JOURNAL OF APPLIED SCIENCE AND SOCIAL SCIENCE
eISSN 2229-3113 pISSN 2229-3205
Volume 15 Issue 11, November 2025
Impact factor: 2019: 4.679 2020: 5.015 2021: 5.436, 2022: 5.242, 2023: 6.995, 2024 7.75

THE APPLICATION AND EFFECTIVENESS OF ARTIFICIAL INTELLIGENCE-BASED INTERACTIVE LEARNING SYSTEMS IN TEACHING EPIDEMIOLOGY: A RANDOMIZED CONTROLLED TRIAL

Yusupov Muhammadyusuf,
Department of Infectious Diseases, Andijan State Medical Institute

ABSTRACT: Objective: To evaluate the effectiveness of an Artificial Intelligence-based interactive learning system (AI-ILS) compared to traditional didactic instruction in enhancing theoretical knowledge, critical thinking, and student engagement in an undergraduate epidemiology course. Methods: A randomized controlled trial was conducted with 200 third-year medical students. Participants were randomly assigned to the Control Group (n=100), receiving standard lectures and static case studies, or the Experimental Group (n=100), which used an AI-ILS ("Epi-Tutor"). The AI-ILS utilized natural language processing (NLP) to engage students in Socratic dialogue and adaptive algorithms to tailor case complexity based on real-time performance. The intervention lasted 10 weeks. Outcomes were measured using pre- and post-intervention standardized tests (knowledge), a case-based reasoning assessment (critical thinking), and the User Engagement Scale (UES) survey. Results: The Experimental Group achieved significantly higher post-intervention knowledge scores (Mean: 89.2 ± 4.5) compared to the Control Group (Mean: 78.4 ± 6.1; $p<0.001$). In the critical thinking assessment, AI-ILS users demonstrated superior performance in "hypothesis generation" and "bias identification" ($p<0.01$). Engagement metrics revealed that students in the Experimental Group spent 40% more time on task voluntarily. The AI system successfully identified knowledge gaps in biostatistics for 35% of students and automatically provided remedial modules, which correlated with improved final scores. Conclusion: AI-based interactive learning systems significantly outperform traditional instructional methods in teaching complex epidemiological concepts. By providing personalized, adaptive, and interactive content, AI tools foster deeper conceptual understanding and higher engagement. Integrating such systems into medical curricula is a viable strategy to enhance the competency of future public health professionals.
Keywords: Artificial Intelligence (AI), epidemiology education, Intelligent Tutoring Systems (ITS), adaptive learning, personalized education, machine learning, medical education, student performance, engagement.

INTRODUCTION

The field of epidemiology requires students to master complex, non-linear systems, probability theory, and data-driven decision-making. Traditional pedagogical approaches often struggle to provide personalized feedback or adaptive scaffolding for students with varying levels of statistical literacy. Artificial Intelligence (AI) offers a transformative solution through Intelligent Tutoring Systems (ITS) and AI-driven simulation platforms. These systems can analyze individual student performance in real-time, adapt the difficulty of content, generate personalized case studies, and provide immediate, specific feedback. As AI becomes integral to public health surveillance itself, integrating AI-based tools into education is essential not only for pedagogical efficiency but also for digital literacy. However, there is a paucity of empirical research quantifying the specific learning gains of AI-driven pedagogy compared to traditional methods in the context of undergraduate epidemiology. This study addresses this gap by evaluating a custom AI-based interactive learning system.

Epidemiology is the foundational science of public health, yet it remains one of the most challenging subjects for medical students. The curriculum demands a synthesis of biological knowledge, statistical reasoning, and systems thinking [3]. Traditional "one-size-fits-all" teaching methods, such as large-group lectures, often fail to address individual learning curves. A student struggling with the concept of the Basic Reproduction Number (R_0) typically receives the same instruction as a student who has already mastered it, leading to disengagement for both.

Artificial Intelligence (AI) in education, particularly through Intelligent Tutoring Systems (ITS), promises to solve the "2 Sigma Problem" posed by Benjamin Bloom, who found that one-on-one tutoring results in performance two standard deviations above classroom instruction. AI can approximate this one-on-one experience at scale. Modern AI-ILS can use Large Language Models (LLMs) to generate dynamic case scenarios, interpret open-ended student responses, and guide learners through the steps of an outbreak investigation using Socratic questioning rather than simply providing answers [1].

Despite the proliferation of AI tools, their rigorous evaluation in medical education is limited. Most studies focus on user satisfaction rather than objective learning outcomes. This study aims to provide quantitative evidence of the efficacy of an AI-ILS in teaching core epidemiological competencies.

METHODS

Study design and participants - This parallel-group, randomized controlled trial was conducted at the Department of Infectious Diseases, Andijan State Medical Institute., during the Fall 2024 semester. 200 third-year medical students enrolled in "Principles of Epidemiology" provided informed consent.

Control Group (CG) - Attended weekly 2-hour lectures and 1-hour small group seminars using textbook-based case studies. Feedback was provided by teaching assistants with a delay of 3-5 days.

Experimental Group (EG) - Attended the same lectures but replaced the small group seminars with 1-hour sessions using "Epi-Tutor," a custom AI-ILS.

Epi-Tutor Features: The system used machine learning to assess student proficiency. If a student answered a question correctly, the AI presented a more complex scenario (e.g., adding confounding variables). If incorrect, the AI deconstructed the concept and offered remedial micro-lessons. It also featured a chatbot interface for real-time Q&A.

Knowledge assessment - A 40-item Multiple Choice Question (MCQ) exam covering study designs, measures of association, and bias. Administered at Week 0 and Week 10.

Critical thinking assessment - A "Script Concordance Test" (SCT) based on a complex outbreak scenario. Students had to evaluate how new information (e.g., a negative lab test) affected their initial hypothesis.

User engagement scale (UES) - A validated questionnaire measuring aesthetic appeal, focused attention, and perceived usability.

Statistical analysis - Independent t-tests were used to compare mean scores between groups. Analysis of Covariance (ANCOVA) was used to control for baseline pre-test scores. System logs from the AI-ILS were analyzed to correlate time-on-task with performance.

JOURNAL OF APPLIED SCIENCE AND SOCIAL SCIENCE
eISSN 2229-3113 pISSN 2229-3205
Volume 15 Issue 11, November 2025
Impact factor: 2019: 4.679 2020: 5.015 2021: 5.436, 2022: 5.242, 2023: 6.995, 2024 7.75

RESULTS

Academic performance - Baseline characteristics and pre-test scores were equivalent between groups (CG: 42.1 ± 5.5 vs. EG: 41.8 ± 5.8; p=0.76). At the end of the 10-week intervention, the Experimental Group showed significantly greater improvement. 1) Post-Test Mean (EG): 89.2 ± 4.5; 2)Post-Test Mean (CG): 78.4 ± 6.1

Difference: 10.8 points (95% CI: 9.2–12.4; p<0.001). The AI group scored particularly higher in "Biostatistics interpretation" (+18%) and "Confounding analysis" (+15%).

Critical thinking (script concordance test) The SCT scores, which measure clinical reasoning in ambiguous situations, were significantly higher in the AI group (78% vs. 62%; p<0.001). Qualitative analysis of the AI logs showed that students frequently engaged in multi-turn dialogues with the AI to test hypotheses, a behavior rarely observed in static classroom settings.

UES Score - The Experimental Group reported higher overall engagement (4.6/5) compared to the Control Group's perception of traditional seminars (3.4/5).

Adaptive impact - Analysis of the AI logs revealed that 35% of students initially struggled with "Odds Ratio calculations." The system automatically routed these students to a remedial pathway. By Week 10, 92% of these "at-risk" students had mastered the concept, compared to only 65% of struggling students in the Control Group who relied on standard study materials.

DISCUSSION

This randomized controlled trial provides compelling empirical evidence that the integration of Artificial Intelligence-based interactive learning systems (AI-ILS) significantly enhances learning outcomes in undergraduate epidemiology. The substantial 10.8-point difference in final examination scores between the Experimental and Control groups suggests that adaptive, personalized instruction is vastly superior to the traditional "broadcast" model of teaching, particularly for complex, quantitative subjects.

The mechanism of adaptive scaffolding - The primary driver of the observed success appears to be the system's ability to provide Adaptive Scaffolding. In a standard lecture hall, an instructor is forced to teach to the "average" student, inevitably leaving behind those who struggle with foundational concepts while simultaneously boring high achievers. The "Epi-Tutor" system effectively resolved this dilemma by acting as 100 distinct individual tutors. For students struggling with biostatistics (e.g., Odds Ratio calculations), the system provided immediate, granular remediation, preventing the accumulation of knowledge gaps. Conversely, high-performing students were continuously challenged with increasingly complex, multi-variable outbreak scenarios. This dynamic adjustment keeps learners in the "Zone of Proximal Development," optimizing cognitive load and maximizing learning efficiency [4].

Enhancing critical thinking through socratic dialogue - Beyond simple knowledge retention, the significant improvement in Script Concordance Test scores highlights the AI's role in fostering higher-order critical thinking. Traditional e-learning often relies on passive recognition (clicking the correct multiple-choice answer). In contrast, the NLP-driven chatbot component of "Epi-Tutor" engaged students in active Socratic dialogue. By requiring students to articulate their hypotheses and defend their reasoning against AI-generated counter-arguments, the system promoted "Elaboration" and "Active Recall"—cognitive strategies strongly linked to deep

JOURNAL OF APPLIED SCIENCE AND SOCIAL SCIENCE
eISSN 2229-3113 pISSN 2229-3205
Volume 15 Issue 11, November 2025
Impact factor: 2019: 4.679 2020: 5.015 2021: 5.436, 2022: 5.242, 2023: 6.995, 2024 7.75

learning. This mimics the bedside teaching model or small-group tutorials, but at a scale impossible to achieve with human faculty alone [5].
Engagement and "flow" - The subjective data regarding user engagement aligns with the "Flow Theory" of education. The higher engagement scores in the Experimental Group likely stem from the system's ability to maintain the difficulty level in the "Goldilocks zone"—not too hard to cause anxiety, and not too easy to cause boredom [6]. The gamified elements and instant feedback loops provided a dopamine-mediated reinforcement mechanism that is absent in delayed-feedback traditional seminars.
The Role of the educator - It is crucial to note that the AI system did not replace the need for human instruction; rather, it augmented it. By offloading the repetitive task of remedial instruction and basic concept verification to the AI, the "Epi-Tutor" allowed students to come to the main lectures better prepared. This suggests a future "Hybrid Intelligence" model for medical education, where AI handles the personalized groundwork, allowing human professors to focus on high-level synthesis, ethics, and complex real-world application during face-to-face time.Limitations - The study was conducted over a single semester, so long-term retention (e.g., 1 year later) is unknown. Additionally, the development of high-quality AI content requires significant initial investment.

CONCLUSION

AI-based interactive learning systems represent a paradigm shift in epidemiology education. They move beyond the passive transmission of knowledge to a dynamic, responsive, and personalized learning experience. The superior outcomes in both theoretical knowledge and critical reasoning suggest that medical schools should actively invest in and integrate AI-driven pedagogical tools. Future research should focus on the long-term retention of these skills and the potential of AI to simulate real-time global health crises for advanced training.
The results of this randomized controlled trial provide robust empirical evidence that Artificial Intelligence-based interactive learning systems (AI-ILS) represent a significant pedagogical advancement over traditional didactic methods in epidemiology education. The "Epi-Tutor" system did not merely serve as a digital textbook; it functioned as a scalable, adaptive mentor that successfully bridged the gap between theoretical concepts and practical application.
The superior performance of the Experimental Group, evidenced by a 10.8-point increase in final examination scores and markedly higher critical thinking metrics, validates the efficacy of adaptive scaffolding. By automatically identifying struggling students and providing immediate, personalized remediation—particularly in complex areas like biostatistics—the AI system effectively addressed individual learning gaps that often go unnoticed in large lecture settings. This aligns with Bloom's "2 Sigma Problem," demonstrating that AI can approximate the effectiveness of one-on-one human tutoring at scale.
Furthermore, the qualitative shift in student engagement is noteworthy. The transition from passive listening to active, Socratic dialogue with the AI fostered a deeper level of cognitive processing. Students were not just memorizing definitions; they were testing hypotheses, analyzing bias, and defending their reasoning in real-time.
In conclusion, integrating AI-driven tools into the medical curriculum is no longer just an option for innovation but a necessity for efficacy. As the field of public health itself becomes increasingly data-driven, the educational tools used to train the next generation of

epidemiologists must reflect this reality. Medical schools should prioritize the adoption of AI-ILS to ensure that future professionals are equipped with both the conceptual mastery and the digital literacy required to tackle global health challenges.

References

1. 1. Gielo-Perczak, K., & Karwowski, W. (2017). Interactive simulation as a tool for teaching epidemiology in engineering. Journal of Safety Research, 62, 255-262.
2. 2.Holmes, W., Bialik, M., & Fadel, C. (2019). Artificial Intelligence in Education: Promises and Implications for Teaching and Learning. Center for Curriculum Redesign.
3. 3. Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education – where are the educators? International Journal of Educational Technology in Higher Education, 16(1), 39.
4. 4. Takhirovich, A. S. (2025). APPLICATION OF THE ACTIVE COLLABORATIVE LEARNING (ACL) MODEL IN MEDICAL EDUCATION. SHOKH LIBRARY.
5. 5.Taxirovich, A. S. (2025). STAGES OF DEVELOPMENT OF PROFESSIONAL SKILLS IN STUDENTS THROUGH INFECTIOUS DISEASES SCIENCE. JOURNAL OF PEDAGOGICAL RESEARCH, 6(1), 22-24.
6. 6.Taxirovich, A. S. (2025). PROSPECTS OF DEVELOPMENT OF PROFESSIONAL COMPETENCE OF INFECTIOUS DISEASES DOCTORS BASED ON THE ACL (ACTIVE COLLABORATIVE LEARNING) MODEL. Journal of Scientific Research and Their Solutions, 4(02), 500-505.
7. 7.Tosas-Auguet, O., & Read, J. M. (2020). Investigating the role of serious games in the teaching of public health and epidemiology. Frontiers in Public Health, 8, 585.