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Biochemistry and Dental Education: A Global Bibliometric Insight into an Overlooked Discipline Using Digital Science Tools

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Abstract: *Biochemistry constitutes a fundamental biomedical science that forms the basis for dental pathophysiology, host–microbial interactions, pharmacotherapeutics, and general systemic–oral disease mechanisms. Although such knowledge has epistemological importance and significance, biochemistry appears to have a diminished presence in curricular visibility due to global shifts toward competency-based, patient-centered educational models and digitally enriched dental education. This paper conducts a comprehensive bibliometric analysis of trends in global biochemistry within dental education research from 1967 to 2025. A sample of 108 peer-reviewed publications indexed in Scopus, Web of Science, and PubMed was reviewed using Bibliometrix and VOSviewer. The performance indicators encompassed annual scientific output, citation metrics, authorship trends, h-index, g-index, and conceptual structure mapping through centrality density thematic analysis. The results show that the number of publication growth after 2015, coinciding with digital transformation and artificial intelligence integration in dental pedagogy. The United States and the United Kingdom have dominated productivity and citation impact, whereas developing regions are still underrepresented. The core themes cluster around "dental education," "biochemistry," and "education." New clusters are forming around AI-assisted learning and adaptive assessment systems. This study offers strategic evidence for the modernization of curricula and the integration of digital technologies in biomedical dental education, particularly in emerging academic ecosystems such as Malaysia.*

Keywords: Bibliometric analysis, Biochemistry, Dental education, Artificial intelligence, Curriculum reform

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1. Introduction

Biochemistry serves as the molecular foundation of dental education by elucidating metabolic regulation, inflammatory cascades, host–microbial interactions, biomineralization, and pharmacodynamics pertinent to oral health and systemic disease. Biomedical sciences have traditionally been positioned as crucial for the advancement of diagnostic reasoning and evidence-based clinical practice in dentistry (Haden et al., 2006; Humphrey et al., 2002). However, recent changes to the contemporary curriculum that focus on emphasizing competency-based education and clinical efficiency have reshaped instructional structures globally (Harden, 2000; Frenk et al., 2010). Although integration models promote clinical relevance, they have also compressed foundational science instruction in several contexts, raising concerns regarding biomedical dilution within predoctoral programs (Anna et al., 2024). At the same time, higher education is undergoing digital transformation characterized by artificial intelligence (AI) applications, adaptive learning platforms, simulation-based assessment, and data-driven feedback systems (Luckin et al., 2016; Topol, 2019). Within dental education, AI-assisted learning tools are increasingly explored to enhance diagnostic calibration and student performance analytics (Danesh et al., 2024).

Bibliometric analysis provides a rigorous quantitative approach for mapping scientific productivity, intellectual structures, and thematic evolution within academic fields (Ahmi, 2023; Donthu et al., 2021; Aria & Cuccurullo, 2017). Through performance indicators and science mapping techniques, bibliometric research enables structured evaluation of disciplinary maturity, collaboration networks, and emerging research fronts. Despite increasing scholarly attention to dental education reform and digital innovation, no systematic bibliometric study has specifically examined the evolution of biochemistry within dental education.

This study addresses this gap by mapping global scientific production, identifying influential authors and institutions, examining collaboration structures, and analyzing thematic development trends. The findings provide evidence-based insights for curriculum modernization and digital enhancement strategies, particularly within emerging academic institutions such as University of Technology MARA (UiTM).

2. Methodology

This study utilized quantitative bibliometric methodology design. We used controlled keywords related to “biochemistry” and “dental education” to find publications in Scopus, Web of Science, and PubMed. After screening, cleaning, harmonization, and deduplication, 108 peer-reviewed English-language documents published from 1967 to 2025 were selected for analysis.

The Bibliometrix R-package (Ahmi, 2024; Aria & Cuccurullo, 2017) was used to look at performance indicators, and the VOSviewer (van Eck & Waltman, 2010) was used to show network visualization. Metrics encompassed annual scientific output, aggregate total citations, citations per annum, h-index, and g-index (Egghe, 2006). We looked at the conceptual structure by using keyword co-occurrence analysis and thematic mapping based on the Callon centrality density framework (Fayad et al., 2024; Hakim et al., 2024; Callon et al., 1991). This framework divided themes into four categories: motor, basic, niche, and emerging quadrants. This comprehensive integrated methodological framework facilitated both the assessment of performance and the structural delineation of the intellectual landscape of biochemistry within dental education.

3. Results and Discussion

3.1 Scientific Production and Citation Impact

The longitudinal distribution of publications demonstrates limited productivity prior to 2000, followed by progressive expansion and accelerated growth after 2015, at figure 1. This trajectory aligns with global digitalization in higher education and renewed emphasis on biomedical integration within competency-based frameworks (Frenk et al., 2010). Citation analysis reveals that early foundational studies focusing on problem-based learning (PBL) and curriculum restructuring remain highly influential (Smith, 2002).

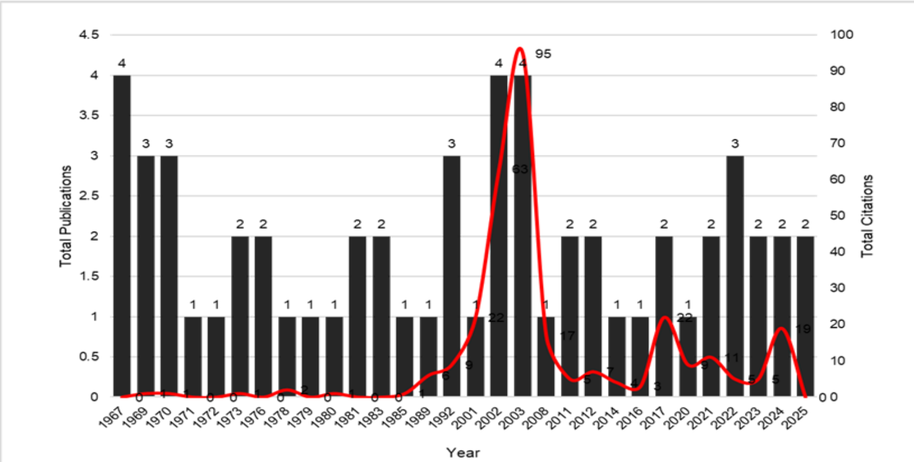

Figure 1: Total Publications and Total Citations by Year

The United States and United Kingdom, at figure 2, dominate both productivity and citation impact, reflecting established research ecosystems and early curriculum reform initiatives (Haden et al., 2006). Increasing citation rates of recent publications suggest expanding scholarly interest in digital assessment and AI applications within dental education (Danesh et al., 2024).

Figure 2: Top Countries Production trends from 1967–2025.

3.2 Authorship and Collaboration Patterns

Authorship patterns indicate a transition from predominantly single-author publications in earlier decades to multi-author collaborative research in recent years, shown at figure 3. This shift reflects broader scientific trends toward interdisciplinary knowledge production (Wuchty et al., 2007). Authors with high h-index and g-index values demonstrate sustained intellectual influence in curriculum innovation and biomedical integration. However, cross-regional collaboration remains limited, particularly involving developing economies, indicating potential for enhanced international research partnerships.

The bibliometric analysis reveals that a core group of authors particularly, Wagner M.J., Henly D.C, Zheng, Meixun, and Adam, Lee A., play a dominant role in steering research on biochemistry and dental education (Table 1 and 2). The upward trend in collaborative authorship emphasizes the interdisciplinary nature of this research field and reflects the global shift toward team-based integrated science education. These patterns are crucial in framing future educational strategies that bridge biochemistry with professional competency, digital learning, and translational outcomes in dental training.

Most productive institutions by total publications: The data in Figure 4 reveal the top institutions globally contributing the highest number of publications in dental biochemistry research. The University of Otago leads the list with 8 publications, signifying its strong and consistent research output in this field. Following closely are the University of the Pacific Arthur A. Dugoni School of Dentistry for 7 publications, both of which are renowned for their interdisciplinary biomedical and dental sciences programs. Institutions from the United States, New Zealand, and China dominate this list, showcasing a geographic concentration of productivity. Notably, several European and China institutions, such as Tufts University, University of Alberta, and College of Stomatology, also feature, reflecting transatlantic scholarly engagement in dental biochemistry. This distribution illustrates that a predominantly Western, Latin American, and ASEAN countries become leaders in terms of publication volume, suggesting a potential research gap and underrepresentation of Southeast Asian institutions.

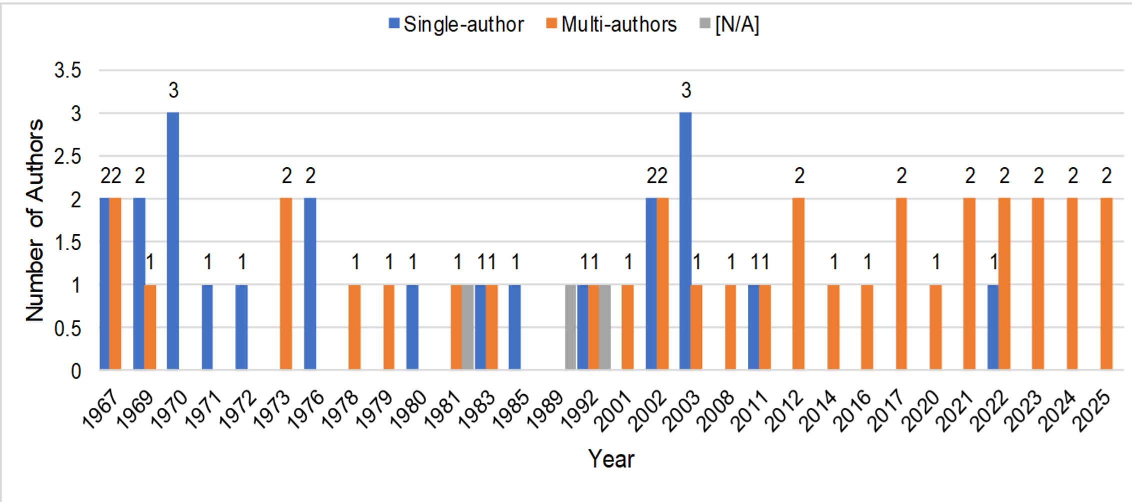

Figure 3: Authorship trends from 1967–2025.

Table 1: The Most Productive Authors

Full Name	Current Affiliation	Country	TP	NCP	TC	C/P	C/CP	*h*	*g*	*m*
Wagner, M.J.	The George Washington University	United States	3	1	1	0.33	1.00	1	1	0.017
Chamorro Gonzalez, Candy	Universidad Católica Luis Amigo	Colombia	2	2	3	1.50	1.50	1	1	0.200
Adam, Lee A.	University of Otago	New Zealand	2	2	7	3.50	3.50	2	2	0.400

Lyon, Cindy	University of the Pacific	United States	2	2	6	3.00	3.00	2	2	0.500
Lalevic Filipovic, Ana	University of Montenegro	Montenegro	2	2	16	8.00	8.00	1	2	0.250
Bowles, W.H.	Texas A&M College of Dentistry	United States	2	1	1	0.50	1.00	1	1	0.018
Markandya, Anil	University of Bath	Italy	2	2	25	12.50	12.50	2	2	0.095
Zheng, Meixun	University of the Pacific	United States	2	2	6	3.00	3.00	2	2	0.500
Stojanovic, Andjela Jaksic	University of Donja Gorica	Montenegro	2	2	16	8.00	8.00	1	2	0.250
Cuenin, Kyle	University of the Pacific	United States	2	2	6	3.00	3.00	2	2	0.500

Note: TP=total number of publications; NCA=number oc contributing authos; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index, m=m-index.

Table 2: The Most Influential and Highly Cited Documents

No.	Author(s)	Title	Source Title	TC	C/Y
1	Henly D.C. (2003)	Use of Web-based formative assessment to support student learning in a metabolism/nutrition unit	European Journal of Dental Education	77	3.35
2	Smith H.C. (2002)	A Course Director's Perspectives on Problem-based Learning Curricula in Biochemistry	Academic Medicine	27	1.13
3	Last K.S. et al. (2001)	Basic science knowledge of dental students on conventional and problem-based learning (PBL) courses at Liverpool	European Journal of Dental Education	22	0.88
4	Danesh A. et al. (2024)	Artificial intelligence in dental education: ChatGPT's performance on the periodontic in-service examination	Journal of Periodontology	19	9.50
5	De Ball S. et al. (2002)	The relationship of performance on the dental admission test and performance on Part I of the National Board Dental Examinations.	Journal of dental education	19	0.79
6	Humphrey S.P. et al. (2002)	Undergraduate basic science preparation for dental school.	Journal of dental education	17	0.71
7	Geissberger M.J. et al. (2008)	Realigning biomedical science instruction in predoctoral curricula: A proposal for change.	Journal of dental education	17	0.94
8	Pagni S.E. et al. (2017)	The benefit of a switch: Answer-changing on multiple-choice exams by first-year dental students	Journal of Dental Education	12	1.33
9	Silva I.F. & Batista N.A. (2003)	Biochemistry in undergraduate health courses: Structure and organization	Biochemistry and Molecular Biology Education	11	0.48
10	Bailit H.L. & Formicola A.J. (2017)	Introduction to "advancing dental education in the 21st century" project	Journal of Dental Education	10	1.11

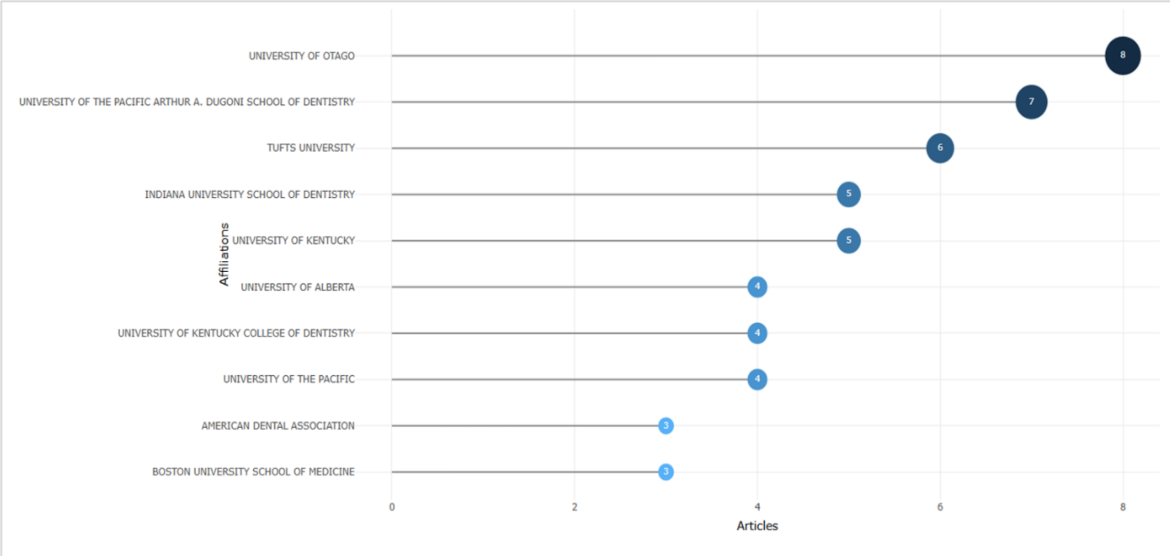

Figure 4: Top Institution trends from 1967–2025.

3.3 Conceptual Structure and Thematic Evolution

Keyword co-occurrence analysis identifies "dental education," "biochemistry," and "education" at figure 5 as central nodes within the intellectual network. Secondary clusters at figure 6 include physiology, microbiology, assessment, and curriculum design. Emerging keywords such as AI and adaptive assessment signal thematic expansion toward technology-enhanced education. The thematic map positions biochemistry within the basic theme quadrant, indicating high centrality but moderate density. Motor themes include methodology and microbiology, while AI-related clusters appear as emerging but not yet fully consolidated domains. This distribution suggests that digital transformation in biochemistry education is progressing but remains in a transitional phase.

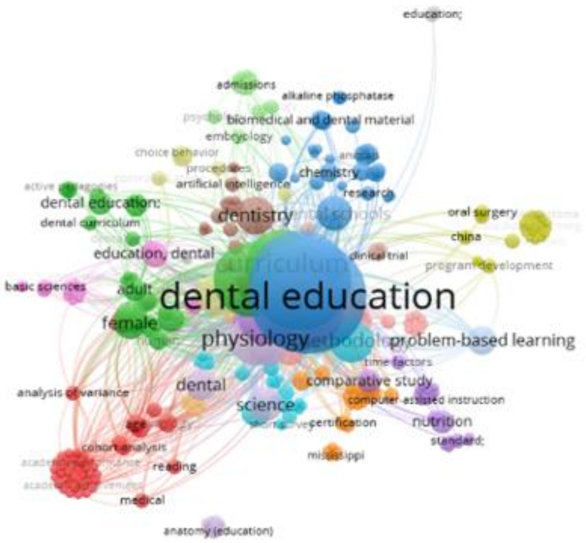

Figure 5: Network and density visualization shows the Top 20 Index Keywords

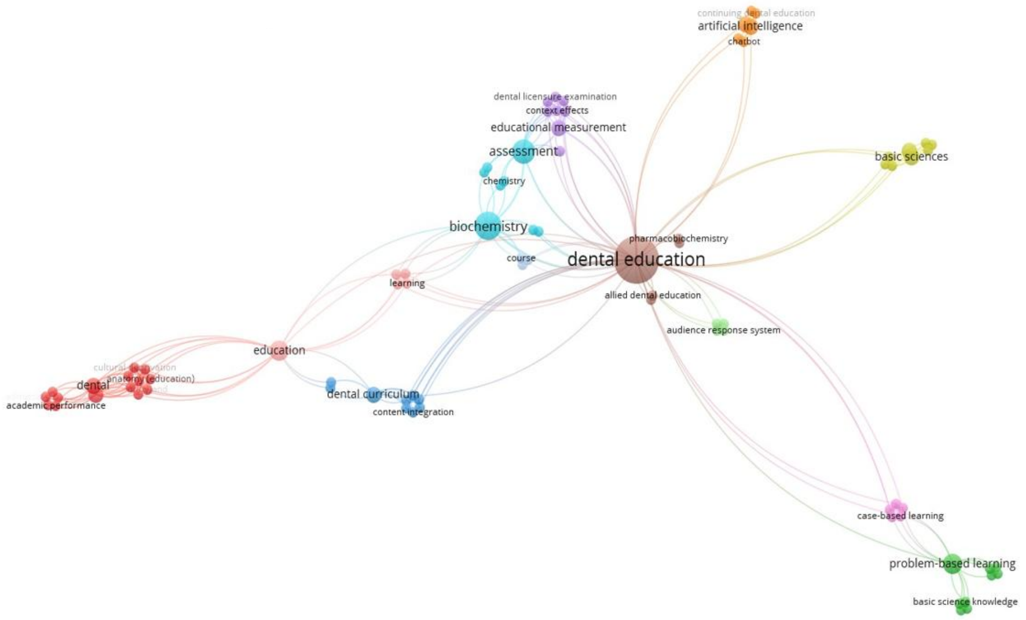

Figure 6: Networking visualization shows the co-occurrence authors keywords and subcluster

3.4 Implications for UiTM

Table 13 enriches findings by comparing teaching and assessment methods employed in international studies versus those implemented at UiTM. Approaches such as PBL (Smith, 2002), formative web-based assessment (Henly, 2003), and biomedical curriculum realignment (Geissberger et al., 2008) serve as models for curricular reform. While UiTM has embraced some of these strategies, particularly PBL and hand skill assessments, there remains substantial room for advancement, particularly in integrating digital assessments, AI-enhanced learning environments, and evidence-based reform proposals. UiTM demonstrates alignment with global pedagogical approaches, including PBL and structured formative assessment (Table 3). However, bibliometric evidence indicates limited regional research visibility in digital biochemistry pedagogy. Strategic integration of AI-supported adaptive learning systems, virtual biochemical simulations, and learning analytics could enhance both instructional quality and international research competitiveness.

Table 3: Comparison of the latest approaches on teaching methods and assessment of biochemistry in Dental Education at UiTM

No.	Author(s)	Title	Source Title	UiTM Approached
1	Henly D.C. (2003)	Use of Web-based formative assessment to support student learning in a metabolism/nutrition unit	European Journal of Dental Education	-
2	Smith H.C. (2002)	A Course Director's Perspectives on Problem-based Learning Curricula in Biochemistry	Academic Medicine	Implemented
3	Last K.S. et al. (2001)	Basic science knowledge of dental students on conventional and problem-based learning (PBL) courses at Liverpool	European Journal of Dental Education	Implemented
4	Danesh A. et al. (2024)	Artificial intelligence in dental education: ChatGPT's performance on the periodontic in-service examination	Journal of Periodontology	-
5	De Ball S. et al. (2002)	The relationship of performance on the dental admission test and performance	Journal of dental education	Implemented

		on Part I of the National Board Dental Examinations.		
6	Humphrey S.P. et al. (2002)	Undergraduate basic science preparation for dental school.	Journal of dental education	Implemented
7	Geissberger M.J. et al. (2008)	Realigning biomedical science instruction in predoctoral curricula: a proposal for change.	Journal of dental education	Proposal for change
8	Pagni S.E. et al. (2017)	The benefit of a switch: Answer-changing on multiple-choice exams by first-year dental students	Journal of Dental Education	Implemented
9	Silva I.F. & Batista N.A. (2003)	Biochemistry in undergraduate health courses: Structure and organization	Biochemistry and Molecular Biology Education	Implemented
10	Bailit H.L. & Formicola A.J. (2017)	Introduction to "advancing dental education in the 21st century" project	Journal of Dental Education	Implemented

4. Discussion

This bibliometric analysis demonstrates that biochemistry remains structurally central within dental education scholarship yet exhibits uneven pedagogical modernization in response to digital transformation. The thematic positioning of biochemistry within the basic theme quadrant, characterized by high centrality but moderate density, indicates intellectual indispensability but limited innovation intensity (Callon et al., 1991). While biochemistry continues to underpin dental curricula conceptually, its integration into digitally enhanced and competency-driven educational frameworks remains incomplete.

The dominance of research output from the United States and the United Kingdom reflects historically established infrastructures supporting curriculum reform and biomedical integration (Haden et al., 2006; Frenk et al., 2010). These regions have progressively implemented integration models consistent with Harden’s (2000) curriculum integration ladder, advancing from discipline-based instruction toward vertically integrated and systems-oriented teaching. However, the bibliometric evidence suggests that although biochemistry is structurally embedded within dental curricula, its digital reinvention, particularly through artificial intelligence and adaptive learning systems, has not yet achieved thematic consolidation.

The emerging presence of AI and digital assessment keywords in the co-occurrence network reflects transitional adoption rather than mature integration. AI-assisted diagnostic support and assessment analytics are increasingly reported within dental education research (Danesh et al., 2024), yet their application within foundational biomedical sciences remains comparatively underdeveloped. The relatively low thematic density of AI-related clusters indicates that digital transformation in biochemistry education is still formative. This pattern is consistent with broader trends in health professions education, where simulation and clinical AI applications often preceded foundational science redesign.

Authorship patterns further reveal the increasing dominance of collaborative research structures, aligning with global shifts toward interdisciplinary knowledge production (Wuchty et al., 2007). However, limited cross-regional collaboration and lower representation from developing countries suggest structural disparities in research capacity. Such imbalances have been observed in broader bibliometric evaluations of educational scholarship (Zupic & Čater, 2015; Donthu et al., 2021).

Within the Malaysian context, dental education is regulated under the Malaysian Dental Council framework and aligned with the Malaysian Qualifications Framework (MQF) and COPPA accreditation standards. While institutions such as UiTM have adopted PBL and formative assessment strategies consistent with international reform trends (Haden et al., 2006), structured digital integration within biochemistry instruction remains limited. The findings suggest that Malaysian dental education could benefit from systematic incorporation of AI-assisted adaptive learning systems, virtual biochemical case simulations, and analytics-driven formative assessment models. Such reforms would align foundational sciences with national digital transformation policies and strengthen academic competitiveness.

Three strategic recommendations emerge from this analysis. First, biochemistry should be vertically integrated across clinical years to reinforce translational application, consistent with higher levels of curricular integration described by Harden (2000). Second, AI-supported formative assessment platforms should be introduced to enhance molecular diagnostic reasoning and personalized feedback mechanisms. Third, collaborative research clusters focusing on digital biomedical education should be developed to improve regional publication visibility and citation impact.

This study has limitations. Bibliometric analysis relies on indexed English-language publications and may underrepresent regional or non-indexed scholarship. Furthermore, bibliometric indicators evaluate research productivity and conceptual evolution rather than direct pedagogical effectiveness. Future investigations should therefore combine bibliometric mapping with empirical assessment of digital biochemistry teaching interventions within Malaysian institutions.

In alignment with the study's objective to evaluate global research trajectories and identify developmental gaps in biochemistry within dental education, several strategic reforms are recommended for UiTM. The integration of AI-supported educational tools, including adaptive assessment systems, AI-assisted feedback mechanisms, and virtual biochemical simulations, would modernize foundational science instruction and align curricula with global digital transformation trends. Expanding structured formative assessments with real-time analytics can enhance knowledge retention and learner engagement (Henly, 2003). Curriculum restructuring based on competency-based frameworks and vertical integration models (Harden, 2000; Frenk et al., 2010) would strengthen translational links between biochemical concepts and clinical reasoning. Continuous faculty development in digital pedagogy and learning analytics is essential to sustain innovation. Additionally, fostering interdisciplinary and international research collaborations would elevate institutional visibility and impact on citations. Establishing a regional Center for Digital Dental Education Innovation would position UiTM as a Southeast Asian leader in revitalizing foundational biomedical sciences, directly contributing to Sustainable Development Goal 4 (Quality Education) and Goal 9 (Innovation and Infrastructure).

5. Conclusion

In conclusion, biochemistry in dental education is not diminished in terms of intellectual relevance but requires a restoration of a more even digital integration. Without the systematic integration of AI, adaptive learning technologies, and translational curriculum design, basic science risks being progressively marginalized within a competency-driven framework. While publication growth has accelerated in the digital age, innovation remains concentrated in established research ecosystems. Strategic reforms informed by curriculum integration theory and digital transformation principles are essential to ensure continued academic resilience and global competitiveness. Emerging AI-assisted pedagogical models show transformative potential but require further consolidation and empirical validation. This study provides the first global bibliometric roadmap of biochemistry in dental education and offers strategic guidance for curriculum modernization and digital transformation, particularly in emerging academic contexts such as UiTM.

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Conflict of Interest
The authors declare that there is no conflict of interest regarding the publication of this study.

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