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Original Article

Education Section

Unveiling Global Research Dynamics in Medical Education Aligned with Sustainable Development Goal 4: A Scientometric Study

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ABSTRACT

Introduction: The pursuit of Sustainable Development Goal 4 (SDG 4), which promotes complete and equitable quality education, is paramount in medical training. Understanding global research trends is crucial to aligning efforts with this goal. The current study maps the intellectual landscape of medical education research to assess its alignment with the principles of SDG 4.

Aim: To analyse global research trends of medical education research, evaluating their focus on quality, inclusivity, and innovation as aligned with SDG 4.

Materials and Methods: A scientometric study was conducted on 11,265 global publications retrieved from the Web of Science database for the time period 2016- 2024, using visualisation tools like VOSviewer and Bibliometrix to examine trends in productivity, citation impact, international collaboration, and thematic evolution.

Results: Research output peaked in 2021 before stabilising. Open-access articles made up 50% of all publications. Both open and closed-access papers received a similar number of citations. The USA led in publication volume with 5,166 papers, while European countries like the Netherlands showed higher citation efficiency (ACPP 13.21). The journal Cureus published the most papers, whereas BMJ Open and the Journal of General Internal Medicine achieved higher citation efficiency. Research in this field is highly collaborative, with an average of 5.45 authors per paper. However, international collaboration remains limited at 15.36%. Thematic analysis highlights a strong focus on evidence-based practices such as simulation and a major shift toward digital learning during the Coronavirus Disease 2019 (COVID-19) pandemic.

Conclusion: Medical education research demonstrates strong alignment with SDG 4 through its emphasis on quality and innovative pedagogies. However, to achieve truly equitable education, it must address the geographical disparities in research influence. The field also needs to promote stronger global collaboration to ensure inclusive sharing of knowledge.

Keywords: Bibliometrics, biomedical research, Global health, Quality assurance - healthcare, Quality health education

INTRODUCTION

The SDGs were established by the United Nations in 2015 as a global framework to address major challenges through sustainable development [1]. Among these goals, SDG 4 (Quality Education) holds a central role as it supports the achievement of all other goals. Its main objective is to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" by 2030 [1,2]. Within this broader context, medical education is especially important because it directly influences healthcare quality, strengthens health systems, and improves population health outcomes. This makes it closely connected to SDG 3 (Good Health and Well-being) [3].

The meaning of quality education in medicine has evolved far from the traditional teaching methods. It now includes innovative approaches, new technologies, and interdisciplinary perspectives [1,2,4]. This broader vision aligns with SDG 4's to focus on relevant and effective learning outcomes. Especially, its target is on education for sustainable development and global citizenship [2,4,5]. The transformative power of medical education also lies in its ability to promote health equity and address social determinants of health. It helps train healthcare professionals who can reduce disparities in access and quality of care [6].

Research that connects medical education and SDG 4 is highly interdisciplinary. It brings together insights from educational psychology, health professions education, health policy, technology, and sustainability science [7]. This diversity encourages innovation but also creates challenges in combining knowledge across fields [7]. Since the SDGs were adopted in 2015, researchers have shown growing interest in how medical education contributes to sustainable development. There has been a clear rise in publications exploring this topic [8-12]. This growing body of work reflects a major shift in how medical education is viewed - not as a separate field, but as a vital part of global efforts to achieve sustainable development [8].

Even though there is notable progress, still challenges remain in ensuring that the medical education is fully aligned with the principles of SDG 4 [2]. The United Nations International Children's Emergency Fund (UNICEF) SDG 4 Report (2025) highlighted that more than one-fifth of primary schools in the world still do not get basic services such as electricity, drinking water, and sanitation facilities [2]. These kinds of conditions might affect medical education institutions in the same regions, limiting their ability to provide quality.

A scientometric analysis of research trends in this domain provides valuable insights which help map the intellectual structure and growth of knowledge related to medical quality education aligned with SDG 4 [13]. The scientometrics method is useful for identifying significant research themes and topics, collaboration trends, and knowledge gaps that may be identified in traditional literature reviews [13]. There are many scientometric studies examining SDG 4 or medical education separately, but not many studies examining their convergence [8-12]. This gap is significant as there is a growing focus on evidence-based approaches in educational policy and practice in the health professions [8].

The present study aimed to provide a comprehensive scientometric analysis of global research trends in medical education aligned with SDG 4 from 2016 to 2024. The primary objective is to map the intellectual landscape and scholarly evolution of this field by quantifying annual publication growth, identifying the most prolific authors, core journals and leading institutions, and assessing the impact of highly cited articles [14]. Furthermore, the study seeks to analyse scientific collaboration of author and country networks to reveal the global distribution of research activity. Another key aim is to elucidate the conceptual structure and thematic evolution of the domain through keyword co-occurrence and co-cited reference analyses, thereby identifying dominant research fronts and emerging trends. Ultimately, this synthesis is intended to highlight current knowledge gaps and propose strategic future directions to advance the agenda of quality education in medical and health professions training [14].

This analysis comes at a critical juncture, as the world approaches the 2030 deadline for achieving the SDGs while simultaneously grappling with the aftereffects of the COVID-19 pandemic, which severely disrupted educational systems worldwide [5]. Understanding research trends in medical education within the SDG framework provides valuable insights for policymakers, educational institutions, and international organisations seeking to strengthen health professions education as part of broader efforts to build sustainable health systems and achieve health-related SDGs [3].

MATERIALS AND METHODS

This scientometric analysis employed peer-reviewed documents indexed in the Web of Science (WoS) database (Clarivate Analytics) as the primary data source. WoS was selected due to its extensive coverage of high-impact academic literature across multiple scientific disciplines [15] and also as the database has a special feature to filter SDG 4-related records. The systematic search was conducted using the query string topic= ("medical education" OR "health education"), and next applied the SDG 4 filter available in WoS to retrieve documents specifically mapped to SDG 4 (Quality Education) [16,17]. The search process was performed on 14th August 2025, covering the publication period 2016-2024 and was selected, yielding a total of 11,265 global publication records, and included all document types available in the WoS database, such as articles, reviews, conference proceedings, and book reviews. The approach aligns with global frameworks for measuring progress toward SDG 4 [18]. The current study utilised secondary data obtained from publicly accessible bibliographic databases and did not involve human or animal participants. However, Institutional approval was obtained from the Department of Studies in Library and Information Science, University of Mysore, Mysuru, under approval ref. No: LIS/Ph.D./176A/2025-26, dated 28th July 2025.

Inclusion and Exclusion criteria: The initial search results were screened based on predefined criteria. Study was included, if they primarily focused on issues of quality, accessibility, or innovation in medical or health professions education in the explicit context of the SDGs, particularly SDG 4. Documents not written in English, letters to the editor, and retracted publications were excluded from the analysis.

Study Procedure

Data extraction and cleaning: The full metadata of the retrieved records, including titles, authors, affiliations, abstracts, keywords, citation counts, and references, were exported in plain text and .txt formats from the WoS interface. This data was subsequently also downloaded in MS Excel for initial cleaning and organisation. The cleaning process involved the manual removal of duplicate entries that were not relevant to the study's focus. Any discrepancies regarding the relevance of specific documents were resolved through discussion and consensus among the research team.

Scientometric analysis and visualisation: The cleaned and standardised data were analysed using two specialised scientometric tools. VOSviewer (version 1.6.20) was applied to construct and visualise scientific collaboration and conceptual structures [19]. It generated co-authorship networks to examine collaboration patterns among countries and institutions, and keyword co-occurrence and co-cited reference networks to reveal thematic clusters and research trends. In these maps, node size indicated frequency or importance, while link strength reflected relationships. Additionally, Bibliometrix (version 4.1.0) with its Biblioshiny interface provided a comprehensive descriptive analysis [20]. This included annual growth of publications, identification of leading authors, Institutions, and countries, evaluation of core journals and highly cited documents, and citation analysis to assess research impact.

RESULTS

Characteristics and Citations Analysis

The scientometric analysis presented in the data [Table/Fig-1] outlined a substantial body of research from 2016 to 2024, comprising 11,265 documents sourced from 1,394 distinct publications. Articles represent the overwhelming majority of document types, with 9,795 entries (86.95%), while reviews constitute a smaller yet significant portion at 1,256 (11.15%). Other forms of publication, such as proceedings papers and book reviews, make up less than 2% of the total output.

Description	Results
Overview of the Data	
Time duration	2016:2025
Sources (Journals, books, etc.,)	1394
Documents	11265
Annual growth rate %	-18.38
Publication average age	4.36
Average citations per pub.	9.938
References	176172
Document contents	
Keywords plus (ID)	5376
Author's keywords (DE)	13438
Authors	
Authors	44221
Authors of single-authored pub.	462
Authors collaboration	
Single-authored publication	487
Co-authors per publication	5.45
International co-authorships %	15.36
Document types	
Article	9795
Proceedings paper	213
Book review	1
Article review	1256

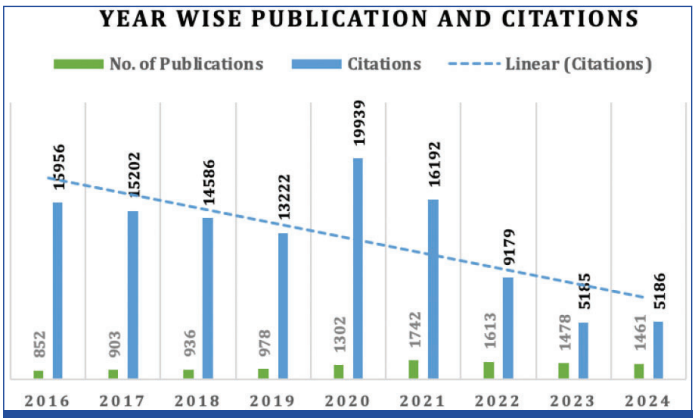
[Table/Fig-1]: Characteristics and citations analysis medical education publications aligned with SDG 4 (2016-2024).

Author collaboration is a defining characteristic of this field, with an average of 5.45 co-authors per document. However, international collaboration is relatively limited, with only 15.36% (1730 publications) of publications involving international partnerships. The research has garnered significant attention, evidenced by a total of 176,172 references and an average of 9.94 citations per document.

Annual Publication Trends

This [Table/Fig-2] reveals a field that peaked in output around 2021 but is now maturing, as shown by a consistent decline in annual

publications since then. The citation analysis clearly demonstrates the time-lag inherent in academic impact; the most influential work comes from the 2016-2020 period, which has years to accumulate citations. The strikingly low citation counts for 2022-2024 are not a measure of quality but simply reflect that these recent publications have not yet had sufficient time to be referenced by other researchers. This trend indicates a transition from rapid growth to a more stable, consolidated state of research.



[Table/Fig-2]: Year-wise distribution articles and citations.

Prolific Authors

The [Table/Fig-3] analysis shows clear differences in productivity and impact among authors. Konge, Lars leads with 68 publications, 900 citations, and the highest h-index [19], reflecting strong productivity and influence. In contrast, Shrivastava and Bobhate have over 30 publications each but minimal citations (39 and 38), indicating low impact. Finn, Gabrielle Maria demonstrates the greatest citation efficiency with 16.6 citations per publication from 25 papers. Similarly, Michael Gottlieb (13.87) and Chan, Teresa [11] achieve high impact despite fewer publications. Overall, citation averages highlight that quality and influence often outweigh sheer publication count.

Authors	No. of publi-cations	Total citations	h-index	Citations per publication	Citation per paper per year
Konge, Lars	68	900	19	13.24	1.47
Shrivastava, Saurabh RamBihariLal	38	39	3	1.03	0.11
Bobhate, Prateek	33	38	3	1.15	0.13
Durning, Steven J.	32	309	8	9.66	1.07
Chan, Teresa	25	341	13.64	11	1.22
Morgan, Helen Kang	25	226	10	9.04	1.00
Finn, Gabrielle Maria	25	415	11	16.6	1.84
Michael Gottlieb	23	319	12	13.87	1.54
Khosa, Faisal	23	238	8	10.35	1.15
Dubrowski, Adam	23	194	7	8.43	0.94

[Table/Fig-3]: Top ten Prolific Authors.

Top Contributing Journals Related to Medical Education

The [Table/Fig-4] analysis reveals two distinct models of impact. The high-volume approach is exemplified by CUREUS, which published 701 articles but yielded a lower average impact (ACPP=5.3, h-index=23). In contrast, the high-impact model is demonstrated by the Journal of General Internal Medicine, which, with only 150 articles, achieved a superior ACPP of 17.74 and an h-index of 25. BMJ Open hybridises these models effectively, combining high output (304 articles) with strong, consistent influence (h-index=27). This indicates a clear trade-off: authors must choose between broad dissemination via high-output journals and prestigious recognition through selective, high-impact publications.

Affiliation with department	Total publica-tions	APP	Total citations	ACPP	h-index
University of Toronto Temerty Faculty of Medicine	213	23.67	2762	13	27
UW Medicine	213	23.67	3170	14.9	27
Univ. of Washington School of Medicine	209	23.22	3127	15	26
Univ. of California San Francisco School of Medicine	188	20.89	2362	12.6	25
Stanford Medicine	186	20.67	2429	13.1	27
Perelman School of Medicine	185	20.56	2793	15.1	23
Stanford University School of Medicine	185	20.56	2379	12.9	26
Pennsylvania Medicine	160	17.78	2350	14.7	21
University of Michigan Michigan Medicine	157	17.44	1662	10.6	20
University of Michigan School of Medicine	150	16.67	1533	10.2	19

[Table/Fig-4]: Top contributing journals related to medical education.

Most Relevant Affiliations

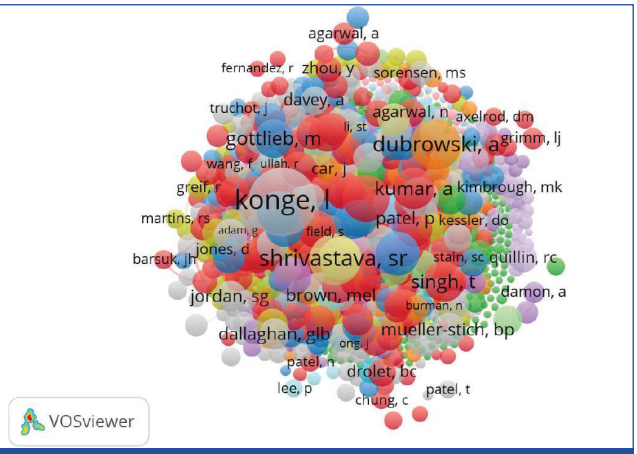
The [Table/Fig-5] reveals a close competition in research output among top institutions, with the Univ. of Toronto and UW Medicine leading in total publications (213 each). However, there is a difference in impact that emerges when analysing citations. UW Medicine and the Perelman School of Medicine demonstrate superior citation efficiency, with high ACPPs of 14.88 and 15.1, respectively, suggesting their work has greater per-paper influence. This is further supported by strong h-index scores of 27 for several top schools, indicating a robust core of highly cited work. In contrast, while productive, the University of Michigan Institutions show a lower citation rate (ACPP 10.22), highlighting a potential quantity-over-impact strategy. The analysis confirms that sometimes high publication volume does not automatically equate to greater academic influence.

Publication titles	Papers	Total citations	Average citations per paper	h-Index	Impact factor
Cureus Journal of Medical Science	701	3713	5.3	23	1.3
BMJ Open	304	3702	12.18	27	2.3
Education for Primary Care	193	1239	6.42	16	1.1
Clinical Teacher	177	1191	6.73	18	1.2
Journal of Interprofessional Care	175	2337	13.35	24	2.6
Journal of General Internal Medicine	150	2661	17.74	25	4.2
American Journal of Surgery	149	2042	13.7	24	2.7
Simul Healthc.: Journal of The Society for Simulation in Health-care	142	2499	17.6	25	2.1
Family Medicine	139	978	7.04	16	1.8
Journal of Surgical Research	134	1529	11.41	18	1.7

[Table/Fig-5]: Most relevant affiliations.

Author Collaboration Analysis

This [Table/Fig-6], the network analysis reveals distinct author roles based on connectivity and impact. Konge, L., is the undeniable hub, with the highest total link strength of 102, 69 documents, and 917 citations, indicating a prolific and central figure who drives a major research cluster. However, influence is not solely determined by connectivity. Singh T, with a strong but lower link strength (47), achieves the highest citation count (425), suggesting their collaborations are particularly impactful. Authors like Chan TM (link strength 70, citations 331) and Nayahangan LJ (link strength 59) appear as crucial connectors within this productive network. Conversely, authors like Shrivastava PS showed high activity but significantly lower citation rates, indicating their collaborative work may be less influential despite being well-connected. The data highlights the difference between being a central connector and a high-impact influencer.



[Table/Fig-6]: Author collaboration analysis.

Most-cited Articles with Citation Count

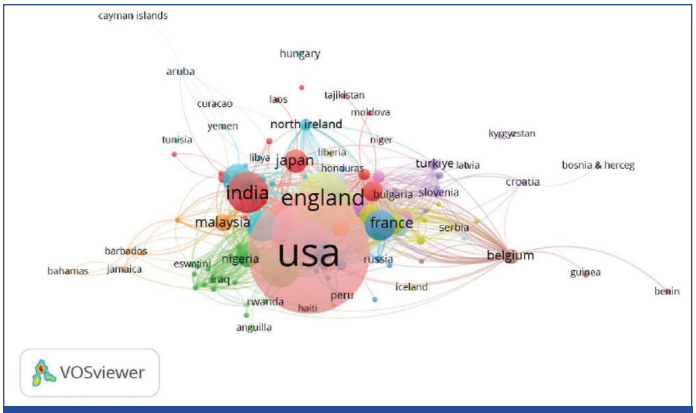
The data in [Table/Fig-7] reveals that recent, urgent global events generate the most rapid citation impact [21-30]. The top-cited article by Mukhtar K et al., (2020) on online learning during Coronavirus Disease 2019 (COVID-19) amassed 574 total citations and an exceptional citation velocity of 143.5 PPY, demonstrating the field's immediate demand for pandemic-era solutions [21]. However, foundational reviews like Estai M and Bunt S (2016) work on anatomy education show more sustained, long-term influence, accruing 525 citations over a longer period [22]. The prominence of 2020 publications, which occupy half the list, underscores a massive scholarly pivot to pandemic-related research. Furthermore, high normalised citations for works like Osseo-Asare A et al., (2018) (22.65) indicate their impact is also significant when compared to others in their field, highlighting diverse areas of influential scholarship beyond the pandemic, from debriefing methods to issues of equity and workforce safety [26].

Most Scientific Production Countries

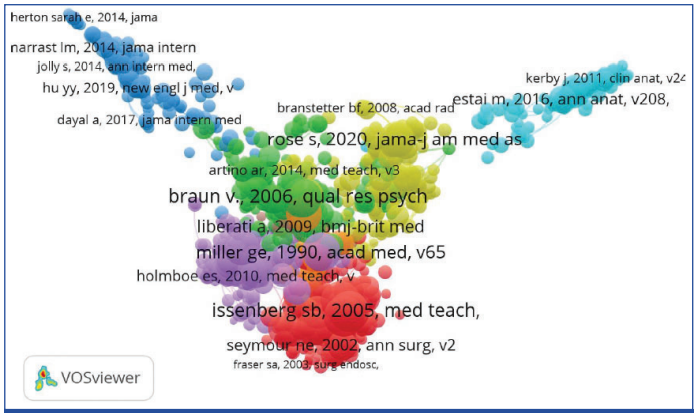
A clear indication that the USA is the dominant contributor in this research field, leading by a huge margin in both volume (5,166 publications) and overall influence (h-index 80, and 58,526 total citations) has been presented [Table/Fig-8]. However, a closer analysis reveals a critical distinction between quantity and efficiency. While the USA and Australia share an identical ACPP of 11.33, smaller European nations demonstrate superior per-paper impact. The Netherlands achieves the highest citation efficiency with an ACPP of 13.21, followed by England (12.72) and Canada (11.87). Conversely, high-output nations like India (604 publications) and Pakistan (356 publications) show significantly lower citation rates (ACPP of 5.23 and 6.68, respectively), suggesting their vast production may not be translating into equivalent global influence.

Author	Article title	Source Title	Pub. year	Total citations	Norm. citations	Publication per year
Mukhtar K et al., [21]	"Advantages, limitations and recommendations for online learning during covid-19 pandemic era"	Pakistan Journal of Medical Sciences	2020	574	37.4	143.5
Estai M and Bunt S [22]	"Best teaching practices in anatomy education: a critical review"	Annals Of Anatomy-Anatomischer Anzeiger	2016	525	28.02	58.33
Dost S et al., [23]	"Perceptions of medical students towards online teaching during the covid-19 pandemic"	a national cross-sectional survey of 2721 UK medical students	2020	488	31.79	122
Dedeilia A et al., [24]	"Medical and surgical education challenges and innovations in the covid-19 era : a systematic review"	In-vivo	2020	420	27.36	105
Sawyer T et al., [25]	"More than one way to debrief a critical review of healthcare simulation debriefing methods"	Simul Healthc.: Journal of the Society for Simulation in Health-care	2016	385	20.55	42.78
Osseo-Asare A et al., [26]	"Minority resident physicians' views on the role of race/ethnicity in their training experiences in the workplace"	Jama Network Open	2018	353	22.65	50.43
Epstein S et al., [27]	"Prevalence of work-related musculoskeletal disorders among surgeons and interventionalists a systematic review and meta-analysis"	Jama Surgery	2018	337	21.62	48.14
Abbasi S et al., [28]	"Perceptions of students regarding e-learning during covid-19 at a private medical college"	Pakistan Journal Of Medical Sciences	2020	321	20.91	80.25
Vallee A et al., [29]	"Blended learning compared to traditional learning in medical education: systematic review and meta-analysis"	"Journal of Medical Internet Research"	2020	309	20.13	77.25
Rangel EL. et al., [30]	"Pregnancy and motherhood during surgical training"	Jama Surgery	2018	292	18.73	41.71

[Table/Fig-7]: Most-cited articles with citation count [21-30].



[Table/Fig-8]: Most scientific production countries.



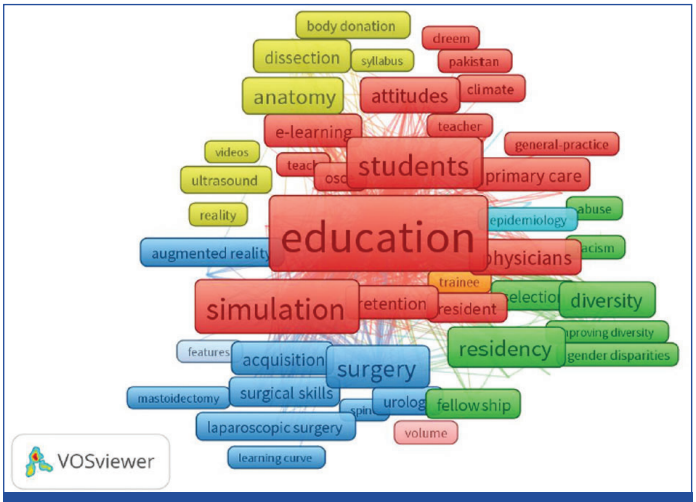
[Table/Fig-10]: Co-cited reference analysis.

This indicates a research landscape where scale and prestige are concentrated in a few Western nations, while emerging producers face a challenge in achieving similar recognition per paper.

Scientific Mapping Analysis

- Co-occurrence analysis: The [Table/Fig-9] keyword co-occurrence examination reveals the dominant intellectual structure of the field. The central, foundational role of "Education" is undeniable, with a massive 3,158 occurrences, establishing it as the primary hub. The closely related terms "Medical Education" (2,381 occurrences) and "Medical-Education" (1,263 occurrences) further solidify this core theme. However, high-impact research is driven by more specific pedagogical approaches and outcomes. The keyword "Simulation" is a major subfield with a very high average citation rate of 13.19, indicating its work is particularly influential. This is echoed by keywords like "Impact" (Avg. citations: 14.91) and "Performance" (Avg. citations: 14.78), which act as key connectors to highly cited literature, showing the field values empirical evidence of educational effectiveness. The presence of "Surgery" in a separate cluster (Cluster 3) signifies a distinct, yet connected, specialised community within the broader medical education landscape.
- Co-cited Reference Analysis: The [Table/Fig-10], the co-cited reference analysis reveals the foundational literature shaping the field. The immense influence of simulation-based education is clear, with Issenberg (2005, Total link strength: 1902) and McGaghie (2011, TLS: 1610) serving as the central, most connected theoretical pillars. The high connectivity of Cook (2011, TLS: 1627) further underscores the field's emphasis on evidence-based educational methods.

Notably, Braun and Clarke (2006, TLS: 901), a qualitative research methodology paper, appears as a highly connected node, indicating its critical role as a tool for investigation. The network is stabilised by a blend of seminal theoretical frameworks, like Miller's (1990, TLS: 1254) pyramid, and modern commentaries on systemic issues, such as Nasca (2012, TLS: 779) on duty hours and Rose (2020, TLS: 769) on the pandemic. This shows the field's intellectual core is built upon both enduring educational theory and responsive, contemporary scholarship.



[Table/Fig-9]: Co-occurrence analysis.

DISCUSSION

Scientometric analysis plays a vital role in formulating effective strategies to enhance research activity [31]. This scientometric analysis of 11,265 publications from 2016 to 2024 offers a complete overview that complements and extends findings from recent analyses of medical education research, while other studies highlighted rapid growth and interdisciplinary fusion in emerging fields like AI in precision medicine, which showed a 34.3% publication increase in 2024 alone [32,33]. Articles account for the majority (86.95%), with reviews forming a significant proportion, reflecting the field's maturity [34]. Collaboration is strong at the author level (5.45 authors per paper), but international collaboration remains modest (15.36%), highlighting the need for greater global partnerships [35].

Flores-Cohaila JA and Bustamante-Ordonez MA (2024) found that mHealth experienced strong, recent growth in 2022 [36], whereas this current study suggests the annual publication trends peaked in 2021, followed by a gradual decline, suggesting the transition from rapid growth to consolidation [31]. Citation analysis indicates that the most influential works were published between 2016-2020, while recent papers (2022–2024) are under-cited due to citation lag. Author-level analysis reveals important differences between productivity and influence: Konge, L. is the most prolific and central collaborator, while scholars such as Gabrielle M. Finn and Michael Gottlieb achieve higher citation efficiency, emphasising that quality and resonance often outweigh sheer output [37]. Han Q (2024) highlighted that international collaboration was more impactful than national [38].

Journal analysis highlights two models of scholarly impact. High-output outlets such as CUREUS contribute substantial volume but lower average citation impact, while selective journals like the Journal of General Internal Medicine achieve greater per-paper influence [34]. BMJ Open balances these strategies by combining visibility with consistent impact. Access models also play a notable role: half of all publications were Open Access, and both open and closed access articles achieved nearly equal citation counts, confirming that visibility alone does not guarantee higher citation impact [39].

Institutional and national contributions revealed the dominance of the United States [36,40,41], which produced nearly half of all publications and led in both total citations and h-index, underlining its central role in shaping the field [42,43]. However, smaller nations such as the Netherlands and England demonstrate superior citation efficiency,

while India and Pakistan, despite substantial publication counts, show lower impact, underscoring disparities between volume and influence.

Keyword co-occurrence and co-cited reference analyses [40] identify "Education", "Medical Education", and "Simulation" as core domains, supported by foundational works such as Barry Issenberg S et al., (2005) [44] and Cook DA et al., (2011) [45]. Pandemic-related publications, such as those by Mukhtar K et al., (2020) [21] and Rose S (2020) [46], further demonstrate how global crises rapidly reshape scholarly agendas.

Overall, the findings indicate that medical education research is a mature yet evolving field, balancing consolidation of core themes with diversification into new areas. Future research should focus on enhancing international collaboration to reduce disparities between high-output but low-impact regions and nations with greater citation efficiency [38,42]. Scholars are encouraged to consolidate core domains such as simulation and medical education while exploring emerging themes, including AI, mHealth, equity, and adaptive learning [36,40,44]. Long-term citation trends, the non citation impacts of open access, and the influence of crises such as COVID-19 warrant further investigation [21,39,46]. Overall, future studies should aim for inclusive, globally relevant research that balances productivity with quality and scholarly resonance [37].

Limitation(s)

This study is subject to certain limitations. First, the analysis relies exclusively on data obtained from the WoS database, which may omit relevant publications indexed in other databases such as Scopus or PubMed. Second, only articles in English were considered, potentially overlooking valuable contributions in other languages. Third, citation counts may not fully reflect the quality or societal impact of research, as disciplinary practices and time since publication influence them. Finally, the study focused on bibliometric indicators without qualitative assessment, which may limit deeper contextual insights into medical education research.

CONCLUSION(S)

This Scientometric analysis highlighted that steady growth in medical education research is consolidating, with annual publications peaking in 2021. Author collaboration is strong (5.45 authors/paper), yet international partnerships remain low at 15.36%. A clear quality-quantity divide exists, where high-output journals see lower impact than selective ones. The United States leads, producing nearly half of all publications, while nations like the Netherlands achieve higher citation efficiency. Despite 86.95% of output being articles, emerging regions show a volume-impact gap. Future progress hinges on boosting global collaboration and enhancing research impact worldwide.

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