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Systematic Review

Critical Review of Dental Education in Pakistan and A Proposed Way Forward: An AI-Integrated BDS Curriculum for Global Competence

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ABSTRACT

Objective: The objectives of this conceptual review are to: (1) characterize the structural, pedagogical and technological attributes of the existing curriculum; (2) delineate deficiencies relative to global standards, with emphasis on AI literacy, faculty capacity and assessment approaches; and (3) outline a comprehensive, sustainable AI-integrated curriculum model informed by Systems Theory and principles of precision education.

Study Design: Systematic Review.

Methodology: A structured search was performed across major scholarly databases—PubMed, Web of Science, Scopus and ERIC. The search targeted three central domains: artificial intelligence in health professions education, precision-based learning approaches and advanced assessment models. Only English-language publications from 2010 to 2025 were included to ensure relevance.

Results: Based on these insights, an enhanced curriculum design is proposed for one university and its affiliated institutions, incorporating forward-looking educational strategies such as precision learning, entrepreneurial skill development, inter-professional education (IPE), programmatic assessment and digital simulation.

Conclusion: Collectively, these elements form an integrated framework intended to cultivate graduates who are proficient in AI-supported dental practice and equipped to meet the evolving demands of contemporary oral healthcare across global contexts.

Keywords: Advanced Assessment Models, Artificial Intelligence, BDS Curriculum, Curriculum Integration, Precision Education.

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INTRODUCTION

Health Professions' Education (HPE) is experiencing accelerated transformation as competency-based paradigms, precision education, and digitally mediated care increasingly shape expectations of clinical training.[1-3] The dental profession—requiring analytical reasoning, advanced procedural skills, and continuous adaptation to technological innovation—is particularly affected by these trends. Ensuring curricular responsiveness has therefore become a critical priority.[4,5]

In Pakistan, the Bachelor of Dental Surgery (BDS) program remains predominantly discipline-oriented and is traditionally aligned with the 7-Star Doctor competency model. However, national and international literature point to a growing discrepancy between this conventional, lecture-driven structure and the competencies required for practice in technologically advanced healthcare environments.[2,6] Limited curricular renewals, reliance on summative evaluation, and insufficient integration of digital and AI-related competencies have collectively constrained the technological readiness of new graduates.[7,8]

To address this gap, the present study undertook a systems-level critique of a widely adopted BDS curriculum within a major province of Pakistan. This review aimed to characterize the structural, pedagogical and technological attributes of the existing curriculum, delineate deficiencies relative to global standards, with emphasis on AI literacy, faculty capacity and assessment approaches, and outline a comprehensive, sustainable AI-integrated curriculum model informed by Systems Theory and principles of precision education.

METHODOLOGY

This systematic review employed a conceptual framework design grounded in a structured literature synthesis, drawing on two established curriculum-development frameworks to analyze and redesign the BDS program. This methodological orientation is consistent with curriculum proposal scholarship in

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health professions education, where theoretical analysis and evidence synthesis precede empirical implementation.[4,10]

Inclusion Criteria: Peer-reviewed empirical studies, reviews or meta-analyses, research addressing technology integration, assessment reform or curriculum redesign in health professions education, and studies relevant to digital simulation, personalized learning or AI-supported instruction were included.[7,8]

Exclusion Criteria: Conference proceedings, editorials or commentaries, non-English publications and studies focusing solely on clinical AI applications without educational implications were excluded.[8]

Systems Theory served as the overarching analytical lens, enabling the curriculum to be viewed as a dynamic network in which modifications in one domain inevitably influence others. This perspective allowed examination of the structural, instructional and technological dimensions of the BDS program as interdependent components rather than isolated elements.[4]

In parallel, Kern's Six-Step Model provided the procedural scaffold for evaluating and redesigning the curriculum. The model was applied sequentially, beginning with identifying educational gaps and conducting a needs assessment, and extending through the stages of defining objectives, selecting strategies and outlining potential implementation pathways.6 Together, Systems Theory and Kern's model ensured a comprehensive and logically structured evaluation of the existing curriculum and informed the development of the proposed AI-integrated framework.

The curriculum analysis centered on a BDS curriculum widely used across dental colleges in Pakistan. Three domains guided the evaluation: Structural Design, Pedagogy and Assessment, and Technological Preparedness.

Attention was given to the organization of the curriculum, including its overall duration, distribution of content across years and the degree of horizontal and vertical sequencing. The structural alignment with the Pakistan Medical and Dental Council (PMDC) "7-Star Competencies" was also reviewed to determine whether foundational expectations matched contemporary professional requirements.

Teaching and learning strategies were examined using the SPICES model (Student-centered, Problem-based, Integrated, Community-based, Electives, Systematic).[16] This facilitated comparison between current teacher-driven, lecture-focused practices and more interactive, student-centered approaches. Assessment procedures were reviewed to determine the balance between formative and summative methods, and to evaluate the presence—or absence—of approaches such as Programmatic Assessment or Entrustable Professional Activities (EPAs).[11,12]

The technological ecosystem, including learning management platforms, simulation facilities and the availability of digital teaching tools, was assessed to determine the institution's capacity to support digitally enhanced or AI-supported instruction. Faculty readiness for adopting technology-based pedagogy was also evaluated.[4] To complement the document review, brainstorming sessions were conducted with experienced faculty members across basic and clinical disciplines. Their practical insights helped triangulate findings, contextualize local challenges and align the analysis with international standards in competency-based education.

To ensure that the proposed curriculum model reflected current evidence and global trends, a meta-synthesis of high-quality literature was conducted. This involved reviewing studies across qualitative, quantitative and mixed-methods traditions, allowing recurring concepts to be identified, compared and synthesized into a cohesive set of guiding principles.[10]

A structured search was performed across major scholarly databases—PubMed, Web of Science, Scopus and ERIC. The search targeted three central domains: artificial intelligence in health professions education, precision-based learning approaches and advanced assessment models.[7,8] Only English-language publications from 2010 to 2025 were included to ensure relevance.

Representative search strings (adapted to the requirements of each database) included:

AI/Digital Dentistry

("Artificial Intelligence" OR "Machine Learning" OR "Generative AI" OR "Digital Dentistry") AND ("Dental Education" OR "BDS curriculum" OR "preclinical training") AND ("Curriculum integration" OR "competency-based")

Assessment & Pedagogy

("Programmatic Assessment" OR "Entrustable Professional Activities" OR "EPAs") AND ("Medical

education" OR "Dental education") AND ("Challenges" OR "Implementation")

Advanced Concepts

("Precision Education" OR "Adaptive Learning" OR "Interprofessional Education") AND ("Health professions education" OR "Graduate competence"

The selected articles underwent thematic analysis. Repeated concepts were grouped into broad categories representing both opportunities (e.g., enhanced skills acquisition, improved personalization, strengthened feedback mechanisms) and challenges (e.g., inconsistent infrastructure, limited faculty expertise, cost and ethical barriers).[5,7,10] These thematic clusters informed the design principles and implementation strategies underpinning the proposed AI-Integrated BDS Curriculum Model.

RESULTS

The evaluation of the existing BDS curriculum using the SPICES framework as the analytical reference (Figure-1) revealed a program that is well-organized structurally yet limited in pedagogical diversity and technological depth. Structurally, the curriculum demonstrates strong horizontal and vertical alignment, with modular and spiral sequencing that supports integration between foundational and clinical sciences. Its competency orientation is consistent with the Pakistan Medical and Dental Council's (PMDC) "7-Star Doctor" expectations, indicating a clear blueprint for professional formation.[1]

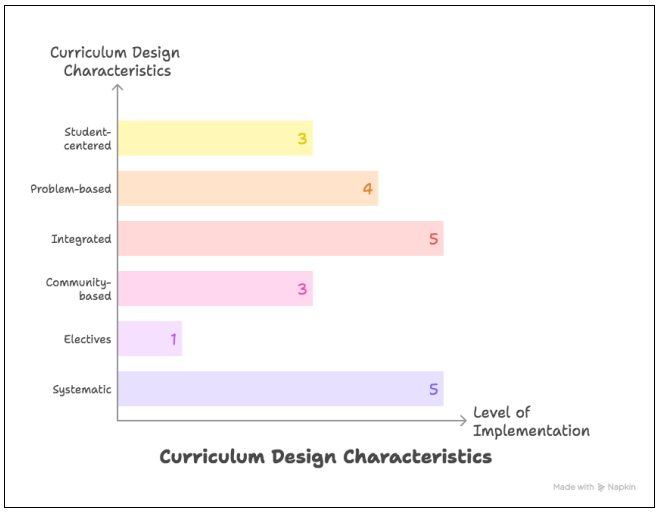

Figure-1: Current BDS Curriculum on SPICES (Student-centered, Problem-based, Integrated, Community-based, Electives, and Systematic) Model

However, when examined through the SPICES lens (Figure-1), several limitations become apparent. While the curriculum is systematic and incorporates elements of integration, it remains predominantly instructor-led and lecture-driven, with fewer opportunities for active learning or student-centered approaches. This imbalance ultimately weakens the overall instruction-to-competence trajectory expected in contemporary dental education.

The curriculum presently lacks meaningful integration of digital tools and simulation-based technologies. Infrastructure for Artificial Intelligence (AI), augmented reality (AR), virtual reality (VR), or haptic simulation is limited or absent, constraining opportunities for early procedural skill development and digital literacy.

Assessment remains heavily weighted toward traditional, high-stakes summative examinations. Such an approach restricts the accumulation of longitudinal performance data, which is essential for competency-based judgments and for supporting learners' development over time.[14]

Faculty development initiatives are insufficient for preparing educators to adopt facilitator roles or engage with digital or AI-supported teaching modalities. Limited training in mentoring, feedback delivery and technology-enhanced instruction hinders the transition toward modern pedagogical expectations.[8]

A notable omission in the current curriculum is the absence of explicit instruction in digital health and AI literacy. This limits graduates' ability to function effectively within a precision-medicine and data-driven care environment, placing them at a disadvantage in comparison to global standards.

In response to the identified gaps, a redesigned five-year curriculum model is proposed, centered on personalization, technological fluency and outcome-based progression. The model updates the traditional competency framework by adding an eighth dimension—the AI-Competent Practitioner—which complements the existing "7-Star Dentist" construct and reflects the realities of modern dental practice. The redesigned model contrasts with the current curriculum as shown in Table-I.

Figure-2 illustrates the restructured curriculum that shifts from a conventional, instructor-centered paradigm to a learner-focused system grounded in

adaptability, digital competency and precision education. Its core features include:

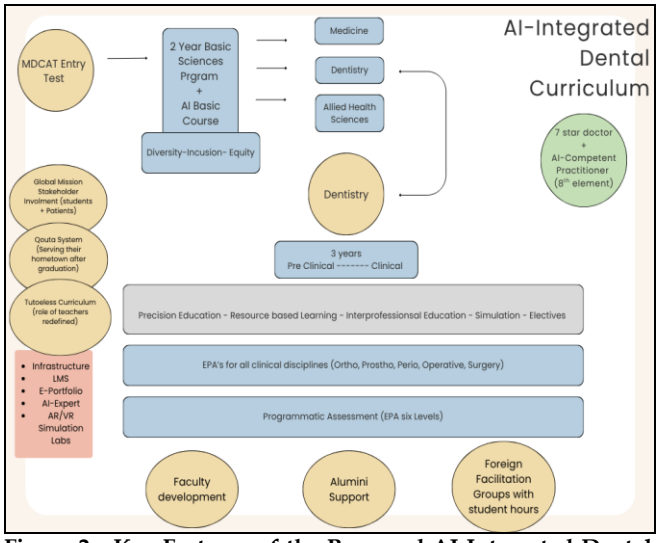

Figure-2 - Key Features of the Proposed AI Integrated Dental Curriculum Model

Entry Point & Foundational Phase

Students begin with an AI Foundational Module, ensuring a standardized baseline in digital literacy from the outset. During Phase I, AI principles are introduced alongside traditional basic sciences, allowing learners to interpret digital imaging, work with data-driven decision-support tools and understand ethical considerations surrounding AI use in healthcare.

Precision Learning and Adaptive Content

A fully functional Learning Management System (LMS) supports a precision-learning ecosystem. By monitoring learner profiles, engagement patterns and performance indicators, the LMS enables adaptive content delivery and personalized feedback. This approach refines cognitive load management, strengthens self-regulated learning and enhances academic efficiency.[3,7]

AI-Enhanced Clinical Training

The clinical component integrates AR/VR simulation and haptic technologies, allowing students to rehearse psychomotor and diagnostic skills within safe, immersive environments. AI-driven feedback mechanisms provide real-time insights into performance accuracy, sequencing and technique refinement, thereby increasing learner confidence before transitioning to patient-based care.[5]

Programmatic Assessment (PA) and EPAs

The model replaces the high-stakes exam-centric structure with Programmatic Assessment, which compiles ongoing, low-stakes assessments into a comprehensive performance profile. Work-based assessments, digital portfolios and multi-source feedback feed into competency decisions. Entrustable Professional Activities (EPAs) are integrated to clearly define performance expectations and guide decisions regarding student readiness for independent tasks.[11,12,14]

Interprofessional Education (IPE)

Structured IPE modules connect dental students with learners from medicine, nursing and allied health professions. This fosters collaboration, shared decision-making and a clearer understanding of interdisciplinary roles, mirroring the integrated-care models emerging globally.[15,19]

Infrastructure and Faculty Development

The model establishes minimum infrastructure requirements—including simulation laboratories, digital learning platforms and AI-enabled teaching tools. Parallel faculty development programs prepare educators to interpret digital learning analytics, deliver high-quality feedback and serve as mentors in technology-rich learning environments.[13]

Table-I: Comparison between Current Curriculum and Proposed AI-Integrated Model

Feature	Current Curriculum	AI-Integrated Model
Entry Pathway	MDCAT Entry Test	MDCAT + AI Foundational Module
Phase I (2 years)	Basic Sciences	Basic Sciences + AI Fundamentals + Diversity, Inclusion, Equity
Phase II (3 years)	Preclinical → Clinical	Integrated Clinical Phases with AR/VR Simulation, AI-Supported Learning
Assessment	Summative Exams	Programmatic Assessment + EPAs + AI Assisted E-Portfolios
Teaching Model	Lecture-based	Resource-Based, Adaptive, and Precision Learning through LMS
Faculty Role	Instructor-centric	Mentor/Facilitator with AI-Assisted Analytics
Clinical Skill Development	Patient-based	AI-guided Simulation Labs (AR/VR + Haptics) → patient
Outcome	7-Star Dentist	7-Star Dentist + AI-Competent Practitioner

DISCUSSION

The BDS curriculum in Pakistan's leading universities possesses strong structural integrity, but its compromised technological preparedness and reliance on outdated evaluation methods weaken its effectiveness. A paradigm shift to an AI-Integrated model is essential, redefining how dental competence is defined, delivered, and assessed.

Precision Education (PE) challenges the traditional one-size-fits-all" approach, leveraging AI and learning analytics to tailor content and pace to individual learners.[7] This approach optimizes engagement and ensures deeper mastery of complex concepts.[3] By integrating PE with the Master Adaptive Learner model, we can equip future professionals with self-regulation and meta-cognitive skills, enabling them to thrive in an evolving healthcare landscape.[7] In dentistry, PE enables personalized practice scenarios in virtual environments, with AI providing targeted feedback to refine psychomotor skills and diagnostic reasoning.[5,8]

Programmatic Assessment (PA) is the natural complement to PE, providing a holistic evaluation framework that tracks student progress and competency development. Successful implementation requires overcoming cultural barriers, where assessment is viewed as a high-stakes, summative filter.[14] PA necessitates faculty development, micro-planning, and a robust system for cumulative decision-making.[11,17]

In traditional, exam-heavy educational cultures such as Pakistan's, the shift to PA is particularly challenging. However, digital e-portfolios present a pragmatic entry point for implementation even in resource-constrained settings. Cloud-based platforms—such as Google Sites or open-source systems like Mahara—require minimal institutional infrastructure and can aggregate evidence of competence across work-based assessments, reflective entries and supervisor feedback over time.[18] Evidence from comparable low- and middle-income country (LMIC) contexts indicates that e-portfolios can function effectively as low-cost longitudinal assessment tools when faculty receive targeted training in feedback and portfolio review.[17,18] Embedding e-portfolio use gradually, beginning with formative reflective logs in the early years and progressively incorporating supervisor-verified EPAs in clinical phases, can ease the cultural transition from summative examinations to competency-based judgment. E-Portfolios and Entrustable Professional Activities (EPAs) together provide a transparent, data-driven framework for assessing student competence.[12,14]

Integrating AI as a core competency is crucial for global competitiveness. This competency encompasses not only software proficiency but also critical understanding of AI's capabilities and limitations.[5] The proposed BDS curriculum embeds AI learning in diagnosis,[8,9] simulation5 and ethics,[7,8] ensuring graduates are digitally literate, innovative, and equipped to leverage AI in clinical practice.[4] Grounding this development in experiential learning theory ensures that AI-related competencies are not treated as add-on modules but are woven into authentic clinical learning experiences from the outset.[20]

LIMITATIONS OF STUDY

This study has several limitations. First, the proposed model is based on theoretical frameworks and literature synthesis rather than empirical implementation data. Second, the review focused primarily on one provincial context within Pakistan, which may limit generalizability to other regions. Third, resource constraints and infrastructure requirements for AI integration were not comprehensively assessed across diverse institutional settings. Fourth, long-term outcome data for AI-integrated dental curricula remain limited globally, making it challenging to predict implementation success. Finally, stakeholder perspectives from students, recent graduates, faculty members, and clinical supervisors were not systematically incorporated into the model development phase through structured interviews or surveys.

CONCLUSION

Pakistan's existing BDS curriculum provides a strong foundation, but its reliance on static pedagogy and summative assessment hinders its effectiveness. The proposed AI-integrated BDS curriculum offers a comprehensive conceptual framework for modernizing dental education in Pakistan. By incorporating precision learning, digital competencies, and programmatic assessment, this model addresses critical gaps identified in the current system while preparing graduates for technologically advanced healthcare delivery. The addition of the AI-Competent Practitioner as the eighth dimension to the traditional 7-Star competency framework acknowledges the fundamental role of artificial intelligence in contemporary dental practice. Successful implementation requires coordinated efforts among educational institutions, regulatory bodies, and clinical partners, supported by sustained investment in infrastructure and faculty development. This model provides a roadmap for institutions seeking to align with international standards while maintaining contextual relevance to Pakistan's healthcare landscape.

The AI-Integrated BDS Model offers a sustainable, evidence-based roadmap for transformation, producing graduates who are clinically skilled, digitally literate, and globally competitive. Successful implementation requires commitment from academic leadership, regulatory bodies, and faculty to invest in infrastructure and cultural transformation.

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Authors' Contribution

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

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

GMS & JSK: Study design, data interpretation, drafting the manuscript, critical review, 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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