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Exploring the Role of Case-based Learning with Artificial Iintelligence in Enhancing Dental Education

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ABSTRACT

Objective: To assess and understand the students' perception and acceptance regarding the Case-based Learning (CBL) with Artificial Intelligence (AI), and to provide deeper insights into this emerging education trend, as well as to offer valuable recommendations for future development and optimization of AI-powered educational tools and platforms.
Study Design: Qualitative Exploratory study.
Place and Duration of Study: Karachi Metropolitan University, Karachi Pakistan, from Nov 2025 to Mar 2026.
Methodology: A qualitative, exploratory design was employed with 100 final-year BDS students. The students attended two lectures on the same topic, one week apart. The first session was conducted as a small group discussion via traditional human facilitation, and the second session employed an AI generated CBL lecture. Data collection was done using a reflection sheet, while it was analyzed thematically using Braun and Clarke's framework.
Results: Reported challenges were minimal, and primarily related to technological interruptions or difficulty engaging with complex case material. Overall, AI-assisted CBL was experienced as a meaningful and cognitively enriching learning approach that supported deeper engagement with clinical concepts while reinforcing the continuing pedagogical role of the instructor.
Conclusion: Our results demonstrate that AI-assisted CBL can effectively bridge the gap between theory and practice. However, the findings also underscore that AI's current role is best characterized as an adjuvant rather than primary facilitator.

Keywords: Artificial Intelligence, Case-Based Learning, Critical Learning, Clinical Reasoning, Dental Education, Educational Technology, Health Professions Education.

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INTRODUCTION

Dental education has transformed because of the technological revolutions and healthcare innovations. Passive learning doesn't involve student interaction and focuses on predetermined study material only.[1] Learning is achieved better with student-centered active learning; allowing the students to interact with each other and the instructor.[2] Active learning strategies are defined as "instructional activities involving students in doing things and simultaneously thinking about what they are doing.[3] It includes case-based learning (CBL), which was first adopted Dr. James Lorrain Smith at the University of Edinburgh in 1912.[4] The goal of CBL is to prepare students for clinical practice, through the use of authentic clinical cases. It links theory to practice, through the application of knowledge to the cases, using inquiry-based learning methods.[5]

Artificial intelligence (AI) is a versatile tool with great potential for educational enhancement. The incorporation of AI in education has been increasing worldwide, and it offers promising opportunities.[6] Large language models (LLMs) such as ChatGPT (OpenAI), which can automatically process and generate natural language, have been integrated into CBL to boost the learning experience.[7] AI eagerness among dental students operates as a framework for intended curricular restructuring.[8] In 2021, Yüzbaşıoğlu et al. reported that current dental curricula don't sufficiently prepare students to integrate AI technologies into their future practice.[9] Studies highlight the significance of critical thinking skills in dentistry, emphasizing on analyzing issues, making swift decisions, and acceptance to new evidence and technologies in complex patient cases.[10]

This study aimed to evaluate the learning experiences of dental students and their perceived

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usefulness of feedback on CBL provided by an AI-based tool compared to a human facilitator.

METHODOLOGY

This qualitative exploratory study was conducted at Karachi Metropolitan University, Larachi, Pakistan from Nov 2025 to Mar 2026, after getting approval from the Institutional Research Ethics Committee (KMDC/KMU/168/2025), and all ethical standards regarding confidentiality were strictly followed throughout the research process.

Inclusion Criteria: Dental students of either gender and any age group, enrolled final year BDS were included.

Exclusion Criteria: Students who did not completely fill up the reflection sheet provided were excluded.

To ensure a comprehensive analysis the study procedure consisted of several steps. Data collection was done using a reflection sheet, which was adapted from a previous lietrature.[10] It was modified and tailored to align with our specific study objectives and contextual requirements, then reviewed by 02 subject experts. The population of the study were final year BDS students, as they transition to methodical instruction embracing both theoretical knowledge and clinical skills in fundamental dental disciplines. They were in their fourth year of a 4-year dental education program and had received theoretical knowledge in courses and working on their hands-on competency in clinical rotations.

A total of 100 study participants were selected using convenience sampling. Initially, students attended a lecture, delivered through human facilitation by a faculty member using conventional teaching methods. The duration of this session was around 60 minutes. After a gap of one week, the same group of students attended a session on the same topic with a CBL approach. This session was conducted by the same faculty member to ensure consistency in teaching. The duration of this session was also around 60 minutes.

The lecture for the CBL session was designed around a clinical case and supported by a presentation prepared using ChatGPT, Gamma and V-maker. The AI-affiliated lecture was produced through a refined prompting approach, so that it aligns with the study objectives and the principles of CBL. To ensure the accuracy of the AI-generated content some standardization measures were implemented such as verification of all AI-generated information against established textbooks and peer-reviewed scientific literature, framing the content in accordance with CBL and the elimination of ambiguities and redundancies, through manual editing and expert judgment.

The presentation lecture included illustrative diagrams, structured case scenarios, and video demonstrations to enhance critical thinking and conceptual understanding. Students were actively engaged during the session through guided discussion and problem-solving facilitated by the instructor. Through CBL, the discussion was centered on the diagnostic evaluation of patients for therapeutic purposes. Relevant information related to past medical history, clinical features, and radiographic examination was provided along with final diagnosis and treatment planning for training purposes. At the end of the CBL session, students were provided with a reflection sheet. Clear instructions were given on how to complete the reflection. Completely filled forms were collected and subsequently analyzed for responses received.

The first segment of the response sheet contained questions pertaining to demographic characteristics, while the second part contained 5 open ended questions regarding innovative learning methodology, overall experience with CBL and AI, future preference for lectures and the comparison between the traditional human facilitation and AI assistant CBL facilitation. The collected data were analyzed using thematic analysis. Thematic analysis serves as a technique for determining, examining, structuring, describing, and documenting themes present in a dataset.[11] Data collection and analysis proceeded simultaneously, and data saturation was considered achieved when no new themes or meaningful insights emerged from successive responses.

In this study, we followed the Braun & Clark six step thematic analysis process. Initially, the process began with textual rendering, familiarizing ourselves with the data, and marking significant quotations that represented the diverse point of views and patterns to our research objectives. The next step was the selection of keywords, which involved identifying recurring points, patterns, or visual aspects within the data. Subsequently, we allocated codes to a fraction of data to preserve their core idea, thereby decoding the complex data into simpler form. The theme-forming step meant arranging these codes into meaningful groups to determine patterns and relationships, giving the understanding of the research question by

transforming from detailed analysis to abstract interpretation. The final step of the process was the development of a conceptual model, creating a representation of the data, to answer the research questions and demonstrate the study's contribution to knowledge.

Any discrepancies identified during this stage were discussed, clarified, and resolved collaboratively. To further enhance methodological rigor, both data triangulation and investigator triangulation were employed. Two researchers independently coded the data to minimize interpretive bias, and a third co-author reviewed the emerging themes and final interpretations to strengthen the trustworthiness of the analysis. Throughout the research process, the authors engaged in continuous reflexive practice, documenting reflections at each stage to ensure transparency and accountability. Confidentiality of all participants was upheld strictly at every step of the research process.

RESULTS

The thematic analysis revealed that students perceived AI-assisted case-based learning as an effective pedagogical strategy that strengthened conceptual understanding and clinical reasoning. Learners emphasized that engaging with structured clinical scenarios enabled them to integrate theoretical knowledge with patient-centered decision-making, promoting analytical thinking rather than rote memorization. Many participants reflected that the approach enhanced confidence in judgment and interpretation of prosthodontic procedures.

The learning experience was described as interactive, engaging, and motivating, with students valuing opportunities for group discussion and reflective dialogue. AI-generated visual and multimedia content further supported comprehension and memory retention by enabling clearer visualization of procedural steps.

Participants generally perceived AI as a useful and well-structured instructional aid; however, they emphasized that it served best as a complementary tool rather than a replacement for human facilitation. Faculty-guided discussion was considered essential for contextual reasoning, clarification of doubts, and application of clinical judgment.

Reported challenges were minimal and primarily related to technological interruptions or difficulty engaging with complex case material. These were framed not as barriers, but as areas requiring refinement and stronger instructional scaffolding within blended learning environments. Overall, AI-assisted CBL was experienced as a meaningful and cognitively enriching learning approach that supported deeper engagement with clinical concepts while reinforcing the continuing pedagogical role of the instructor. Key themes are expressed in Tables I, II, III and IV.

Table-I: Theme 1: Enhanced Conceptual Understanding and Clinical Reasoning (n=100)

Sub-Theme	Description	Supporting Quotes
Concept building & knowledge integration	AI-assisted CBL supported understanding of prosthodontic concepts and improved clarity of core principles	"It helped in concept building and cleared my understanding of the topic." P07 "It supported us in relating theory to patient-based scenarios." P32
Development of clinical reasoning	Learners reported improvement in judgment, planning, and interpretation of cases	"The session improved my critical thinking and decision-making approach." P21 "CBL helped in problem-solving and clinical judgment." P18
Analytical thinking beyond rote learning	Structured case flow encouraged reflection rather than memorization	"It initiated analytical thinking rather than rote learning." P10 "The real-life case example made me think about why the treatment was chosen." P44

**P: Participant ID*

Table-II: Theme 2: Engagement, Motivation, and Interactive Learning Experience (n=100)

Sub-Theme	Description	Supporting Quotes
Active participation & engagement	Students valued interactive discussions over traditional lectures	"The session was interactive and engaging." P03 "Group discussion helped us share views and understand better." P27
Increased motivation & interest	The session stimulated curiosity and learner attention	"It was fun, different, and motivating to learn." P15 "It was interesting and kept me focused throughout." P05
Visual learning & memory retention	AI-generated images and videos aided recall and comprehension	"The pictorial explanation helped with memory retention." P30 "Videos made it easy to visualize tooth preparation steps." P12

**P: Participant ID*

DISCUSSION

This research study explored the impact of AI-assisted CBL on the learning experiences of final-year BDS students at Karachi Metropolitan University. After analyzing the themes of the students' reflections, four key aspects were identified: the importance of AI tools in enhancing conceptual and clinical understanding, improving student engagement and motivation, the usage of AI as a supportive tool, and challenges and operational hurdles. The findings

generally indicated that students perceived AI-assisted CBL as an effective pedagogical strategy that strengthened conceptual understanding and class engagement.

Table-III: Theme 3: Perception of AI as a Supportive but Not Independent Tool (n=100)

Sub-Theme	Description	Supporting Quotes
AI as structured learning support	Participants found AI explanations clear and systematic	"AI provided sufficient knowledge in a broad spectrum." — P23 "The explanation was clear and well-structured." — P28
Complementary role with faculty guidance	Students preferred blended facilitation formats	"Best approach is AI with teacher guidance together." P36 "Human facilitation helps in discussion and doubt clarification." P14
Need for clinical reasoning depth	Some learners perceived limited contextual judgment in AI content	"AI lacks clinical reasoning and real-time clarification." P09

**P: Participant ID*

Table-IV: Theme 4: Challenges and Practical Constraints (n=100)

Sub-Theme	Description	Supporting Quotes
Technical and multimedia constraints	Occasional interruptions affected session continuity	"There were multimedia and technical issues during the session." P11 "The presentation could have been clearer with more examples." P20
Cognitive load & case complexity	Difficult topics required greater facilitation support	"The topic was conceptually difficult but helpful in learning." P04 "Required more clarity in complex crown design planning."P26

**P: Participant ID*

A primary finding of this study was that AI-assisted CBL significantly supported concept building and knowledge integration. Participants in this study reported that engaging with structured clinical scenarios helped them relate theoretical principles to clinical scenarios. These observations are aligned with the findings of Wei *et al*., whose meta-analysis demonstrated that AI interventions in problem-based and case-based learning significantly improved knowledge acquisition by 46% across various medical and dental subjects.[12] Similarly, several other studies observed that medical students who used AI tools performed significantly better in exams and completed assignments faster than those in control groups.[13-19]

Conversely, a cross-sectional study conducted in Karachi, Pakistan, comparing ChatGPT-3.5 with dental students in an anatomy examination, revealed that students outperformed the AI (74.28% vs. 60%), specifically in those MCQs that required clinical reasoning.[20] This critical detail is revealed in our study as well: AI is perceived as more effective for basic knowledge acquisition than for complex clinical reasoning. Participants expressed that AI provided sufficient knowledge but noted that it sometimes provided limited contextual judgment. This finding is similar to a previous study, which found that in medical education, ChatGPT-4 addressed epidemiology and diagnosis well, but it struggled with complex topics and occasionally omitted critical details.[14] Li *et al*. also reported that students rated AI highly for basic knowledge but noted specific limitations in its ability to foster innovative thinking and deep clinical reasoning, which appears consistent with the pattern seen in our results.[13]

This limitation can be due to the fact that AI predicts outcomes based on historical data patterns, while complicated clinical reasoning requires biological cognition and real-life experiences, which cannot be replicated by AI.

Students described the learning experience in this study as interactive, engaging, and motivating. A key factor contributing to this was the use of AI-generated images and videos, including illustrative representations and video demonstrations of tooth preparation. This method of demonstration helped in the memory retention of complicated steps of tooth preparation. This trend is in accordance with another study, which found that technology-enhanced CBL (TEL-CBL) groups, that utilized tools like 3D anatomy software and AI-simulated virtual patients, outperformed their peers and reported a vastly enhanced learning experience.[15] Furthermore, the interactive nature of the group discussions in the current study helped students share views and understand the material better. This high level of satisfaction and engagement is a common theme in other studies.[12,14]

A significant theme that emerged from the thematic analysis was the perception of AI as a supportive tool rather than a replacement for human instructors. Participants emphasized a preference for a blended approach and considered faculty-guided discussion essential for contextual reasoning and the clarification of doubts. This theme is in line with the findings of Li *et al*., where it was established that students felt AI tools reduced valuable interpersonal interactions and could lead to homogenized learning outputs. Other studies report similar observations stating that use of AI in medical education requires

significant caution and a clear understanding of its limitations.[12,16,17] Our study's findings reinforce the idea that while AI can provide standardized facilitation and reduce faculty workload—as explored in the study's rationale —the instructor's role remains vital for providing guided learning and addressing complex clinical scenarios, which require real-time clinical experience.

Despite the overall positive feedback, the study identified practical challenges, primarily related to technological interruptions, which affected the continuity of sessions and the cognitive load associated with complex case material. These findings align with a previous study, which raised concerns about students potentially missing critical information when using AI as a pedagogical tool.[14]

This study provides unique insights into an emerging educational trend by specifically focusing on the qualitative perceptions of final-year dental students regarding AI-supported CBL. Local literature on this subject is heterogenous, fragmented and inconsistent in methodology. Though there are multiple local studies on awareness and readiness of AI used for education purposes, in medical students and faculty, but interventional studies specifically employing thematic analysis are missing.[21,22]

The results of our study prove that the future of AI in dental education lies in its ability to augment, not replace, traditional learning methods. By using AI as a supplementary tool, we can enhance learning and facilitate interactive sessions. Future research should focus on evaluating different AI tools, exploring diverse dental subjects, and investigating the effectiveness of various AI-integrated pedagogical approaches.

LIMITATIONS OF STUDY

Several limitations in this study warrant consideration when interpreting the findings. First, a non-probability convenience sampling technique was employed within a single institutional context, thereby restricting the external validity and generalizability of the results to broader dental education landscapes. Second, the study's reliance on a qualitative design predicated on self-reported reflections introduces the potential for response and social desirability biases, which may affect the authenticity of participant perceptions. Third, the intervention was constrained by a short-term study duration and lacked longitudinal follow-up, precluding the assessment of sustained learning, retention, or long-term educational outcomes. Lastly, the cohort was restricted to final-year Bachelor of Dental Surgery (BDS) students, potentially neglecting variances in perspectives across different stages of academic progression

CONCLUSION

This study contributes to the growing body of evidence regarding the efficacy of AI in dental education by specifically addressing the lack of research locally on its use for CBL in dentistry. The results demonstrate that AI-assisted CBL can effectively bridge the gap between theory and practice. However, the findings also underscore that AI's current role is best characterized as an adjuvant rather than primary facilitator.

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Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

SN & AS: Data acquisition, data analysis, critical review, approval of the final version to be published.

YN & SH: Study design, data interpretation, drafting the manuscript, critical review, approval of the final version to be published.

AA & SSF: Conception, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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