ACCSCIENCE PUBLISHING

Artificial Intelligence in Health

BRIEF REPORT

Feasibility of artificial intelligence-driven personalized learning for internal medicine residents: Integrating adaptive artificial intelligence in flipped classrooms

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Citation: Sanchez-Gonzalez MA, Ascio N, Shah O, Matejka A, Terrell M, Muddassir S. Feasibility of AI-driven personalized learning for internal medicine residents: Integrating adaptive AI in flipped classrooms. *Artif Intell Health*. 2025;2(4):139-145.
doi: 10.36922/AIH025130023

Received: March 25, 2025

1st revised: May 23, 2025

2nd revised: May 30, 2025

3rd revised: June 4, 2025

4th revised: June 13, 2025

Accepted: June 16, 2025

Published online: July 16, 2025

Abstract

Medical residency training faces persistent challenges in delivering individualized learning experiences. While flipped classroom models promote engagement, they often lack real-time, personalized feedback. Artificial intelligence (AI)-driven platforms offer a promising solution by dynamically adapting content to residents' evolving needs. This study evaluated the feasibility and effectiveness of integrating adaptive AI beings into a flipped classroom model for internal medicine residents. The AI-powered platform, edYOU, incorporated a personalized ingestion engine to customize learning content and an intelligent curation engine to ensure content integrity. Residents interacted with AI beings capable of adjusting real-time content delivery based on performance and progress. Learning outcomes were assessed using platform engagement metrics, simulation-based quiz results, and resident feedback. Among eligible residents, 92% actively used the platform, spending an average of 32.3 h (a few minutes to 148 h). A significant positive correlation was observed between time spent on the platform and quiz performance ($r = 0.63$, $p<0.001$), with 82.57% of educational topics engaged. Learners spent more time on difficult content areas, highlighting the system's ability to adapt to individual challenges. Integrating AI into the flipped classroom proved feasible and was associated with improved engagement, learning efficiency, and academic performance. These results support using AI-enhanced educational tools to foster tailored, learner-centered experiences in graduate medical education. Further research is warranted to optimize implementation strategies and evaluate the long-term impact of AI-driven learning environments on resident development and competency outcomes.

Keywords: Artificial intelligence; Personalized learning; Internal medicine; Flipped classroom; Residency training; Medical education

1. Introduction

Artificial intelligence (AI) has recently transformed medical education by offering personalized, adaptive learning experiences and content delivery. Traditional medical residency training programs (graduate medical education) face challenges in meeting the diverse learning needs of trainees, as standardized approaches often fail to accommodate individual differences in knowledge acquisition and clinical preparedness.[1] Flipped classroom models, which shift passive learning outside the classroom and emphasize active engagement during instructional sessions, have demonstrated improved learner engagement, comprehension, and new language acquisition.[2,3] The evolution of AI in education has followed both incremental and disruptive paths, supporting personalized learning through increasingly sophisticated cognitive models that could enhance the flipped classroom methodology.[4] When enhanced by AI, flipped classroom models further personalize instruction, offer real-time feedback, and significantly accelerate the acquisition of new skills and languages by adapting content to individual learning needs and preferences.[3,5]

Traditional flipped classroom models, while effective in promoting active learning, often fail to account for the heterogeneity of learner progression, intrinsic cognitive load, and the unpredictable demands of clinical training environments.[6] In fact, traditional flipped classroom models are inherently limited by their reliance on pre-designed, static, repetitive content and a lack of responsive feedback mechanisms.[1,7] These models often fail to account for the heterogeneity of learner progression, cognitive load, and the dynamic nature of clinical training environments. As a result, residents may struggle to bridge understanding gaps or receive timely clarification on complex topics, particularly when self-directed study occurs outside of scheduled instructional time. In this context, AI-driven educational platforms offer a compelling advancement by introducing real-time adaptability into the flipped classroom structure. A systematic review of AI applications in higher education reveals widespread use in intelligent tutoring, predictive analytics, and learning support tools.[8] These systems can analyze user input, track performance patterns, and deliver content dynamically tailored to individual learning trajectories.

Through automated feedback loops and continuous assessment, AI platforms can identify areas of difficulty, reinforce core concepts, and adjust content delivery accordingly – features that are otherwise challenging to implement in traditional didactic or blended formats.[1] While early studies have demonstrated the feasibility and learner satisfaction associated with AI-enhanced instruction in undergraduate medical education, their application in graduate medical education, particularly within the time-constrained and high-stakes context of residency training, remains underexplored.[9] Given the increasing demands for competency-based education and personalized learning environments in graduate medical education, integrating AI into residency curricula may represent a transformative step in optimizing knowledge acquisition, supporting just-in-time learning, and ultimately improving patient care outcomes across healthcare systems.[10-12] In this vein, through real-time adaptation, the AI beings provide personalized support, ensuring residents receive targeted reinforcement in areas of difficulty. Prior research has demonstrated that AI-assisted learning enhances engagement, reduces study time, and improves performance in formative as well as summative assessments.[13,14] Given the increasing demand for competency-based medical education, AI-driven platforms have the potential to bridge gaps in traditional learning methods by offering scalable, data-driven solutions tailored to individual learning needs.

Accordingly, the present study sought to evaluate the feasibility of integrating adaptive AI beings into a flipped classroom model for internal medicine residents. Addressing the aforementioned deficiencies of earlier models, the AI-driven platform used in this study leverages natural language processing and machine learning algorithms to assess learner's progress and optimize instructional delivery. This novel integration aims to advance the pedagogical utility of flipped learning by offering a scalable, data-informed solution that delivers real-time personalization within the demanding context of graduate medical education.

2. Data methods

2.1. Study design and setting

This study employed a feasibility design to evaluate integrating an AI-driven learning platform into an internal medicine residency program. The AI-enhanced flipped classroom model was implemented at HCA Florida Oak Hill Hospital's Internal Medicine residency program, with participation of residents from post-graduate years 1 to 3. The 6-month educational intervention examined resident engagement, learning efficiency, and performance changes in preparation for in-service examinations. Residents were introduced to the AI platform through detailed orientation sessions and continuous access to the platform throughout the study period. The platform provided adaptive learning pathways tailored to each resident's performance. Engagement was monitored through various metrics, including total study time, frequency and duration of interactions, and completion rates of educational modules. This study also assessed subjective feedback to gauge resident satisfaction and perceived benefits of the AI-driven learning approach. Data collection extended to performance outcomes on simulation-based quizzes, aligning engagement metrics with academic progress.

2.2. AI-driven learning platform

The study utilized the edYOU platform, an adaptive, AI-based educational system designed to personalize learning experiences in graduate medical education. The platform's adaptive content delivery is grounded in key principles of adaptive hypermedia, which personalize learning pathways based on user modeling.[15] The platform also integrates two core components: The personalized ingestion engine (PIE) and the intelligent curation engine (ICE). The PIE technology, which follows adaptive learning principles, continuously curates diverse instructional materials from validated academic sources.[16] It uses natural language processing to tailor content delivery based on each learner's demonstrated knowledge, response patterns, and engagement history. This dynamic tailoring allows the system to adjust the difficulty and sequencing of content in real time, supporting individualized progression through the curriculum. The ICE, in turn, ensures the integrity, relevance, and safety of the educational material by implementing automated content validation protocols, including toxicity filtering, bias mitigation, and source verification. The above-mentioned safeguards were purposely designed to maintain academic rigor while minimizing the risk of misinformation or inappropriate content. Medical residents interacted with AI beings (Figure 1) capable of conducting naturalistic dialogue, providing immediate, context-sensitive feedback, and tracking learner progress through analytics-driven personalization. This combination of adaptive delivery and content governance enabled a responsive, structured learning environment aligned with competency-based medical education principles.

Figure 1. Adaptive AI beings on the edYOU platform
Abbreviation: AI: Artificial intelligence.

2.3. Implementation and data collection

Medical residents were introduced to the AI-driven flipped classroom model through an initial orientation session that provided an overview of the platform's capabilities, including navigation, interaction protocols with the AI beings, and expectations for independent learning. Following orientation, residents were encouraged to utilize the platform beyond scheduled didactic sessions to supplement their self-directed study. The platform's design allowed for asynchronous interaction, enabling learners to access content, receive feedback, and revisit complex concepts at their own pace. Engagement metrics – including total time spent on the platform, percentage of topics completed, frequency of interactions with AI beings, and depth of follow-up queries – were passively and systematically logged by the platform's analytics infrastructure. These objective measures of engagement were paired with performance on simulation-based formative assessments and standardized in-service examination scores to evaluate learning outcomes. In addition, subjective feedback was gathered through post-intervention surveys, which included quantitative ratings and open-ended questions to assess perceived usefulness, ease of use, and the platform's ability to support individualized learning. This multi-modal evaluation strategy allowed data triangulation across usage, performance, and user perception domains.

2.4. Statistical analysis

Descriptive statistics were employed to summarize resident engagement and platform utilization metrics, including total hours spent on the platform, number of completed modules, and frequency of interactions with AI beings. Pearson correlation coefficients were calculated to assess the association between platform usage and academic outcomes, with quiz performance as the primary dependent variable. Statistical significance was determined a priori at a two-tailed alpha level of $p<0.05$. All analyses were conducted using the IBM Statistical Packages for the Social Sciences Statistics for Windows, version 28.0 (IBM Corp., Armonk, NY, USA).

3. Results

Data are expressed as mean and standard deviation unless otherwise specified. Descriptive statistics are summarized in Table 1.

Table 1. Summary of descriptive statistics

Variable	Mean	SD	Min	Max
Total hours	15.5	40.91	0.18	124.41
Total correct	10.89	11.52	1	34
Questions attempted	28.44	21.32	6	73
Quiz accuracy	0.31	0.21	0.05	0.71
Average of time per question (s)	658.39	564.05	153	1827.77

Abbreviation: SD: Standard deviation.

Table 2. Pearson correlation matrix of resident engagement and quiz performance variables

Variables	Total hours	Questions attempted	Quiz accuracy
Questions attempted	0.784*		
Quiz accuracy	0.308	0.492	
Average time per question (s)	0.357	0.279	0.889**

Notes: Values represent Pearson correlation coefficients (r); *$p<0.05$; **$p<0.01$.

A total of 92% of eligible internal medicine residents actively engaged with the AI-driven learning platform over the 6-month study period. Residents spent an average of 32.3 h interacting with the AI beings, with engagement ranging from a few minutes to 148 h (Figure 2). The platform was used most frequently in the evenings, with 78% of participants accessing it thrice weekly, demonstrating successful integration into residents' study routines.

During a 6-month pilot, the internal medicine residents consistently engaged with the AI-powered learning platform, with 78% accessing it at least thrice weekly, primarily in the evenings. The control chart shows a mean session time of 10.31 min and an upper control limit of 77.08 min, reflecting occasional high-engagement periods.

Analysis of performance outcomes revealed a strong positive correlation between platform usage and quiz performance ($r = 0.63$, $p<0.001$), indicating that greater engagement with the AI-driven flipped classroom model was associated with improved knowledge retention and test scores. Residents who dedicated more time to AI-based learning achieved quiz accuracy rates of up to 85%, while those with lower engagement had significantly lower scores (Table 2).

In addition, 82.57% of the educational topics were actively engaged, and residents spent more time on challenging subject areas, suggesting that the AI beings effectively guided individualized learning paths. Subjective feedback from residents indicated that the platform was intuitive, adaptable, and beneficial for reinforcing complex concepts, with many participants expressing a preference for AI-driven learning over traditional self-study methods.

Total time spent on the platform averaged 5.42 h, with ±1.93 h SEM, showing variability in engagement (Figure 3). Some residents had significantly higher usage, reflecting diverse study behaviors.

4. Discussion

The primary objective of this study was to evaluate the feasibility of integrating an AI-driven personalized learning platform into internal medicine residency training. Our findings indicate that the adaptive AI beings significantly enhanced resident engagement and exam performance. In addition, the strong correlation between platform usage and quiz performance ($r = 0.63$, $p<0.001$) underscores the effectiveness of AI-driven education in improving learning outcomes while echoing findings from educational data mining, which links behavioral metrics to learning outcomes.[17] These results suggest that AI-enhanced flipped classrooms can provide personalized, data-driven learning experiences that improve study efficiency while maintaining educational rigor.[18] Given the increasing reliance on competency-based education models in graduate medical training, this study highlights the potential role of AI in optimizing individualized learning pathways and supporting residents and educators in the transition to adaptive, technology-enhanced instruction.[2,19]

The present findings align with previous research demonstrating the benefits of AI-driven learning in medical education. Studies have shown that AI-based adaptive learning models improve knowledge retention, engagement, and self-directed study habits.[1,5] The association between AI engagement and quiz performance is consistent with prior work, which identified AI-driven feedback mechanisms as a key contributor to improved assessment scores and learner's confidence.[13] Similarly, AI-supported flipped classrooms have enhanced active learning and self-efficacy, reinforcing our study's conclusions regarding AI-driven personalized learning approaches.[20] However, our results diverge from studies that report mixed student reception of AI integration, where concerns regarding algorithmic bias and the accuracy of AI-generated content were noted. These discrepancies highlight the need for continued refinement of AI-assisted learning models, focusing on transparency in how content is curated and personalized. As seen in clinical AI applications, a lack of clarity in algorithmic processes can hinder trust and adoption. Similarly, educational AI systems must ensure explainability and accountability to gain acceptance and deliver equitable outcomes. Clear

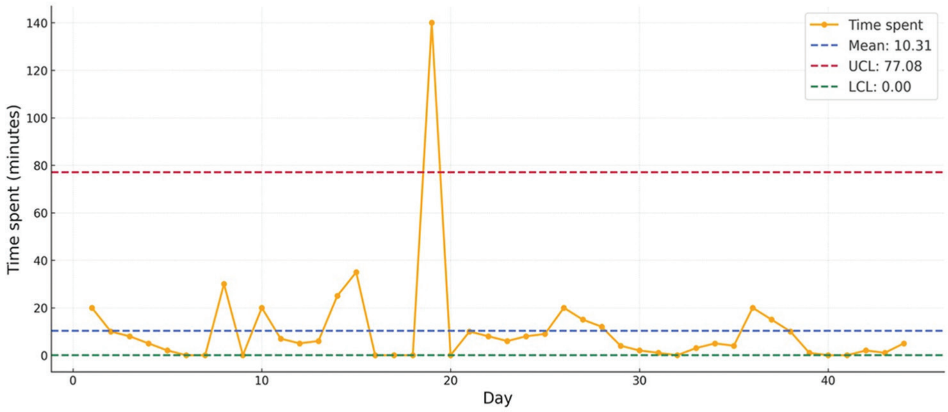

Figure 2. Control chart for time spent on the AI-powered learning platform
Abbreviations: AI: Artificial intelligence; LCL: Lower control limit; UCL: Upper control limit.

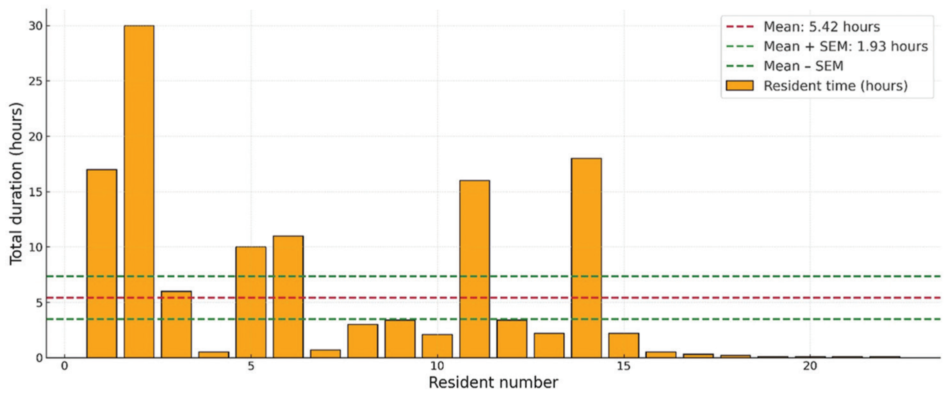

Figure 3. Total duration per resident on the AI-powered learning platform, expressed as mean and SEM, with the outliers removed
Abbreviations: AI: Artificial intelligence; SEM: Standard error of the mean.

governance around content curation is essential for scaling these tools responsibly.[21]

In the present study, we posit that the ICE played a critical role in upholding ethical standards, mitigating misinformation, and ensuring the pedagogical validity of AI-generated educational content. By integrating automated safeguards such as source verification, toxicity filtering, and bias mitigation, ICE directly addresses concerns raised in prior literature regarding the reliability of AI-driven instructional material.[22,23] This technological advancement represents an ethically sound, meaningful evolution over earlier AI-enhanced learning systems by combining adaptive personalization with structured content governance. In addition, early AI technologies such as Verbot™ demonstrated the potential for digital agents to enhance classroom engagement and delivery.[24] As such, the platform supports individualized learning trajectories and reinforces the academic integrity necessary for implementation in medical education.[25]

While this study provides valuable insights into AI-enhanced medical education, several limitations must be acknowledged. First, the educational research study was conducted within a single internal medicine residency program, without a comparison or control group, potentially limiting the generalizability of findings across different specialties and training environments. Second, although engagement and quiz performance were strongly correlated, long-term educational outcomes, such as board examination performance or clinical decision-making improvements, were not assessed. In addition, resident perceptions of AI-based learning were collected through surveys. However, the study did not include qualitative interviews or focus group discussions, which could have provided more profound insights into learner's experiences and preferences. Recent studies have shown that generative AI tools can support learner's motivation and improve knowledge retention in higher education contexts.[26] Future research should explore multiinstitutional studies, integrate longitudinal performance tracking, and incorporate resident and faculty perspectives on AI adoption in medical education.

5. Conclusion

Integrating AI-driven adaptive learning platforms presents several opportunities for improving residency training and, potentially, quality of care. Program directors and medical educators should consider incorporating AI-assisted flipped classrooms to supplement traditional didactic instruction, allowing residents to engage with material at their own pace while receiving real-time feedback on areas requiring improvement. In addition, AI platforms should be designed with human oversight mechanisms, ensuring that educational content remains accurate, unbiased, and aligned with competency-based training standards. To further enhance engagement, residency programs should integrate faculty development initiatives that train educators in AI-assisted pedagogical strategies, fostering collaborative learning models that combine AI-driven insights with expert mentoring. As AI technologies evolve, ongoing evaluation of their educational impact, scalability, and ethical use is essential. Future research should also examine how AI-based learning affects long-term clinical performance, interprofessional collaboration, and patient outcomes – areas critical to the future of medical education and healthcare delivery.

Acknowledgment

None.

Funding

The authors declare that edYOU provided the e-learning platform for the study. No external grants or additional financial support were received for this article's research, analysis, or publication.

Conflict of interest

The authors declare that they have no competing interests.

Author contributions

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Writing – original draft: Marcos A. Sanchez-Gonzalez
Writing – review & editing: All authors

Ethical approval and consent to participate

This study qualifies for exemption from IRB review under the U.S. Department of Health and Human Services (HHS) Human Subject Regulations Decision Charts. Research involving educational tests, survey procedures, interview procedures, or observation of public behavior, where identifiable information is not recorded or disclosure would not place subjects at risk. As such, this study does not require formal approval by an Institutional Review Board or the acquisition of informed consent, in accordance with federal guidelines.

Consent for publication

This educational research project used only aggregated, fully de-identified assessment data, with no protected health information (PHI), personally identifiable information, or images of participants. As such, this study qualifies for exemption from IRB review under the U.S. Department of Health and Human Services (HHS) Human Subject Regulations Decision Charts.

Availability of data

Data are available from the corresponding author upon reasonable request.

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