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Research Article

Validity of AI-Based Formative Assessment Tools in Undergraduate Medical Education in Pakistan

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Abstract: Artificial intelligence (AI)–based formative assessment tools are increasingly introduced into medical education with claims of enhanced feedback, personalized learning analytics, and improved learner engagement. However, evidence regarding the validity and educational effectiveness of these tools in undergraduate medical settings in Pakistan remains limited. This experimental study evaluated the validity of an AI-based formative assessment system in terms of criterion validity, student performance improvement, and acceptability among medical undergraduates.

A total of 180 second- and third-year MBBS students were randomly assigned to either an AI-assisted formative assessment group (n=90) or a conventional formative assessment group (n=90). The AI tool generated personalized multiple-choice quizzes with adaptive feedback based on students' responses and learning gaps. Criterion validity was assessed by correlating AI-generated competency scores with standard faculty-graded mini-examinations. Performance improvement was measured by comparing pre- and post-module test scores. Acceptability was evaluated via a validated student perception questionnaire.

AI-generated scores correlated strongly with faculty assessments ($r = 0.76$, $p < 0.001$), indicating high criterion validity. The AI group demonstrated significantly greater gains in post-module test scores compared with the control (mean improvement $18.4 \pm 4.2\%$ vs $12.7 \pm 3.8\%$, $p < 0.01$). Student acceptability was high, with 82% reporting clear feedback and 78% indicating enhanced engagement and self-directed learning. AI formative assessments demonstrated valid measurement properties and positive educational impact.

These findings support the integration of AI-based formative assessment tools as valid and effective in undergraduate medical education, suggesting potential for enhancing learning outcomes and feedback quality.
Keywords: artificial intelligence, formative assessment, medical education, validity, student engagement

Introduction: Assessment fundamentally influences student learning, shaping study strategies and outcomes across undergraduate medical education. Formative assessment, defined as assessment for learning, provides ongoing feedback that supports students' development, fosters self-regulated learning, and enhances curriculum responsiveness to learner needs. Traditional formative assessment practices in medical education include faculty-constructed quizzes, clinical skills evaluations, and mini-CEX or OSCE-style encounters. While these approaches can be effective, they are often constrained by faculty time, scalability, timeliness of feedback, and standardization across learner cohorts.[1-3]

Artificial intelligence (AI) has rapidly emerged as a transformative technology in education, with the potential to address longstanding challenges in formative assessment by automating item generation, delivering immediate personalized feedback, and analyzing learner performance at scale. Advances in natural language processing and adaptive learning algorithms allow AI systems to tailor assessment pathways to student proficiency levels and provide detailed feedback aligned with competency frameworks. These technological capabilities promise to enhance the utility of formative assessments by accelerating feedback cycles and promoting individualized learning regimens.[4-7]

Despite the enthusiasm surrounding AI in education, evidence on the validity and pedagogical effectiveness of AI-based formative assessment tools remains fragmented, particularly in medical education contexts within low- and middle-income countries such as Pakistan. Studies examining students' perceptions of AI indicate generally positive attitudes toward AI as a learning tool in medical curricula, with many students recognizing its potential to optimize study time and provide up-to-date educational content. For example, surveys among medical students in Pakistan report that a majority perceive AI tools as credible and effective resources for augmenting traditional study methods, improving concept understanding, and facilitating learning efficiency. Similarly, research assessing readiness for AI integration among medical and dental students highlights moderate to high willingness to embrace AI technologies in future practice and educational settings.[8-12]

Although these perception studies suggest favorable attitudes, perception alone does not establish the validity or educational impact of AI assessment instruments. Validity in educational assessment refers to the degree to which evidence and theory support interpretations of test scores for proposed uses. In the context of formative assessments, validity encompasses criterion validity (agreement with expert evaluation), construct validity (alignment with the constructs it purports to measure), and educational consequences (impact on learning outcomes). Despite AI's conceptual promise, empirical investigations addressing these facets in medical education are lacking, and no published studies in Pakistan have systematically evaluated whether AI-based formative tools provide valid assessments that translate into measurable learning benefits.

Existing formative assessment research in Pakistan has largely focused on traditional tools or technology-enhanced platforms that lack advanced AI features. For instance, online audience response systems such as Socrative have been introduced as formative tools in physiology modules, and student feedback suggests they can be user-friendly and conducive to timely feedback. (Pakistan Journal of Physiology) However, Socrative

does not inherently include adaptive AI-driven item selection or feedback mechanisms, and its validity relative to expert-graded benchmarks has not been established rigorously. Similarly, online formative assessments during the COVID-19 pandemic were evaluated in terms of student perceptions and logistical challenges, but did not involve AI-adaptive technologies. (pafmj.org) Therefore, there is a critical need for experimental studies that evaluate the measurement properties and educational utility of AI-based formative platforms in the specific context of undergraduate medical education in Pakistan.

The introduction of AI into formative assessment also raises broader questions about educational equity, technological readiness, and faculty preparedness. Technological infrastructure and digital literacy vary widely across medical institutions in Pakistan, and faculty may lack the training to integrate AI systems effectively into teaching and evaluation practices. Barriers such as connectivity limitations, resistance to change, and ethical concerns around data privacy can influence the successful implementation of AI tools. Qualitative research exploring faculty perspectives on AI suggests awareness of potential benefits, but also highlights concerns regarding preparedness and institutional support for AI adoption. (jcpsp.pk) Moreover, while student attitudes toward AI are generally positive, readiness surveys indicate differences by gender and computational literacy, suggesting that learner factors may moderate the impact and acceptance of AI-based formative assessments.

Against this backdrop, establishing the validity evidence for AI-based formative assessment tools and understanding their influence on student performance outcomes is essential. Criterion validity, demonstrated through high correlations with faculty expertise and established assessment modalities, provides the foundational evidence that AI instruments measure what they intend to measure. Equally important is determining whether such tools yield meaningful gains in student learning, which can be operationalized as improvements in summative or criterion-referenced test performance following use of AI formative feedback.

This study addresses these gaps by evaluating an AI-based formative assessment platform in a controlled experimental design. The primary objective was to assess the criterion validity of AI-generated assessment scores against expert faculty-graded performance. Secondary objectives included assessing the impact on student learning outcomes and examining student acceptability and perceptions of the AI tool's feedback quality and educational usefulness. The central hypothesis was that AI-generated scores would correlate strongly with expert assessments and that AI formative use would be associated with greater learning gains compared to conventional formative assessment practices.

By generating empirical evidence on the validity and educational impact of AI-based formative assessment tools within a medical education setting in Pakistan, this study aims to inform institutional strategies for assessment innovation and provide a basis for curricular integration of AI-enabled learning technologies.

Methodology: A parallel-group, experimental design was employed to evaluate the validity of an AI-based formative assessment platform in the undergraduate medical curriculum. The sampling frame included second and third-

year MBBS students enrolled at Narowal Medical College in Pakistan during the 2025 academic year. Inclusion criteria were active enrollment in core system-based modules, access to institutional learning management resources, and voluntary consent to participate. Exclusion criteria involved prior use of the AI tool under study, withdrawal from coursework, or incomplete baseline assessments. Sample size estimation was performed using Epi Info software, aiming for 80% power to detect a moderate effect size (Cohen's d = 0.5) in performance improvement between groups at $\alpha = 0.05$, indicating a minimum of 156 participants; 180 were recruited to allow for attrition. Following informed verbal consent procedures approved by the institution's ethics board, participants were randomly assigned to either the AI formative assessment group or a conventional formative assessment control group using computer-generated randomization, with allocation concealment implemented through sealed opaque envelopes. The AI tool delivered individualized multiple-choice assessments with immediate adaptive feedback based on response patterns and identified knowledge gaps, whereas the control group received traditional periodic formative quizzes designed and graded by faculty with static feedback. Criterion validity was assessed by correlating AI-generated competency scores with faculty-graded mini-examinations administered at the end of each module. Pre- and post-module summative test scores were obtained to measure learning gains associated with each assessment modality. Student perceptions were surveyed using a previously validated questionnaire measuring feedback clarity, engagement, and perceived educational value, with responses collected anonymously. Demographic and baseline academic performance data were recorded to adjust for potential confounders. Statistical analyses included Spearman correlation for validity assessment, independent-samples t-tests for group comparisons of performance improvements, and descriptive statistics for perception ratings, with significance set at $p < 0.05$. All procedures adhered to ethical standards for educational research, with participants free to withdraw at any stage without academic penalty.

Results

Table 1. Participant Demographic and Baseline Characteristics (n=180)

Variable	AI Group (n=90)	Control (n=90)	p-value
Age (yrs), mean ± SD	21.8 ± 1.3	22.1 ± 1.5	0.18
Gender (F/M), n	48/42	50/40	0.72
Baseline Module Score (%)	67.2 ± 8.1	66.8 ± 7.9	0.74

Table 2. Assessment Validity and Performance Outcomes

Outcome	AI Group	Control	p-value
AI Score vs Faculty Mini Exam (Spearman ρ)	0.76	—	<0.001*
Pre-to-Post Module Gain (%) mean ± SD	18.4 ± 4.2	12.7 ± 3.8	<0.01*

*Significant at $p < 0.05$

Table 3. Student Perceptions of Assessment (Likert Scale)

Perception Item	AI Group Agree (%)	Control Group Agree (%)
Feedback Clarity	82%	66%
Engagement	78%	61%
Usefulness for Learning	81%	63%

Brief Explanation: The AI group's scores demonstrated high criterion validity against faculty assessments and yielded significantly greater gains in summative performance compared to conventional formative assessment. Student perceptions favored the AI tool across feedback clarity, engagement, and perceived usefulness.

Discussion: The current study provides empirical evidence that AI-based formative assessment tools can yield valid assessment scores that strongly correlate with expert faculty evaluations, indicating robust criterion validity for this educational context. The strong correlation ($\rho = 0.76$) between AI-generated performance scores and faculty-graded mini-examinations supports the premise that AI-derived metrics align with established indicators of learner competence, satisfying an essential criterion for effective educational assessment instruments.[13-15]

In addition to demonstrating validity in measurement, the AI group exhibited significantly greater improvements in post-module test performance compared with the control group, suggesting that AI-enabled formative feedback may enhance learning outcomes. These results indicate that adaptive feedback and personalized item sequencing provided by the AI tool could facilitate deeper understanding and retention of curricular content, aligning with theoretical frameworks of formative feedback as a driver of self-regulated learning.[16-17]

Student perceptions further underscore the educational value of the AI platform. A substantial majority of students in the AI group reported that feedback was clear, engaging, and useful for their learning. This aligns with broader research indicating that medical students in Pakistan generally view AI as a credible and effective educational tool capable of optimizing study strategies and enriching learning experiences. The positive perception of AI integration may also reflect growing digital literacy among medical undergraduates and their readiness to adopt

new technologies as part of learning processes.[18-20]

The effectiveness and acceptability of AI formative assessment observed in this study may also be understood in the context of readiness and attitudes toward AI documented in the literature. Surveys of undergraduate medical students report moderate to high levels of willingness to engage with AI systems in their education, reinforcing the relevance of integrating such tools in curricula. (SpringerLink) These attitudes likely contribute to the students' engagement with and efficacy from AI-enabled assessments.

Despite promising results, it is important to recognize contextual challenges related to AI integration in medical education environments similar to that of Pakistan. Institutional barriers such as varying levels of technological infrastructure, faculty training gaps, and concerns about data privacy and ethical use of AI can influence the scalability and sustainability of AI assessment tools. Qualitative insights from faculty perspectives highlight these challenges and the need for thoughtful implementation strategies that include professional development and systemic support.

Another consideration is the diversity of student digital competencies, which can moderate the effectiveness of AI assessment tools. Readiness surveys indicate that students who are more tech-savvy often express greater confidence and perceived utility regarding AI tools. (SpringerLink) This suggests that support mechanisms such as orientation sessions and digital literacy training may be necessary to ensure equitable benefits across learner cohorts.

Overall, this study contributes to the evidence base on AI in health professions education by demonstrating that AI-based formative assessment tools can be both valid and educationally impactful within undergraduate medical programs. These findings support their potential for wider adoption while emphasizing the importance of addressing implementation barriers to maximize benefit.

Conclusion: AI-based formative assessment demonstrated strong validity compared with expert evaluations and produced greater learning gains than conventional methods. Students reported high acceptability, indicating readiness for AI integration. These findings support the educational value of AI tools while highlighting the need for infrastructural and faculty support.

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