradual processes of institutional negotiation rather than immediate structural transformation. Building on these observations, the article introduced a developmental trajectory model to conceptualize how educational systems may adapt as emerging technologies become incorporated into professional training.

Viewed through this framework, the current integration of AI in medical education appears to occupy an early and still-evolving phase of institutional adaptation. AI tools are increasingly present in clinical and educational contexts, yet many curricular structures, assessment models, and governance frameworks continue to reflect assumptions developed in a pre-AI informational environment. Whether these structures will undergo incremental adjustment or deeper transformation remains an open empirical question. As AI continues to reshape clinical practice, sustained dialogue among educators, policymakers, and professional organizations will be essential to ensure that medical education evolves in ways that preserve the intellectual, ethical, and humanistic foundations of medical practice while preparing future physicians to work effectively within technologically mediated healthcare systems.

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