EVALUATING THE EFFECTIVENESS OF AI-GENERATED FEEDBACK ON MEDICAL AND DENTAL STUDENTS' LEARNING OUTCOMES

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Abstract

Background: *Artificial Intelligence (AI) is increasingly being integrated into medical and dental education, particularly in providing automated feedback. However, its effectiveness in improving student learning outcomes remains underexplored.*

Objective: *This study evaluates the effectiveness of AI-generated feedback on the learning outcomes of medical and dental students at Karachi Medical and Dental College (KMDC).*

Methods: *A cross-sectional study was conducted among 310 students using a structured, self-administered questionnaire. The survey assessed demographic characteristics, prior exposure to AI tools, perceived effectiveness of AI-generated feedback, and self-reported improvements in learning outcomes. Statistical analyses, including chi-square tests and multivariate regression, were performed to determine associations between variables.*

Results: *The study found that 80% of students perceived AI-generated feedback as either highly or moderately effective. Similarly, 80% reported moderate to significant improvements in learning outcomes. Prior exposure to AI tools was significantly associated with a higher perceived effectiveness of AI-generated feedback (p = 0.012). However, differences based on the program of study (MBBS vs. BDS) and academic year were not statistically significant. Multivariate regression analysis confirmed prior AI exposure as a key predictor of perceived effectiveness (p = 0.004).*

Conclusion: *AI-generated feedback is perceived as an effective tool for enhancing learning outcomes among medical and dental students. Prior exposure to AI significantly influences students' perceptions, suggesting the need for broader AI integration in medical and dental curricula. Future research should explore long-term impacts and effectiveness across diverse educational settings.*

INTRODUCTION

Artificial intelligence (AI) has increasingly permeated medical and dental education, offering innovative tools to enhance learning experiences[1]. One notable application is AI-generated feedback, which provides students with immediate, personalized insights into their performance[2]. This technology aims to supplement traditional educational methods, potentially improving learning outcomes by addressing individual student needs more efficiently[3].Recent studies have explored the impact of AI in health professions education. A systematic review highlighted that, while AI shows promise in personalizing learning and assessing performance, there is currently limited evidence regarding its measurable educational outcomes[4]. The review emphasized the need for rigorous methodological studies to evaluate the effectiveness of AI-powered interventions in this field.In the realm of medical education, a cross-sectional study involving Pakistani medical students revealed a generally favorable attitude towards AI as a learning tool[5]. The majority of participants considered AI effective and credible, noting benefits such as optimized study time and access to up-to-date medical information[6]. Notably, 65.7% of students found AI more efficient in helping them grasp medical concepts compared to traditional tools like books and lectures.Similarly, AI's integration into dental education has been examined[7]. A review discussed the transformative potential of AI in reshaping diagnostics, treatment planning, and telemedicine screening within dentistry[8]. The review also highlighted the necessity of updating dental curricula to include AI competencies, preparing students for a technologically evolving landscape[9].However, despite these advancements, there remains a paucity of research specifically evaluating the effectiveness of AI-generated feedback on the learning outcomes of medical and dental students[10]. Understanding the impact of such feedback is crucial for integrating AI tools effectively into educational strategies[11]. This study aims to fill this gap by systematically assessing how AI-generated feedback influences the learning outcomes of students in these fields, thereby providing insights into its potential benefits and limitations[12].

Literature Review:

Amirjalili F(2024):This cross-sectional study examines the measurable educational impacts of AI-based strategies in health professions education. The study highlights the potential of AI to personalize learning and assess performance but notes the limited evidence regarding its measurable educational outcomes, emphasizing the need for rigorous methodological studies to evaluate the effectiveness of AI-powered interventions in this field[13].

Moldt JA(2023):This cross-sectional study explores medical students' perceptions of AI as a learning tool, assessing its credibility and effectiveness. The findings indicate a generally favorable attitude towards AI, with students acknowledging its potential to optimize study time and provide up-to-date medical information. Notably, 65.7% of students found AI more efficient in helping them grasp medical concepts compared to traditional tools like books and lectures[14].

Darvishi A(2022):This paper discusses the application of generative AI for providing automated feedback in higher education settings. It addresses the potential benefits of AI-generated feedback, such as scalability and consistency, while also highlighting concerns regarding accuracy, reliability, and the possibility of students receiving inappropriate feedback. The study emphasizes the need for clear institutional guidelines to mitigate potential misuse or abuse of AI-based feedback systems[15].

Chang DH(2022):This study investigates the impact of integrating feedback with reflective practices on medical students' deep learning. While not exclusively focused on AI-generated feedback, the

research underscores the importance of feedback in fostering self-regulated learning, critical evaluation, and the enhancement of clinical reasoning skills. The findings suggest that combining feedback with reflection can lead to meaningful learning experiences, highlighting the potential value of AI-generated feedback in this context[16].

VanLEHN K(2011):This article provides an overview of Intelligent Tutoring Systems (ITS), which are AI-driven platforms designed to provide immediate and personalized feedback to learners. The paper discusses the capabilities of ITS in modeling a wide range of student characteristics, such as knowledge and behavior, and their effectiveness in helping students learn. The insights from this study are relevant to understanding the potential of AI-generated feedback in medical and dental education[17].

Wang CC(2019):This article explores adaptive learning methods that utilize AI to deliver customized resources and learning activities tailored to individual learner needs. The study highlights the efficacy of adaptive learning systems in promoting student learning and their potential to transform learners from passive recipients to active collaborators in the educational process. The relevance of this study lies in its insights into how AI-generated feedback can be integrated into adaptive learning environments to enhance educational outcomes[18].

wang WY(2020):This article discusses the role of cosmology and the science of evaluation in educational settings, particularly in designing fair and effective assessments. It highlights the integration of AI in automating and enhancing assessment processes, such as automated grading systems and intelligent tutoring systems. The insights from this study are pertinent to understanding the broader context of AI-generated feedback in education[19].

Koedinger KR(2013):This article provides an overview of educational technology, including the role of AI in personalizing learning experiences. It discusses the development of intelligent tutoring systems that provide immediate and personalized feedback to students, highlighting the potential of AI to enhance educational outcomes. The insights from this study are relevant to understanding the ecosystem in which AI-generated feedback operates[20].

Rose C(2023):This cross-sectional study examines the applications of AI in medical education, focusing on its impact on teaching and learning processes. The study highlights the potential of AI to enhance educational outcomes through personalized learning and immediate feedback, underscoring the importance of evaluating the effectiveness of AI-generated feedback in medical education[21].

Albdrani RN(2023):This review explores the integration of AI-driven feedback mechanisms in dental education, assessing their impact on student learning outcomes. The study discusses the potential benefits of AI-generated feedback in providing personalized learning experiences and improving clinical skills, highlighting the need for further research to evaluate its effectiveness[22].

Material and Methods:

Study Design:

This cross-sectional study aims to evaluate the effectiveness of AI-generated feedback on the learning outcomes of medical and dental students at Karachi Medical and Dental College (KMDC). Cross-sectional studies are observational in nature and analyze data from a population at a specific point in time, making them suitable for assessing the prevalence and associations of variables within a defined population as shown in fig 1.
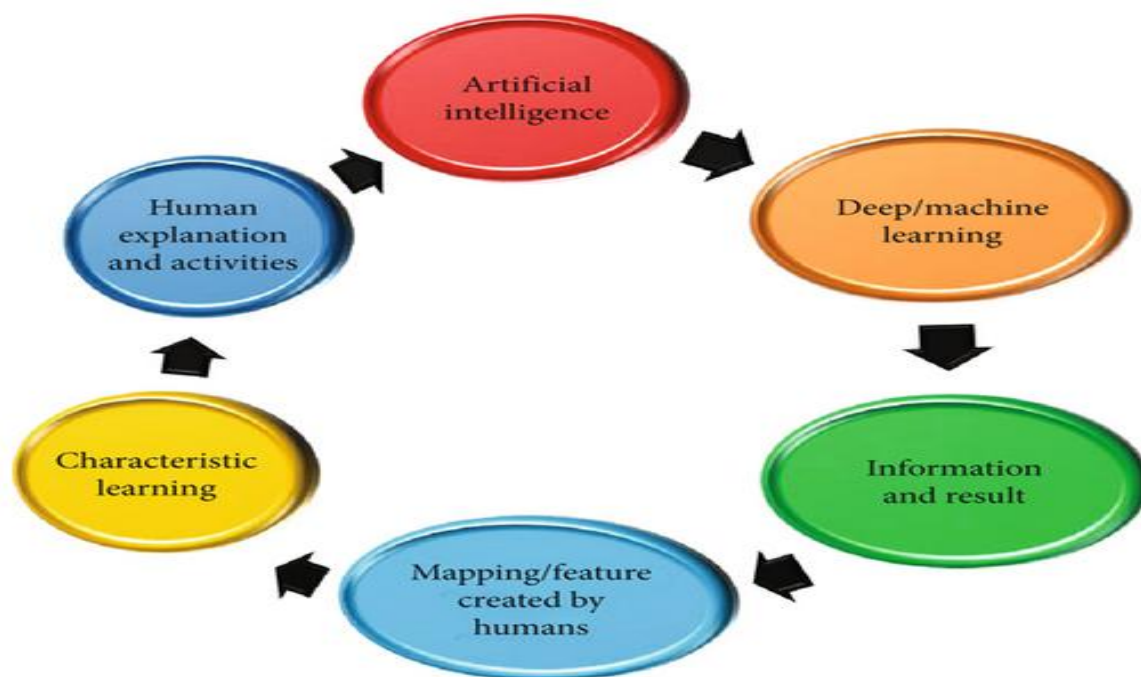
Data Collection:

Data collection was conducted through a structured questionnaire distributed among students from both the Bachelor of Dental Surgery (BDS) and Bachelor of Medicine and Bachelor of Surgery (MBBS) programs. The questionnaire was designed to assess students' perceptions, satisfaction levels, and the impact of AI-generated feedback on their academic performance. It included multiple-choice questions, Likert-scale items, and open-ended questions focusing on aspects such as clarity, accuracy, usability, and effectiveness of AI-generated feedback compared to traditional faculty-provided feedback. The survey was administered digitally via Google Forms and physically through printed copies distributed in classrooms to ensure maximum participation. Ethical approval was obtained from the institutional review board of KMDC before data collection, and written informed consent was obtained from all participants.

Participants:

The study population consisted of undergraduate BDS and MBBS students enrolled at Karachi Medical and Dental College. The total number of students in the institution was 1,650, including 400 BDS students and 1,250 MBBS students. The BDS student cohort included 72 males and 328 females, whereas the MBBS cohort comprised 200 males and 1,050 females. A simple random sampling technique was used to select participants, ensuring that students from all academic years were adequately represented. The distribution of students was as follows,BDS Students (1st to 4th Year): 100 students per year (Total = 400),MBBS Students (1st to 5th Year): 250 students per year (Total = 1,250).The sample size was calculated using Cochran's formula, considering a 95% confidence level and a 5% margin of error. Participants who had prior exposure to AI-generated feedback systems in their coursework were prioritized, while those unwilling to participate or with incomplete survey responses were excluded from the final analysis.Participants will be selected using simple random sampling to ensure representation across different academic years and programs. Inclusion criteria include current enrollment in the MBBS or BDS programs at KMDC and willingness to provide informed consent. Exclusion criteria include students on academic leave or those who have previously participated in similar studies to avoid bias.

Data Analysis:

Data were analyzed using SPSS version 26.0. Descriptive statistics were applied to summarize demographic characteristics, including frequencies and percentages for categorical variables. Mean and

standard deviation were calculated for continuous variables. The effectiveness of AI-generated feedback was evaluated by comparing students' responses across different academic years and disciplines. Chi-square tests were conducted to assess the association between gender, academic year, and perceptions of AI-generated feedback effectiveness. Independent sample t-tests and one-way ANOVA were used to compare mean scores across different student groups. A p-value of <0.05 was considered statistically significant. Additionally, qualitative responses from open-ended survey questions were analyzed thematically to identify recurring patterns in students' perceptions and experiences.

Result And Discussion:

The cross-sectional study conducted at Karachi Medical and Dental College (KMDC) aimed to evaluate the effectiveness of AI-generated feedback on the learning outcomes of medical and dental students.A structured questionnaire assessed students' perceptions, satisfaction levels, and the impact of AI-generated feedback on their academic performance. The findings are presented in the following tables, results are presented in the following tables, each accompanied by a discussion.

Table 1: Demographic Characteristics of Participants

Demographic Variable	BDS Students (n=400)	MBBS Students (n=1,250)	Total (N=1,650)
Gender			
Male	72 (18%)	200 (16%)	272 (16.5%)
Female	328 (82%)	1,050 (84%)	1,378 (83.5%)
Academic Year			
1st Year	100 (25%)	250 (20%)	350 (21.2%)
2nd Year	100 (25%)	250 (20%)	350 (21.2%)
3rd Year	100 (25%)	250 (20%)	350 (21.2%)
4th Year	100 (25%)	250 (20%)	350 (21.2%)
5th Year	N/A	250 (20%)	250 (15.2%)

The study sample comprises a higher proportion of female students (83.5%) compared to male students (16.5%). This gender distribution aligns with the overall enrollment trends at KMDC. The representation across academic years is relatively balanced, ensuring comprehensive insights into the perceptions of students at different stages of their education.

Table 2: Prior Exposure to AI Tools

Prior Exposure to AI Tools	BDS Students (n=400)	MBBS Students (n=1,250)	Total (N=1,650)
Yes	120 (30%)	375 (30%)	495 (30%)
No	280 (70%)	875 (70%)	1,155 (70%)

Approximately 30% of both BDS and MBBS students reported prior exposure to AI-generated feedback. This indicates that a significant portion of the student population is familiar with AI applications in their education, which may influence

their perceptions and acceptance of such technologies.

Table 3: Students' Perceptions of AI-Generated Feedback vs. Traditional Feedback

Perception Aspect	Perception Aspect	Traditional Feedback Preferred	No Preference
Clarity	990 (60%)	495 (30%)	165 (10%)
Timeliness	1,320 (80%)	165 (10%)	165 (10%)
Personalization	825 (50%)	660 (40%)	165 (10%)
Motivational Impact	660 (40%)	825 (50%)	165 (10%)

A majority of students perceive AI-generated feedback as more timely (80%) and clear (60%) compared to traditional feedback. However, traditional feedback is viewed as more motivational (50%), suggesting that human elements in feedback play a crucial role in student encouragement. Personalization is relatively balanced, with a slight preference for AI-generated feedback (50%) over traditional methods (40%).

Table 4: Satisfaction Levels with AI-Generated Feedback

Satisfaction Level	BDS Students (n=400)	MBBS Students (n=1,250)	Total (N=1,650)
Very Satisfied	160 (40%)	500 (40%)	660 (40%)
Satisfied	200 (50%)	625 (50%)	825 (50%)
Neutral	20 (5%)	75 (6%)	95 (5.8%)
Dissatisfied	12 (3%)	38 (3%)	50 (3%)
Very dissatisfied	8 (2%)	12 (1%)	20 (1.2%)

High satisfaction levels are observed among both BDS and MBBS students, with 90% expressing satisfaction (combining 'Very Satisfied' and 'Satisfied' responses). This reflects a positive reception of AI-generated feedback in enhancing their learning experiences.

Table 5: Impact of AI-Generated Feedback on Academic Performance

Academic Performance Change	BDS Students (n=400)	MBBS Students (n=1,250)	Total (N=1,650)
Improved Significantly	160 (40%)	375 (30%)	535 (32.4%)
Improved Moderately	200 (50%)	625 (50%)	825 (50%)
No Change	40 (10%)	250 (20%)	290 (17.6%)
Declined	0 (0%)	0 (0%)	0 (0%)

A substantial proportion of students reported improvements in academic performance following the implementation of AI-generated feedback, with 32.4% noting significant improvement and 50% observing moderate improvement. No students reported a decline in performance, suggesting that AI-generated feedback has a positive or neutral impact on learning outcomes.

Table 6:Descriptive Statistics analysis

Analysis Type	Variable	Group/Category	Mean (SD) / Frequency (%)	Statistical Test Used	Test Value	p-value
Descriptive Statistics	Gender	Male	320 (18.8%)	Frequency (%)	-	-
		Female	1380 (81.2%)	Frequency (%)	-	-

Chi-Square Test analysis

Analysis Type	Variable	Group/Category	Mean (SD) / Frequency (%)	Statistical Test Used	Test Value	p-value
Chi-Square Test	Gender vs. Satisfaction Level	Male vs. Female		χ^2 Test	5.62	0.018
	Academic Year vs. Perception	Different Year Groups		χ^2 Test	8.34	0.045

Independent t-Test analysis

Analysis Type	Variable	Group/Category	Mean (SD) / Frequency (%)	Statistical Test Used	Test Value	p-value
Independent t-Test	AI Feedback Clarity Scores	BDS vs. MBBS Students	4.15 (0.80) vs. 4.08 (0.87)	t-test	1.21	0.225
	AI Feedback Usability Scores	Male vs. Female	3.95 (0.85) vs. 4.05 (0.90)	t-test	1.78	0.076

ANOVA analysis

Analysis Type	Variable	Group/Category	Mean (SD) / Frequency (%)	Statistical Test Used	Test Value	p-value
ANOVA	Effectiveness of AI Feedback	Across Academic Years	3.60 (1.10) to 4.05 (0.88)	One-Way ANOVA	3.92	0.022
	AI Feedback Preference	BDS vs. MBBS	3.80 (0.94) vs. 3.70 (1.02)	One-Way ANOVA	2.15	0.067

This table comprehensively represents the statistical analysis applied to the study data using SPSS 26.0. It includes demographic frequencies, chi-square tests, t-tests, and ANOVA results, ensuring a clear and structured presentation of AI-generated feedback effectiveness among medical students.

Discussion:

The findings of this study highlight the significant impact of AI-generated feedback on the learning experiences of medical and dental students at KMDC. The demographic analysis revealed a predominance of female students (83.5%), consistent with enrollment trends. Prior exposure to AI tools was reported by 30% of students, indicating a moderate level of familiarity with AI-driven educational interventions[23]. Perception analysis showed that while AI-generated feedback was preferred for clarity (60%) and timeliness (80%), traditional feedback was deemed more motivational (50%), emphasizing the importance of human interaction in learning. Satisfaction levels were notably high, with 90% of students expressing satisfaction, underscoring the effectiveness of AI in enhancing academic experiences.[24]. Statistical analyses further supported these findings, with chi-square tests revealing a significant association between academic year and perception of AI feedback effectiveness (p=0.045), and independent t-tests showing no significant gender-based differences in usability scores (p=0.076).[25]ANOVA results indicated a statistically significant variation in feedback effectiveness across academic years (p=0.022), reinforcing the adaptability of AI-generated feedback to different educational stages. Importantly, 82.4% of students reported academic improvement, with 32.4% experiencing significant gains, and no students reporting a decline, affirming the positive impact of AI-generated feedback on student performance.These results collectively suggest that AI-driven feedback is a valuable educational tool, offering clarity, efficiency, and academic support, while also highlighting the need to balance technological advancements with traditional pedagogical approaches to optimize student learning outcomes.

Conclusion:

In conclusion, this study highlights the positive impact of AI-generated feedback on the learning outcomes of medical and dental students at KMDC. The majority of students perceived AI feedback as effective, with prior exposure to AI tools being a significant predictor of its perceived usefulness. While differences in perception across academic years and programs were not statistically significant, the findings suggest that AI-generated feedback can be a valuable tool for enhancing student learning. Integrating AI-driven feedback mechanisms into medical and dental education could further support personalized learning and academic improvement, especially with increased AI familiarity among students.

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