

# Medical Education Research Trends, 1989–2018: A Bibliometric and Social Network Analysis

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## Research Article

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# Abstract

**Background** We are now in the third generation of medical education reform. To fully grasp this transformation, we need to identify the field's knowledge structure. This study conducted a bibliometric analysis to discover the general publication statue during the last three decades (1989–2018) with an eye for identifying prolific institutions, core journals, international collaboration, and the evolution of key themes.

**Methods** We retrieved 15,329 papers from the Web of Science Core Collection database that were published between 1989 and 2018 , and we analysed them to determine prolific institutions, core journals, institutional collaboration statue, and hot spots of research. R studio, SciMAT, and VOSviewer were jointly applied. For a better understanding of thematic evolution in the field, we split the study period into three sub-periods with equal time spans.

**Results** We discovered that, worldwide, scholars are increasingly attracted to research on medical education. *Medical Education* is the most prolific journal in the field. While the US publishes an overwhelming proportion of the most relevant papers, articles published by the UK are, on average, most frequently cited. We identify five key research centres based on the most prolific academic institutions, and our analysis of relevant collaborations reveals that international collaboration is common. The hottest themes during each sub-period are revealed and how they evolve across different time spans are also detected.

**Conclusions** This bibliometric study identifies the scientific structure of medical education research over the past three decades. Ultimately, it may help scholars identify new topics and future research challenges in this field and, moreover, highlight meaningful evidence for policymakers in the field of medical teaching innovation.

## Background

Today, medical education is a broad discipline, generally defined as the theory and practice of training medical practitioners with the aim of improving human health<sup>1</sup>. Medical education extends from the preliminary training of a future-doctor (i.e. medical school) to the training that follows the doctor's certification (e.g. residency and continuing medical education)<sup>2</sup>. While it may seem straightforward, the constitution of medical education has been an ongoing subject of debate since the early 1900s, up until Abraham Flexner published his famous 1910 report<sup>3</sup>. More specifically, Flexner's report proposed a science-based learned method. The method quickly gained popularity, and ultimately came define to the bulk of medical education during the first half of the twentieth century. Notably, Flexner's science-based medical learning method enabled health professionals to develop knowledge that doubled the human life span during the twentieth century<sup>4,5</sup>. In the wake of Flexner's heyday, three generations of educational reforms emerged<sup>4,6</sup>:

1. The first generation, initiated in the early 1920s, affirmed science-based courses.
2. The second generation, launched in the middle of twentieth century, introduced problem-based pedagogies.
3. The third generation, that in which we find ourselves today, is system-based and seeks to improve the performance of health systems while leveraging global knowledge<sup>6</sup>.

While significant advances have been made in medical education in recent years, increasing opportunities for mutual learning about and joint solutions to the demands of medicine are facilitated by the intensification of technology and the related ease of global knowledge sharing<sup>1,6</sup>. To be sure, the vigorous development of computer science and artificial intelligence (AI) extensively influence medical learning and teaching<sup>7-12</sup>. Meanwhile, the quantity of research on medical education has increased rapidly over the past several decades. Researchers, educators, students, and policymakers would thus benefit from access to a concise review of such articles when they want to quickly glean an overall understanding of field. While an analysis of such advances may offer insights into the development of medical education, reviewing a high quantity of documents could also hamper a detailed analysis of this specialized area<sup>13</sup>. Bibliometrics can quicken document analyses by automatically classifying articles into topics and themes.

Today, bibliometrics is a widely used research technique for quantifying literature based on a set of mathematic and statistical methods<sup>14</sup>. Many disciplines use this technique to assess scientific production and changes in trending research themes<sup>14-18</sup>. However, the nuances of medical education have rarely been explored using the bibliometric method, and little to no work of such type has been done on studies from the last three decades. To respond to this gap, we have sought to identify the knowledge structure of medical education by:

1. reviewing all articles published since 1989 (over 13,000)—we chose this period because during the past three scientific research outputs in this field rapidly increased,
2. identifying and visualizing the hidden research patterns in the field during the last three decades,
3. exploring the relationships of keywords and research institutions based on their deployment in published documents,
4. discovering the evolution of various themes in the field during the past 30 years (with 10-year sub-periods),
5. suggesting hot—i.e., generative and increasingly popular—spots for future research.

In short, our objective is to present a holistic view of the publications of medical education over the past three decades and to uncover the dynamic of research trends and collaboration networks in this area.

## Methods

## Data collection

We selected the Web of Science Core Collection (WoSCC), which provides comprehensive citation data for various academic disciplines, as a source of data, as it provides more data on our topic than other databases<sup>19</sup> and offers detailed information about bibliometric analysis. As it is impossible to include all aspects of the medical education field by keywords searching, we just focus on “medical education” itself in this study, so as to give an overview about the overall development of medical education. A total of 13,529 articles about “medical education” published between 1989 and 2018 were retrieved. We included all these publications without specifying their subjects and disciplines; this enabled us to collect all relevant documents in the field.

## Methods and analytical tools

We utilized multiple pieces of software to perform a text mining analysis and visualization. Bibliometrix (an R package) was used for tabulation and analysis, VOSviewer was used to visualize the collaboration network, and SciMAT was used to identify research trends during each time span by drawing a strategic diagram.

More specifically, Bibliometrix is a statistical package written in R, a programming language and open source software with rich statistical and visualization capabilities that enables the analysis and visualization of bibliometric data retrieved from WoSCC and Scopus<sup>20</sup>. Meanwhile, VOSviewer is a good tool for analysing the nuances of network data, such as co-occurrences of scientific terms and collaborations among research institutions<sup>21</sup>. Last, SciMAT was developed as a powerful science mapping tool and features multiple modules that simplify analyst workflow<sup>22</sup>.

### 1) Descriptive analysis by Bibliometrix

Information about publications, national scientific production, journal publications, relevant institutions, frequently-cited terms, and globally-cited documents were calculated and ranked using the Bibliometrix R package. Scientific collaboration (more than 5 times) among different regions across the globe was visualized on a map.

### 2) Term co-occurrence and institution collaboration visualization by VOSviewer

Term co-occurrence helps articulate the conceptual structure of a scientific field by

highlighting the co-occurrence of words extracted from the titles, abstracts, and keywords of publications. The visualization technique presents its findings in networks with different colours and lines of various thickness. In these visualization networks, different colours represent different clusters such as research topics, relevant journals, institutional collaboration and co-authorship. Meanwhile, line thickness represents the relative strength of the connection between parameters. Last, the relative size of each parameter indicates its frequency.

### 3) Trends analysis of research using SciMAT's strategic diagram

A strategic diagram is a two-dimensional space built by plotting themes according to their

centrality ( $c_i = \text{rank}_i^c / N$ ,  $\text{rank}_i^c$  refers to the position of theme  $i$  in a themes list with ascending centrality) and density ( $d_i = \text{rank}_i^d / N$ ,  $\text{rank}_i^d$  refers to the position of theme  $i$  in the themes list in ascending sort of density) values of each cluster. With exact values of  $c_i$  and  $d_i$ , all clusters could be mapped as spots on the four quadrants of the strategic diagram<sup>23</sup>. Therefore, the spots in different quadrants demonstrate different degrees of development and importance:

1. Both well-developed and important: spots in the upper-right quadrant represent strong centrality and high density.
2. Well-developed but not important: spots in the upper-left quadrant refer to weak—namely, marginal—centrality and high density.
3. Both weakly developed and marginal: spots in the lower-left quadrant with both low centrality and density.
4. Important but not well-developed: spots in the lower-right quadrant indicate low density and high centrality.

For a better understanding of the dynamic of research trends in medical education during each

sub-period, we divided the past three decades into three stages: 1989–1998, 1999–2008, 2009–2018.

## Results

### Distribution pattern of retrieved articles

A total of 13,529 articles on ‘medical education’, published between 1989 and 2018 by 43,733 authors, were retrieved from WoSCC. Figure 1 indicates that during this period the number of annual publications steadily increased, and have done so dramatically since 2014. Since 2000, the average citation rate has demonstrated a reverse trend because of the cumulative citation effect, that articles published earlier might have a higher citation throughout the following years. Table 1 details several summary statistical indices for these publications during the study period, including citations, authors, keywords, and collaboration status.

**Table 1. Summary of bibliometric data on medical education (1989–2018)**

Description	Results
Documents	13,529
Sources (Journals, Books, etc.)	1,885
Keywords Plus (ID)	8,795
Author's Keywords (DE)	13,979
Period	1989–2018
Average citations per documents	13.87
Authors	43,733
Author Appearances	62,015
Authors of single-authored documents	762
Authors of multi-authored documents	42,971
Single-authored documents	823
Documents per Author	0.309
Authors per Document	3.23
Co-Authors per Documents	4.58
Collaboration Index	3.38

### Geomap visualization of medical education research

Figure 2 presents a geomap visualization of the distribution of publications by country. As the legend indicates, the more literature published in a particular count, the more intense the colour red on the map. Notably, this map makes clear that field publications mainly in the US, the UK, Canada, Australia, Germany, Netherlands, Iran, China, and India. Figure 3 displays the ten countries with the most publications during last 30 years along with the average citation curve of each article. Notably, the US published the most articles (14,737; 50.21% of publications by the top ten) and the UK has the highest article citation rate (21.74), followed by the Netherlands (19.71), Canada (18.64), and the US (16.99). Iran (3.25) and India (3.20), ranked 7<sup>th</sup> and 9<sup>th</sup> in publication frequency respectively and demonstrated relatively lower citation rates.

### The distribution of research institutions and their collaboration

Figure 4 reveals that the University of Toronto published most frequently (529 papers, accounting for 3.91% of all publications in the field), followed by the University of California San Francisco (402, 2.97%), the University of Michigan (364, 2.69%), Maastricht University (342, 2.52%), and Harvard University (329, 2.43%).

Co-authorship analysis reveals scientific communications between institutions and helps identify influential institutions. To analyse co-authorship among our academic institutions, we selected for collaborative organizations with at least five publications in the field: 943 out of 7854 institutions qualified. Figure 5 details that this global scientific collaboration network includes twenty clusters (in different colours) that centre around the top five most prolific institutions shown in Figure 4 as follows: light green for the University of Toronto, light grey for the University of California San Francisco, green for the University of Michigan, light pink for Maastricht University, and light blue for Harvard University. Link strengths were 111, 147, 126, 110, and 168, respectively. The highest link strengths are between Harvard University and Beth Israel Deaconess Medical Center, Brigham and Women's Hospital, and Massachusetts General Hospital at 36, 33, and 31, respectively. These are thus most active collaborating pairs. Meanwhile, the most active collaborator with the University of Toronto is McMaster University (link strength=29). The University of California San Francisco collaborated the most with Stanford University (link strength=17). Maastricht University most significantly collaborated with Vrije Universiteit Amsterdam (link strength=18). Each of these prolific centres engaged in co-authorship except Maastricht University and Harvard University. Figure 6 indicates that the worldwide collaboration evidenced in Figure 5 was common over the last three decades.

In this illustration, each node represents a research institution, and the size of each node indicates the number of its scientific publications on medical education between 1989 and 2018. The closer two nodes, the stronger their relation. Meanwhile, the larger a node, the more active the institution. Next, we turn to the total strength of co-authorship links.

### Top twenty journals related to medical education

All of the 13,529 publications published across 1,885 journals, 1,547 journals (or 81%) did not publish more than five papers related to medical education during the past 30 years (2754 publications in total). Meanwhile, approximately 1550 (or 82.07%) of journals published only 2,753 papers (or 20.35%). We extracted the top twenty prolific journals, which had published 5,764 papers or 42.6% of publications in our sample. To be sure, most of our journals did not specialize in medical education. We focused on the top twenty journals and analysed their scientific outputs and citation rate. Table 2 reveals that

these journals specialize in medical education, and that the top three journals are *Medical Education* (1240, 21.51%), *BMC Medical Education* (897, 15.56%), and *Medical Teacher* (812, 14.09%). The papers published in these three journals made up 51.16% of all of the publications in the top 20 journals, which situates them as main source for medical education research.

**Table 2. Top twenty most prolific journals with medical education-related papers (1989–2018)**

Rank	Journals	Publication number (n)	Percentage of sample	Cumulative percentage
1	MEDICAL EDUCATION	1,240	21.51	21.51
2	BMC MEDICAL EDUCATION	897	15.56	37.07
3	MEDICAL TEACHER	812	14.09	51.16
4	ACADEMIC MEDICINE	716	12.42	63.58
5	TEACHING AND LEARNING IN MEDICINE	235	4.08	67.66
6	FAMILY MEDICINE	178	3.09	70.75
7	AMERICAN JOURNAL OF SURGERY	163	2.83	73.58
8	JOURNAL OF SURGICAL EDUCATION	155	2.69	76.27
9	ACADEMIC PSYCHIATRY	151	2.62	78.89
10	PATIENT EDUCATION AND COUNSELING	137	2.38	81.26
11	ANATOMICAL SCIENCES EDUCATION	133	2.31	83.57
12	MEDICAL EDUCATION ONLINE	131	2.27	85.84
13	ACADEMIC RADIOLOGY	116	2.01	87.86
14	ADVANCES IN MEDICAL EDUCATION AND PRACTICE	110	1.91	89.76
15	NURSE EDUCATION TODAY	110	1.91	91.67
16	PLOS ONE	102	1.77	93.44
17	ADVANCES IN HEALTH SCIENCES EDUCATION	98	1.70	95.14
18	EUROPEAN JOURNAL OF DENTAL EDUCATION	97	1.68	96.83
19	JOURNAL OF SURGICAL RESEARCH	94	1.63	98.46
20	ACADEMIC EMERGENCY MEDICINE	89	1.54	100.00

The H index, which stands for 'high citations', is defined as the max value of  $h$ : each of the  $h$  publications of a journal or an author been cited at least  $h$  times to measure both the productivity and citation rate of journals or scientists. Figure 7 details the H indices of the top twenty journals.

#### Top ten most cited papers on medical education

To identify the most influential papers on medical education, we analysed the top ten most frequently cited publications: nine were published during the sub-period of 1999–2008, and only one was published between 2009–2018; no highly-cited papers were published between 1989–1998. Three of the top ten most cited papers were published in *Academic Medicine* and *Medical Education*, two in *JAMA*, one in *Lancet*, and one in the *New England Journal of Medicine*. The article with the highest total citation (TC) is Parker's 1999 piece 'Health literacy: report of the council on scientific affairs', which has been cited 793 times, an average of 39.65 times per year. This article argues for the improvement of the physician-patient communications skills of medical students and clinicians to bridge the inadequate medical literacy of patients to facilitate, better medical outcomes. The runner up is Ruiz's 2006 article, 'The impact of e-learning in medical education', which has been cited 733 times and boasts the highest average citation rate at 56.36 per year. In the article, Ruiz concludes that e-learning technologies can revolutionize the field, in part by situating the educator as a facilitator of learning processes<sup>24</sup>. Third is Charon's 2001 'Narrative medicine – a model for empathy, reflection, profession, and trust', which emphasizes the importance of medical narrative competence for effective medical practice<sup>25</sup>. Other notable papers argue that: assessments of medical education must be based on solid scientific evidence (Downing SM<sup>26</sup>), future clinicians must learn empathy (Hojat M<sup>27</sup>), problem-based learning curricula is effective (Colliver JA<sup>28</sup>), students should be assessed for clinical confidence (Wass V<sup>29</sup>), professionalism should play a central role in medical education and practice (Papadakis MA<sup>30</sup>), and clinicians should possess strong reasoning skills (Norman G<sup>31</sup> and Eva KW<sup>32</sup>). Table 3 details these results.

**Table 3. The top ten most cited papers in the field of medical education**

Rank	DOI	First author	Title	Journal	Institution	Year	Total Citations(TC)	TC per Year
1	10.1001/jama.281.6.552	PARKER RM	HEALTH LITERACY - REPORT OF THE COUNCIL ON SCIENTIFIC AFFAIRS	JAMA-JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION	COUNCIL SCI AFFAIRS	1999	793	39.65
2	10.1097/00001888-200603000-00002	RUIZ JG	THE IMPACT OF E-LEARNING IN MEDICAL EDUCATION	ACADEMIC MEDICINE	VA MED CTR	2006	733	56.3846
3	10.1001/JAMA.286.15.1897	CHARON R	NARRATIVE MEDICINE - A MODEL FOR EMPATHY, REFLECTION, PROFESSION, AND TRUST	JAMA-JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION	COLUMBIA UNIV	2001	678	37.6667
4	10.1046/J.1365-2923.2003.01594.X	DOWNING SM	VALIDITY: ON THE MEANINGFUL INTERPRETATION OF ASSESSMENT DATA	MEDICAL EDUCATION	UNIV ILLINOIS	2003	583	36.4375
5	10.1097/ACM.0B013E3181B17E55	HOJAT M	THE DEVIL IS IN THE THIRD YEAR: A LONGITUDINAL STUDY OF EROSION OF EMPATHY IN MEDICAL SCHOOL	ACADEMIC MEDICINE	THOMAS JEFFERSON UNIV	2009	519	51.9
6	10.1097/00001888-200003000-00017	COLLIVER JA	EFFECTIVENESS OF PROBLEM-BASED LEARNING CURRICULA: RESEARCH AND THEORY	ACADEMIC MEDICINE	SO ILLINOIS UNIV	2000	511	26.8947
7	10.1016/S0140-6736(00)04221-5	WASS V	ASSESSMENT OF CLINICAL COMPETENCE	LANCET	GUYS KINGS AND ST THOMAS SCH MED	2001	479	26.6111
8	10.1056/NEJMSA052596	PAPADAKIS MA	DISCIPLINARY ACTION BY MEDICAL BOARDS AND PRIOR BEHAVIOR IN MEDICAL SCHOOL	NEW ENGLAND JOURNAL OF MEDICINE	UNIV CALIF SAN FRANCISCO	2005	407	29.0714
9	10.1111/J.1365-2929.2005.02127.X	NORMAN G	RESEARCH IN CLINICAL REASONING: PAST HISTORY AND CURRENT TRENDS	MEDICAL EDUCATION	MCMASTER UNIV	2005	406	29
10	10.1111/J.1365-2929.2004.01972.X	EVA KW	WHAT EVERY TEACHER NEEDS TO KNOW ABOUT CLINICAL REASONING	MEDICAL EDUCATION	MCMASTER UNIV	2005	361	25.7857

### Keywords and trends

We visualized the top ten keywords (Figure 8) and strategic diagrams for each sub-period (Figure 9).

Figure 8 reveals the top keywords across the sub-periods. The top three are 'education', 'students', and 'medical students'. In addition to these three words, five high-frequency keywords appear on all three sub-period lists—'medical education', 'care', 'curriculum', 'school', and 'skills'—but differ in rank across sub-periods. Meanwhile, 'competence' and 'physicians' appear only in the first sub-period, while 'performance' and 'attitude' appear in both the other two sub-periods.

A strategic diagram was used to analyse the major themes in the field of medical education during each sub-period. The diagram was generated by SciMAT involves four quadrants: the right-upper quadrant represents motor themes, the right-lower basic and transversal topics, the left-upper well-developed but isolated themes, left-lower emerging or declining themes<sup>33</sup>. The size of each labelled circle is proportional to the number of publications on a given theme.

Figure 9a illustrates that keyword co-occurrences between 1989–1998 emerge in 10 clusters. Notably, COMPETENCE (Density(D)=2.46, Centrality(C)=1.5, H index(Hi)=11) and TEACHING-METHODS (D=1.48, C=1.24, Hi=10) are the two motor themes, which suggests that teaching methods and student competence were the two main research topics during this period. Research on medical education increased over the next two sub-periods. 42 clusters were present between 1999–2008 (Figure 9b), and COMPETENCE (D=0.36, C=1.99, Hi=10) and EDUCATION,-MEDICAL,-UNDERGRADUATE,-METHODS (D=0.14, C=1.72, Hi=10) were present in the right-lower quadrant, indicating that these were the key themes of this period. ADULTS (D=1.56, C=2.46, Hi=27), SIMULATION (D=0.56, C=2.31, Hi=9), ATTITUDES (D=1.57, C=2.12, Hi=9), PATIENT-SIMULATION (D=0.72, C=1.97, Hi=11) and OPERATING-ROOM (D=2.47, C=1.56, Hi=13) were some of the motor topics during this time frame; this suggests that research mainly pivoted to themes such as adult expectations, simulation education, and student attitudes. SKILLS (D=0.25, C=0.99, Hi=10) and COMMUNICATION (D=0.28, C=1.29, Hi=20) are emerging themes here, indicating that researchers were starting to focus on skills in clinical practice and patient-physician communication. Figure 9c shows a dramatic increase in the number of research topics with a total number of 100. COMPETENCE (D=0.06, C=0.49, Hi=6), a basic theme during 1999–2008, became a declining theme in the third sub-period and BEHAVIOR and WOMEN demonstrated trends similar to that of COMPETENCE, suggesting that during this time span, scholars explored medical education across a variety of topics and benefitted from the rapid development of mobile communication technology. To be sure, teaching and learning with apps was a hot topic during this period: the theme APPS (D=2.63, C=1.53, Hi=5) as a motor theme lays in the right-upper quadrant, and CLINICAL SKILLS (D=0.35, C=0.69, Hi=6) and PATIENT SIMULATION (D=0.42, C=0.61, Hi=6) remain motor topics in this study period.

As Figure 9d details, in chronological order, the three sub-periods involve 259, 674, and 1092 keywords, respectively. As we have split our study time into only three periods, we can only see from the second period that the number of new keywords is 447, compared to 15 transient ones during the same time span. Furthermore, 674 keywords are evident in the second period, with 227 hanging over from the first period and a similarity index of 0.88. Six hundred and fifty-nine out of 674 keywords from the second period passed directly to the third period (the similarity index was 0.98) and 433 new keywords emerged in the third period. Ultimately, over 88% of 960 keywords remained relatively constant between periods, implying that research on medical education is worth long-term study.

Each circle in this chart represents a given sub-period. The numbers inside each circle indicate the number of total keywords during that time span, the arrows on top of them indicate the flow of new (downward arrows) or transient (upward arrows) keywords during that period, the numbers above arrows that connect two circles indicate the number of keywords these two sub-periods share, and the numbers in parentheses refer to the similarity index.

## Discussion

This is the first bibliometric study on medical education based on papers published between 1989–2018. In this study, the general status and evolution of hot spots in research were jointly analysed using R studio, VOSviewer, and SciMAT. We collected papers from WoSCC published between 1989 and 2018 because this time span witnessed a vigorous development of medical education. This work yields better understandings of the past and current nuances of medical education research worldwide and thus sheds light on the field's future trends.

We retrieved 13,529 relevant papers from WosCC. Since 1989, the annual number of relevant publications has shown a clear upward trend, especially after 2010—the number of publications in 2018 (1,634) is almost four-fold that of 2008 (494)—suggesting that the field has attracted many scholars. Meanwhile, the US has published the most scholarly work on the topic, followed by the UK, Canada, Australia, and Germany—notably, the US has published more than all other countries mentioned above combined. However, UK papers are most frequently cited, followed by those from the Netherlands, Canada, and the US, implying that these countries are global leaders in medical education research. Along these lines, we find that the most productive institution is a Canadian university—the University of Toronto—followed by three American universities—the University of California San Francisco, University of Michigan, and Harvard University—and one Dutch University—Maastricht University.

While a total of 1,885 journals have published papers related to medical education during the last three decades, 42% of all articles were published by only twenty journals. Notably, the journals *Medical Education*, *BMC Medical Education*, and *Medical Teacher* published 20% of these papers. *Medical Education* boasts 1,240 relevant publications and the highest H index (87) and, moreover, ranks first among all medical education-related journals, which implies that *Medical Education* is the bellwether in this research field. Meanwhile *Academic Medicine*, *Medical Teacher*, and *BMC Medical Education* rank 2<sup>nd</sup> to 4<sup>th</sup> by total publications, but demonstrate a reverse H index order. Overall, these four journals are core journals: they have the strongest influence in the field of medical education.

An analysis of institutional collaboration was visualized in this study, with twenty research centres identified. To clarify the collaboration network, we zoom in on the top five research centres, ranked by their publications: the University of Toronto, University of California San Francisco, University of Michigan, Maastricht University, and Harvard University. Among them, Harvard University collaborated most with Beth Israel Deaconess Medical Center, Brigham and Women's Hospital, and Massachusetts General Hospital. These five research centres all demonstrated collaborative relationships with each other with the exception that Maastricht University and Harvard University did not exhibit a relationship. Figure 6 makes clear that such international collaborative relationships are extensive. Internationalized medical education research might enhance the quality of global medical education.

We identified 2,025 keywords that co-occurred over 4 times; 259 appeared in the first sub-period from 1989–1998, 674 between 1999–2008, and 1,092 between 2009–2018—more than 88% of all keywords remained constant between sub-periods. This phenomenon reveals that medical education research demonstrates inheritance and constancy. Here, it is helpful to note that, during the first stage, relatively few research topics on medical education were apparent: TEACHING-METHODS and COMPETENCE were the hottest topics of study, while studies about STUDENTS and SCHOOL emerged as basic. Research on relevant topics began to increase and diversify during the second stage, with scholars focusing on medical simulation education and topics related to behaviour and psychology, such as parent expectations and student attitudes. At the same time, COMPETENCE appeared as a basic theme; it was not hot over the last decade during which, notably, new topics of interest, such as ‘patient-physician communication’ and ‘clinical practice skills’, emerged. There was an obvious explosion of new themes during the last stage: one hundred themes were evident (compare this with the ten themes present during the first stage). Besides some study spots such as medical simulation education, clinical practice skills, and patient-physician communication skills, education based on apps and smartphones became hot new topics of study. The theme TEACHING-METHODS appears to be a key basic theme. Meanwhile, during the last stage, the theme of COMPETENCE declined while new research topics such as UNDERGRADUATE, STRESS, ASSESSMENT, and PROGRAM emerged, implying that scholars are increasingly focusing on medical simulation education for undergraduates, improving clinical practice skills, medical teaching and learning with intelligent terminals, and the assessment of teaching and learning.

Our research has two main limitations. First of all, this study used "medical education" as the search term, which may lead the retrieve results miss some specific teaching reform topics, such as PBL, flipped classroom, virtual simulation teaching, etc., which makes the research level more macro. Secondly, WOSCC database was taken as the unique data source to gather bibliometric data, which may do not cover all research areas or all publications.

In sum, this study sought to understand how scientific studies related to medical education over the past thirty years have evolved and developed. We identified prolific institutions, core journals, institution collaboration statue, and hot research topics during each study sub-period. To better visualize results, R studio, SciMAT, and VOSviewer were jointly used. Ultimately, we found that medical education is gaining scholarly interest and, moreover, that systematically measuring the trends of scientific publications using a bibliometric method is a useful tool for qualifying completed research on a given subject.

Our systematic mapping of existing research might help scholars identify new and relevant research challenges and provide evidence for policymakers in the field of medical teaching innovation. In general, we provide a summary of the existing interests in medical education research that researchers in other fields can use to quickly overview the subject and efficiently identify their research questions.

## Declarations

**Ethics approval and consent to participate:** not applicable.

**Consent for publication** not applicable

**Availability of data and materials** The datasets used and/or analyzed the current study are available from the corresponding author on reasonable request.

**Competing interests:** The authors declare that they have no competing interests.

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**Authors' contributions:** YJL, QY, and DSH contributed to the conceptions and overall design of this study, CHL, HY, and JZ performed the search, PG, YML, and FFB analyzed the data, and all authors contributed to data collection and the data interpretation. YJL drafted this article and all authors revised its critical content. All authors have read and approved the final manuscript.

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## Figures

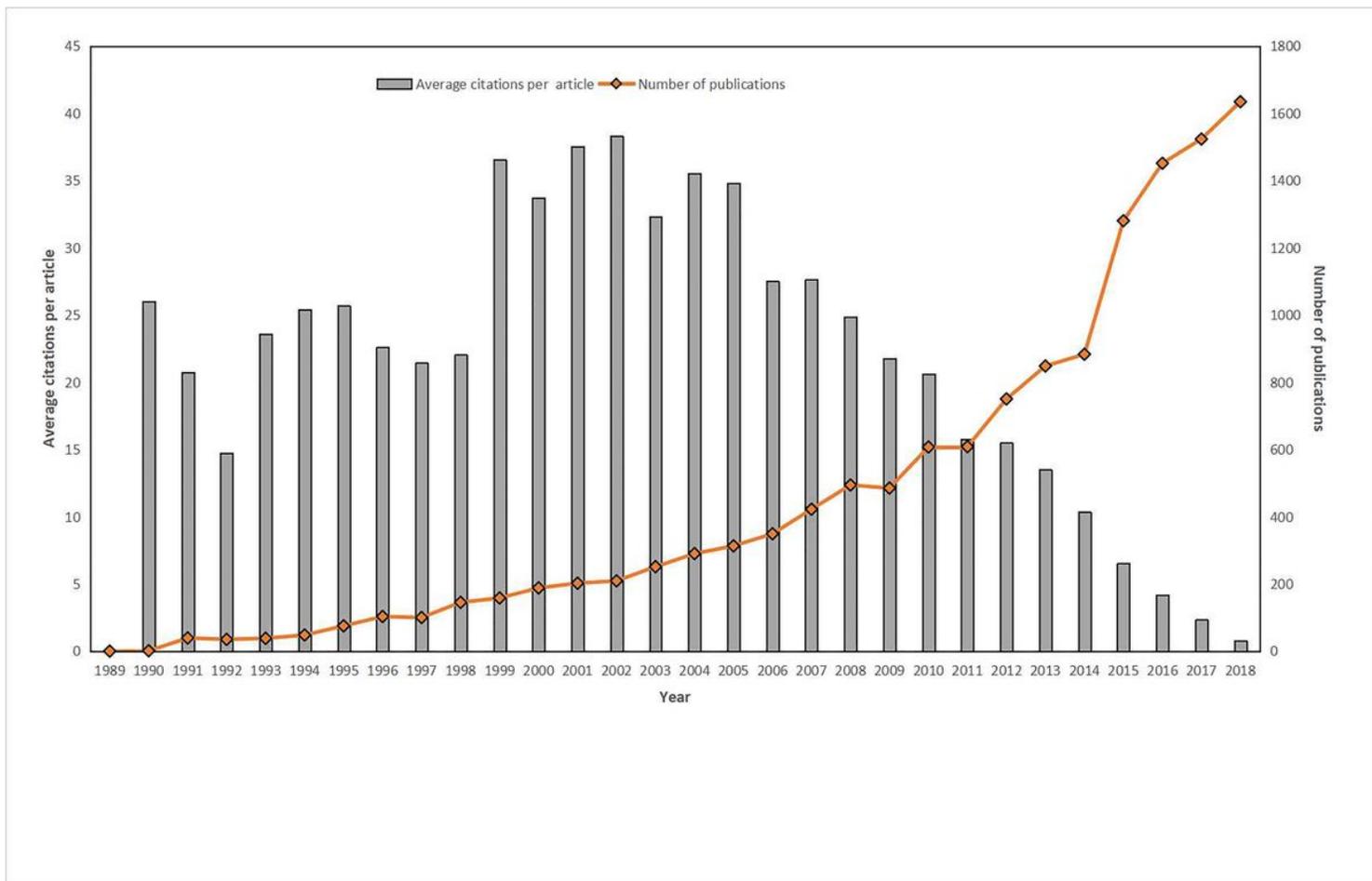


Figure 1

Growth in medical education publications between 1989 and 2018

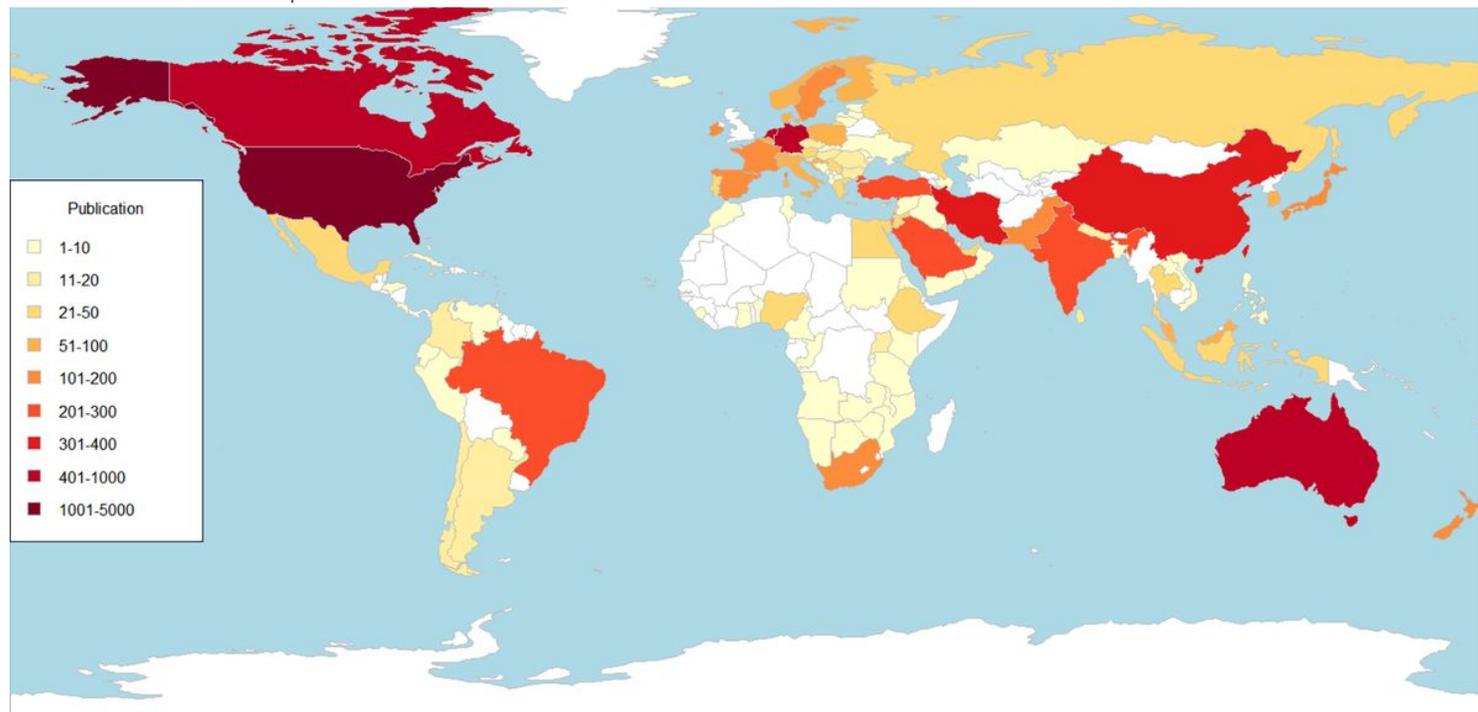


Figure 2

Geomap visualization of the distribution of first authors with articles on medical education (1989–2018)\* \*The boundaries in this map do not express any opinion concerning the legal status of any territory, city or area or the delimitation of frontiers and boundaries. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

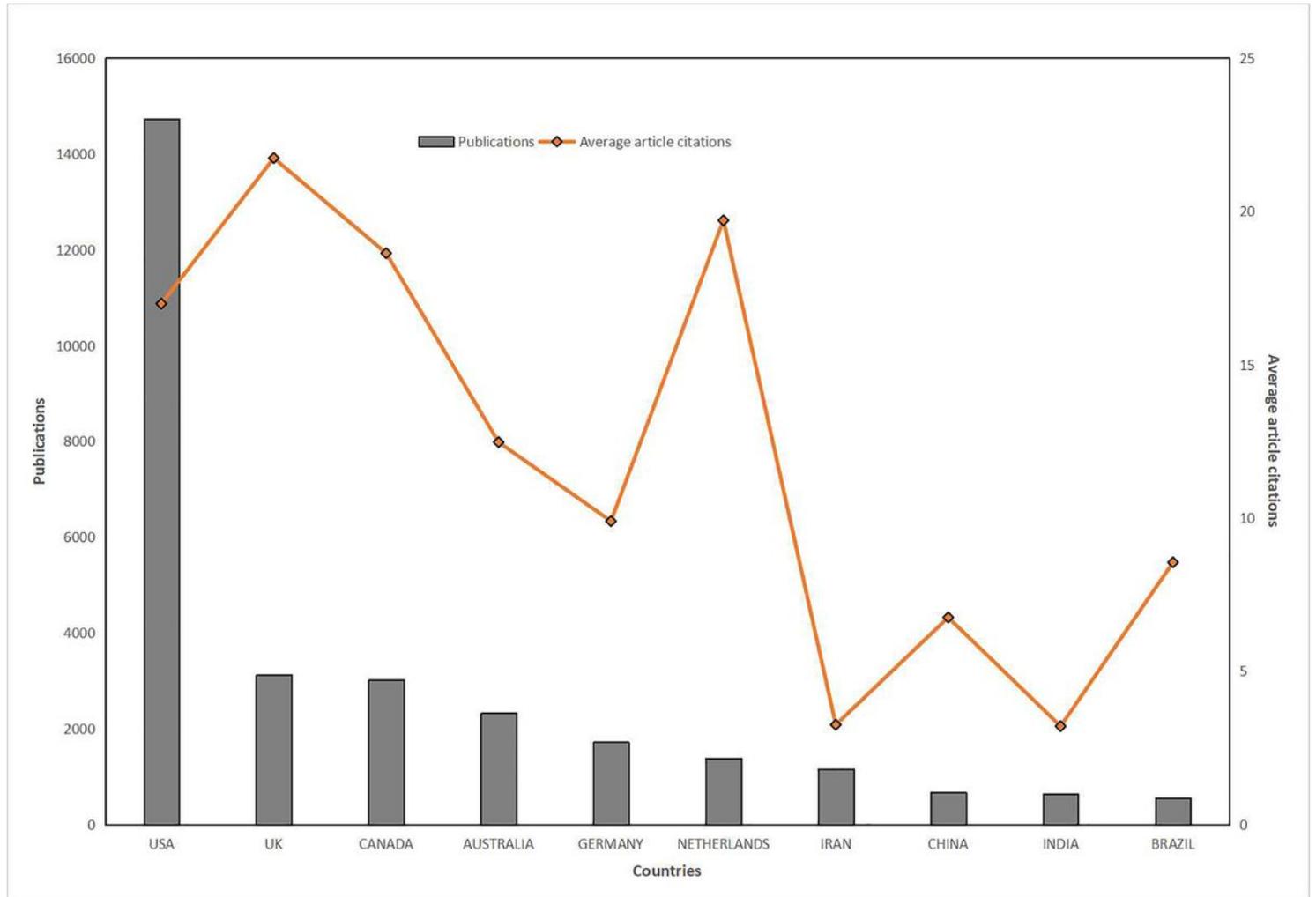


Figure 3

Top 10 Countries with the most scientific outputs and average citations for each article

## Most Relevant Affiliations

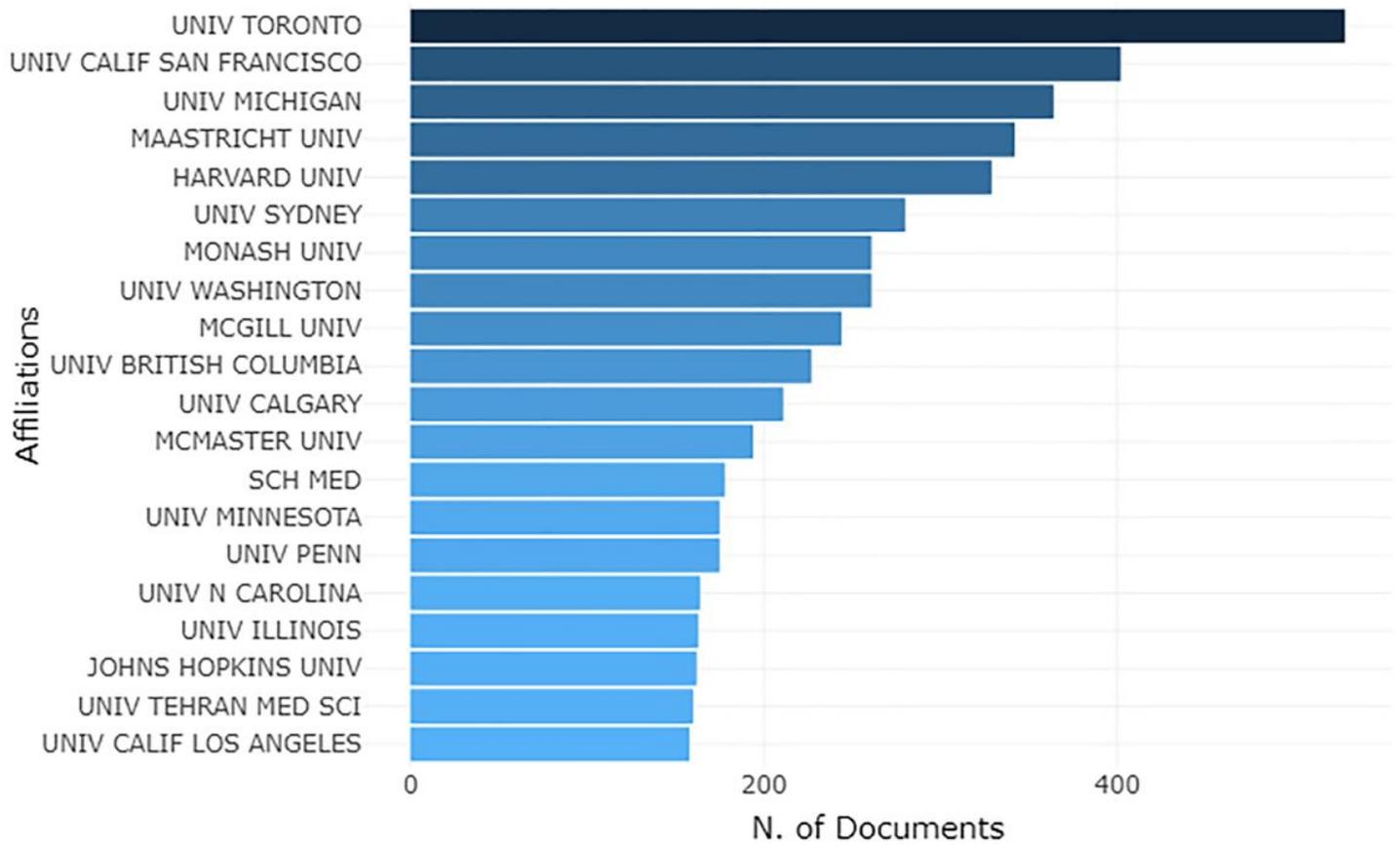


Figure 4

Top twenty prolific affiliations in medical education research

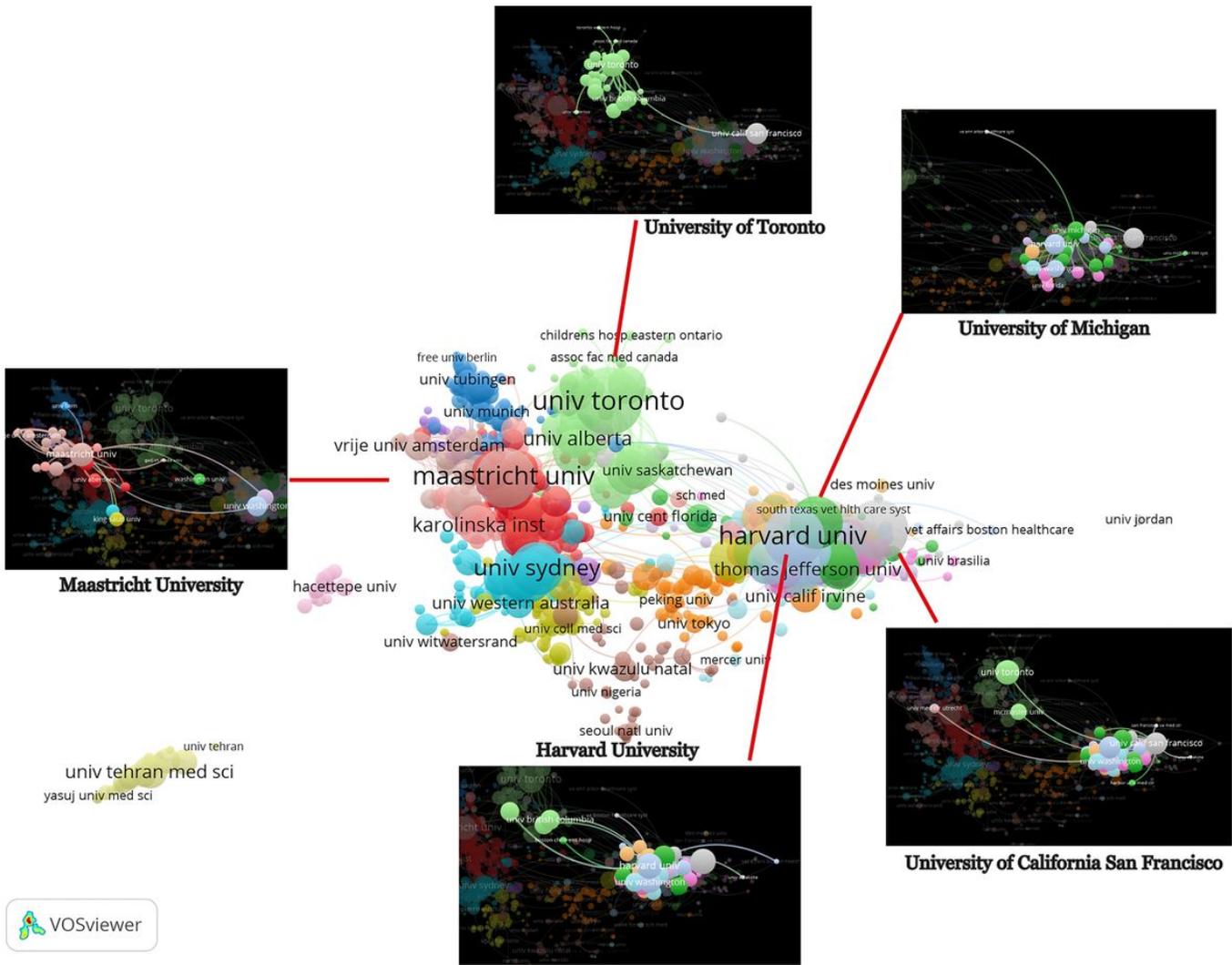
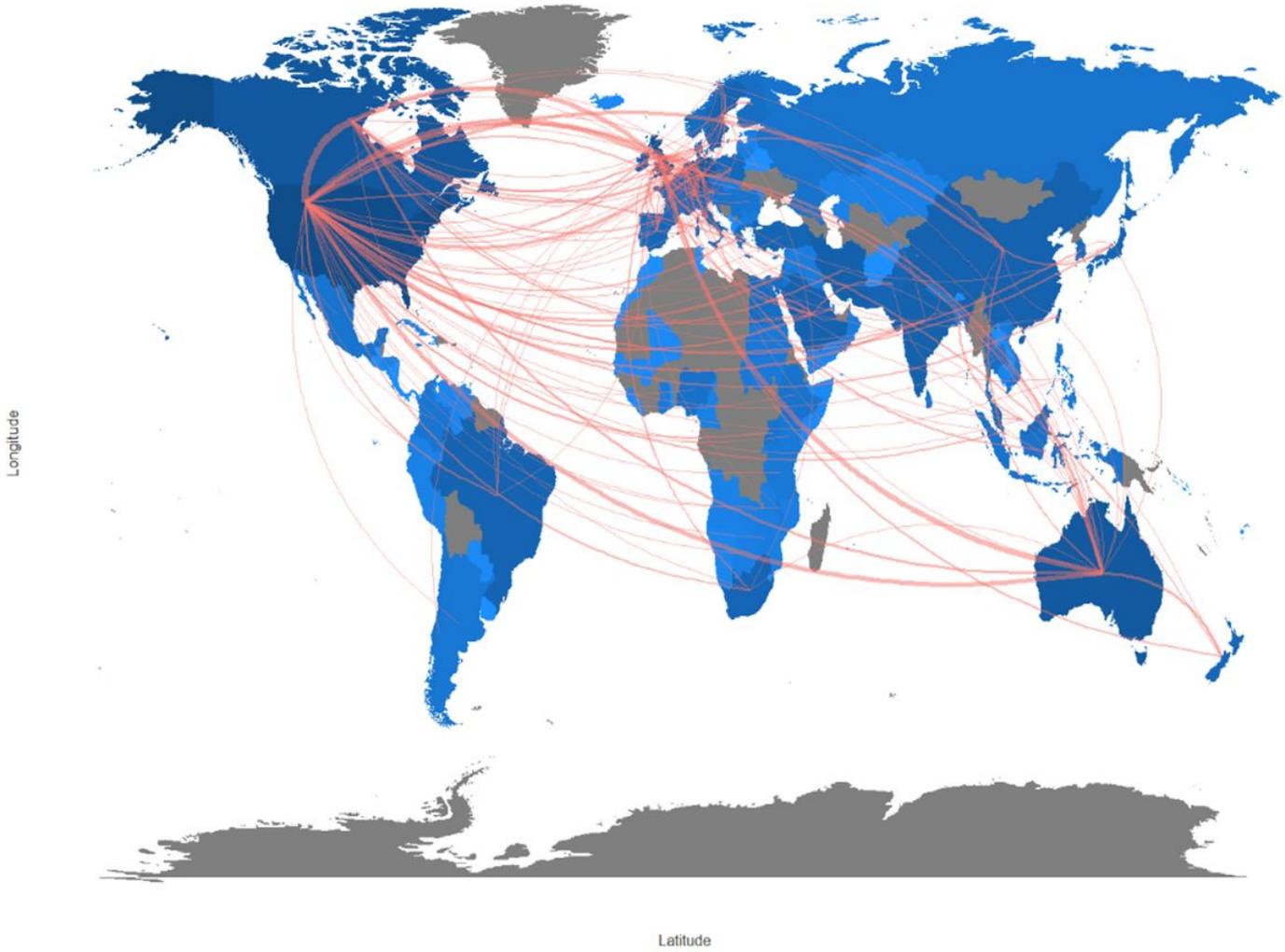


Figure 5

Collaboration network of medical education scholarship.



**Figure 6**

Geomap visualization of medical education research collaborations between regions from 1989 to 2018\* (red lines indicate at least five collaborated publications and intensity of blue indicates the number of articles published, with more intense colour signifying more publications) \*The boundaries in this map do not express any opinion concerning the legal status of any territory, city or area or the delimitation of frontiers and boundaries. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

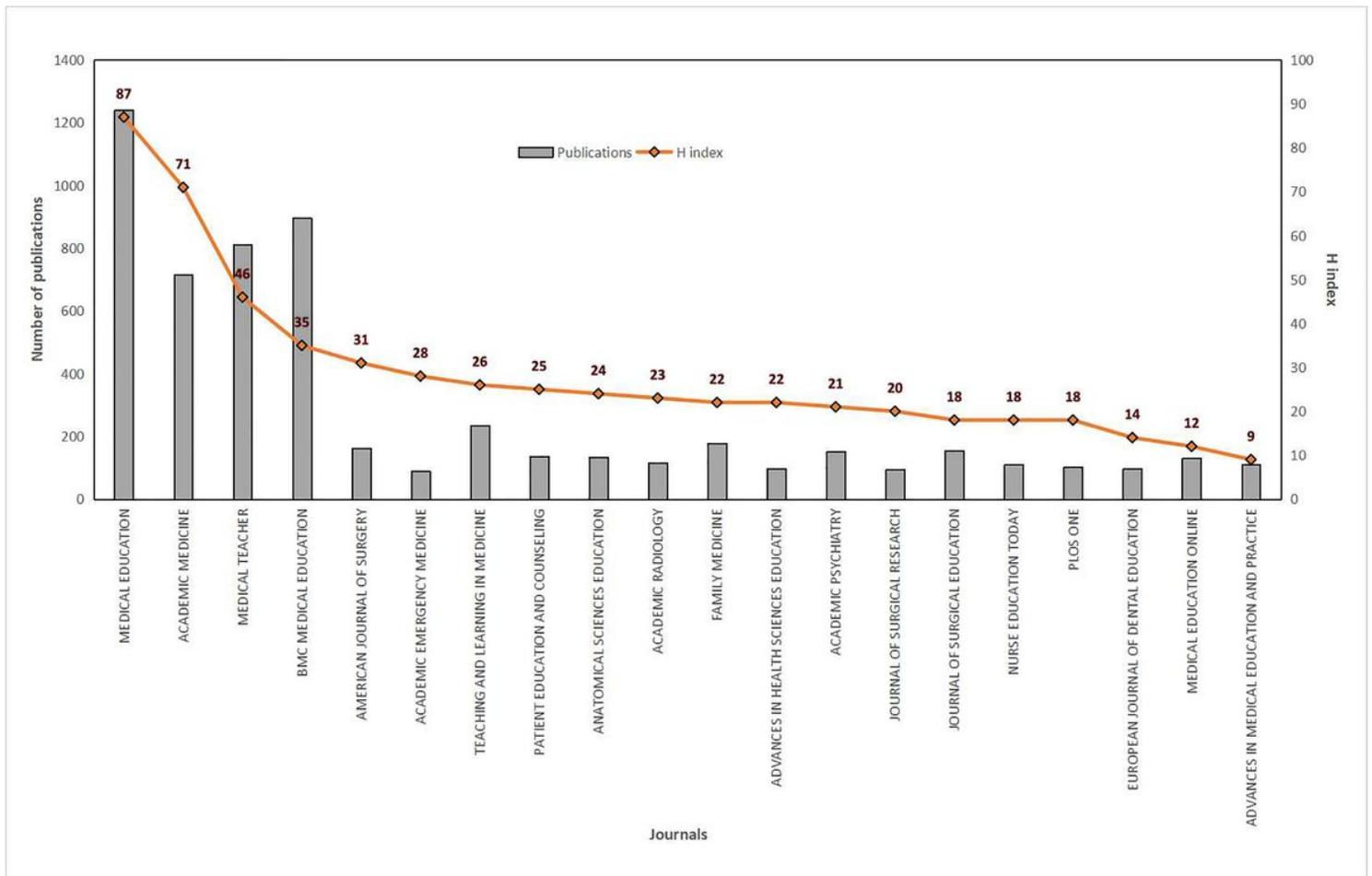
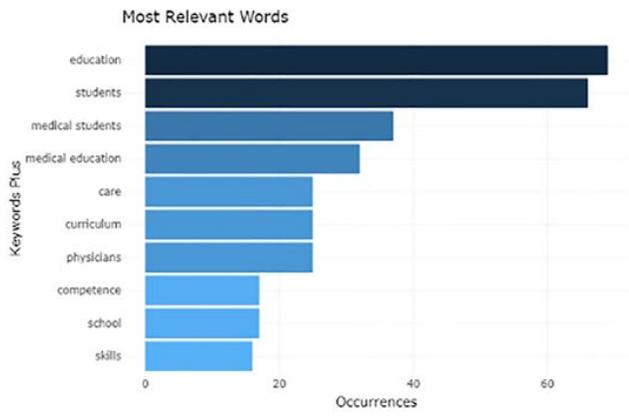
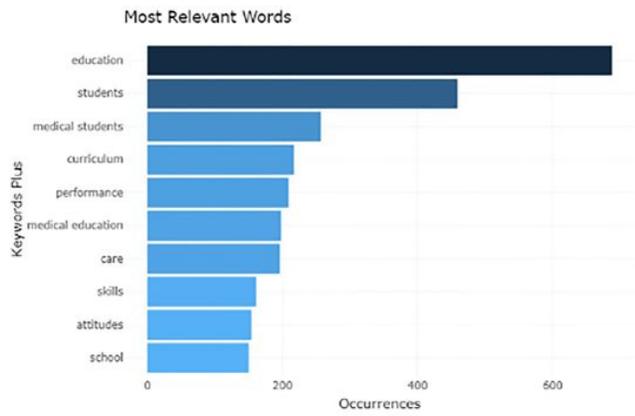


Figure 7

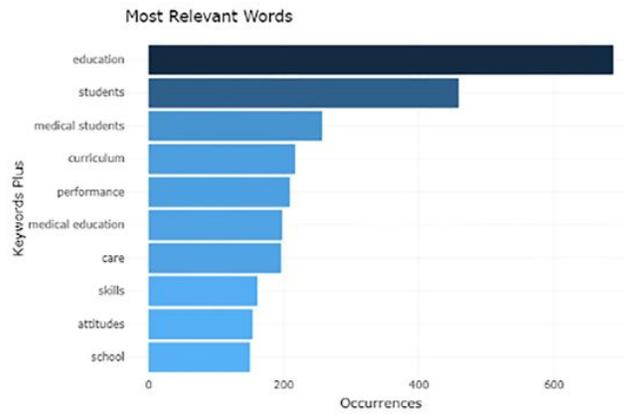
Publication number and H index of top twenty journals that publish research on medical education



(a) Sub-period 1989-1998



(b) Sub-period 1999-2008



(c) Sub-period 2009-2018

Figure 8

Top ten keywords during 1989-1998 (Figure 8a), 1999-2008 (Figure 8b), 2009-2018 (Figure 8c) (the more intense the blue, the more frequent the term)

