# The Top-Cited Articles in Medical Education: A Bibliometric Analysis

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## Abstract

### Purpose
To identify and examine the characteristics of the 50 top-cited articles in medical education.

### Method
Two searches were conducted in the Web of Knowledge database in March 2014: a search of medical education journals in the category "Education, Scientific Discipline" (List A) and a keyword search across all journals (List B). Articles identified were reviewed for citation count, country of origin, article type, journal, authors, and publication year.

### Results
Both lists included 56 articles, not 50, because articles with the same absolute number of citations shared the same rank. The majority of List A articles were published in *Academic Medicine* (34; 60.7%) and *Medical Education* (16; 28.6%). In List B, 27 articles (48.2%) were published in medical education journals, 19 (33.9%) in general medicine and surgery journals, and 10 (17.9%) in higher education and educational psychology journals. Twenty-six articles were included in both lists, with different rankings. Reviews and articles constituted the majority of articles; there were only 8 research papers in List A and 13 in List B. Articles mainly originated from the United States, Canada, the Netherlands, and the United Kingdom. The majority were published from 1979 to 2007. There was no correlation between year and citation count.

### Conclusions
The finding that over half of List B articles were published in nonmedical education journals is consistent with medical education's integrated nature and subspecialty breadth. Twenty of these articles were among their respective non-medical-education journals' 50 top-cited papers, showing that medical education articles can compete with subject-based articles.


In the scientific community, number of citations is commonly used as a parameter in evaluating the impact of a researcher's work or of a publication.[1] Citation frequency is important not just for authors and journals but also for the universities and the nations where the work was completed.[2] Although research funding is often highlighted and used as an indicator in quantifying the research activity of academic institutions,[3] yearly citation ratings can be another parameter used in assessing university rankings globally.[4] Citation ratings can also reflect the impact of a country in terms of research productivity and improving the quality of life of its citizens.[5]

The number of citations attracted by an article can be used in assessing that article's relative significance in a particular field.[6,7] Therefore, identifying articles that have exerted the most citation influence on a particular field could help scholars become familiar with "classic," landmark works and highlight topics for further research in the area. Recent studies have identified the top-cited articles in microsurgery,[8] urology,[9] pediatric orthopedic surgery,[10] orthopedic surgery,[11] foot and ankle surgery,[12] rehabilitation,[13] "respiratory system,"[14] complementary medicine,[15] and nursing.[16] However, to date, no studies have identified the top-cited articles in medical education. Therefore, the aim of this study was to identify the 50 most frequently cited articles in medical education published in journals with impact factors and to examine their characteristics. To make the study more comprehensive, two lists of top-cited medical education articles were constructed: one list of articles identified from medical education journals included in the Web of Knowledge category for science education and one list of articles identified by a keyword search across journals listed in the Web of Knowledge to capture medical education articles published in general medicine and specialty journals.

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## Method

### Search strategy and study selection

Although Scopus and Google Scholar provide citation tracking, the Web of Knowledge was used to conduct this research because it covers cited publications back to the 1900s. Furthermore, it covers the Science Citation Index Expanded (1900–present) and the Social Sciences Citation Index (1900–present). The Web of Knowledge is regularly updated, enabling researchers to trace changes in numbers of citations over the years. In contrast, Google Scholar is difficult to search and the citation records include textbooks, non-peer-reviewed papers, and articles published in languages other than English. Scopus was not considered because the breadth of its years of coverage is not nearly as great as that of the Web of Knowledge.

### Searching medical education journals

From March 1 to 12, 2014, the author and two research assistants used the search tools available within the Web of Knowledge to retrieve the top-cited articles published in medical education journals since 1900. A total of 34 journals were listed in the Web of Knowledge category "Education, Scientific Discipline"; among them, only 13 journals were related to medical education. These 13 journals were *Academic Medicine*; *Advances in Health Sciences Education: Theory and Practice*; *Advances in Physiology Education*; *American Journal of Pharmaceutical*

*Education*; *Biochemistry and Molecular Biology Education*; *BMC Medical Education*; *CBE–Life Sciences Education*; *Journal of Biological Education*; *Journal of Continuing Education in the Health Professions*; *Journal of Surgical Education*; *Medical Education*; *Medical Teacher*; and *Teaching and Learning in Medicine*.

The articles published in each of the 13 journals were sorted using the "sorted by" option "Times cited—highest to lowest." The results showed each journal's articles organized in a descending order, with the articles cited most frequently at the top of the list. A copy of the results was printed out for further analysis. The findings from the 13 journal searches were arranged in a single list on one Excel spreadsheet (Microsoft Excel 2010, Microsoft Corp., Redmond, Washington) in descending order based on the number of citations attracted by each article.

The author and the two research assistants independently applied the inclusion and exclusion criteria (described below) to assess each article in the list. The judgments were based on the abstract of each article. The outcomes were discussed in a meeting; no paper was excluded from the list by the author or the two research assistants, and all articles matched the inclusion criteria. The combined list was reviewed again with regard to the number of citations allocated to each article. The articles with the most citations were identified and ranked from 1 to 50 to create the final list of top-cited articles in medical education journals (List A). If articles shared the same absolute number of citations, they were given the same rank.

**Searching using keywords**

From March 1 to 12, 2014, the author and two research assistants conducted a second search in Web of Knowledge using keywords to identify the top-cited medical education articles in any journal listed in the Web of Knowledge regardless of journal subject category. The aim of this search was to identify highly cited articles published since 1900 across all journals listed in the Web of Knowledge, not just those published in journals listed under the category "Education, Scientific Discipline." The list created by this keyword search (List B) was compared with the list created by the category search described above (List A).

The keyword search used the following terms: *problem-based learning*, *case-based learning*, *team-based learning*, *medical students*, *medical simulation*, *multiple-choice questions*, *extended matching questions*, *mini-CEX*, *OSCE*, *formative assessment*, *summative assessment*, *continuing assessment*, *online assessment*, *self-development*, *staff training*, *curriculum*, *curriculum outcomes*, *program evaluation*, *self-regulated learning*, *self-directed learning*, *professionalism*, *medical ethics*, *clinical skills*, *simulated patient*, *standardized patient*, *medical education*, *clinical teacher*, *facilitator*, *tutor*, *teaching basic science*, *learning anatomy*, *student feedback*, *feedback*, *role model*, *mentoring*, *clerkship*, *medical informatics*, and *e-learning*. These keywords were identified using the taxonomy used in medical education journals and the proceedings of major medical education conferences such as the annual meetings of the Association of American Medical Colleges, the Association for Medical Education in Europe, the Canadian Conference on Medical Education, and the Association for the Study of Medical Education. Using Web of Knowledge tools, the results for each keyword were arranged using the "sorted by" option "Times cited—highest to lowest." For each keyword, the most frequently cited articles were identified. A copy of the results for each keyword was printed out for further analysis. The outcomes for each keyword were placed in one Excel spreadsheet, where the articles were arranged in a single list from highest to lowest number of citations.

The author and the two research assistants independently applied the inclusion and exclusion criteria (described below) to assess each article in the list. The judgments were based on article abstracts. The outcomes of this process were discussed in a meeting; any differences were resolved through discussion after reading the full article. The articles with the most citations were ranked from 1 to 50 to create the final list of top-cited medical education articles across all journals (List B). If articles shared the same absolute number of citations, they were given the same rank.

**Inclusion and exclusion criteria**

Articles eligible for inclusion were those addressing areas of interest in medical education and to the medical education community and published in journals listed in the Web of Knowledge (i.e., journals with impact factors). *Medical education* was defined as a discipline covering the education of and the practice of skills by students enrolled in medical schools/colleges to become doctors; residency training; continuing medical education; and specialized postgraduate medical training (e.g., by organizations such as the Royal College of Physicians in the United Kingdom and the Royal Australasian College of Physicians in Australia and New Zealand).

Educational systems and assessment methods vary by specialty, governing body, and country. However, throughout the different stages of medical education, the discipline of medical education focuses on a number of subspecialties including curriculum design and implementation, assessment, faculty development and training, medical technology and medical informatics, medical education research, medical professionalism, teaching and learning methods, problem-based learning, and clinical teaching.[17] The keywords used in our second search covered most subspecialties in medical education.

Therefore, the inclusion criteria for this study were articles published in journals listed in the Web of Knowledge and in the English language from 1900 to the date of the search covering (1) topics on medical education; (2) medical education issues related to medical students, interns, residents, or physicians; and/or (3) educational principles/theories from education or psychology that can be of value to the medical education community. The exclusion criteria were (1) articles in languages other than English or reviews including studies not published in English and (2) articles focused on education issues not of interest to the medical education community (e.g., articles on mathematics, engineering, or physics education, or other areas that do not target the heart of medical education).

**Assessing the articles**

The full text for each article included in List A or List B was obtained from the Saudi Digital Library (www.digitallibraryplus.com/). Following the methods of Lefaivre et al,[11] each article was reviewed and the following information was recorded: (1) the first author's name and affiliation; (2) organization and country of origin (when there was more than one author, the first

author's information was used); (3) number of citations; (4) year of publication; and (5) article type (review, article, educational guide, or research paper). For the purposes of this study, *reviews* were defined as articles reviewing recent progress in a particular topic, critically reviewing the current status of the literature and creating an understanding of the topic by discussing related literature, and/or identifying gaps in knowledge and highlighting future directions for research. *Articles* were defined as original reports with conclusions that represent a substantial advance in the understanding of important problems or issues. They provoke thought and ideas, and they aim to establish new directions. *Educational guides* were defined as articles written by a team of experts and aimed at providing teachers and educators with a resource on principles, current evidence, applications, and regulations. Educational guides are usually used as reference resources. *Research papers* were defined as systematic investigations into and the study of problems using valid and reliable methods in order to establish new findings and conclusions. Research papers may use qualitative, quantitative, or mixed methods.

### Evaluating the journals

The journals that published the articles identified using keyword searches (List B) were evaluated. For these journals, the following key information was collected: (1) 2012 Journal Impact Factor; (2) language; (3) discipline; (4) number of citations for the article ranked no. 1 (i.e., the article with the highest number of citations among all articles published in the journal); and (5) number of citations of the article ranked no. 50 (i.e., the article ranked 50th among all articles published in the journal). Web of Knowledge citations numbers were used to identify the articles ranked no. 1 and no. 50 for each journal. The aim was to check whether the 50 top-cited articles identified by keywords in non-medical-education journals were among the 50 top-cited articles in each of the journals in which they were published.

### Statistical analysis

Analysis was conducted using SPSS version 18.0 for Microsoft Windows (SPSS Inc., Chicago, Illinois), and results were reported as totals and percentages. The Pearson correlation coefficient ($r$) was calculated to determine whether the number of years since publication was correlated to the total number of citations.[18] This relationship was examined to see whether the high numbers of citations obtained by these top-cited articles were related to their age rather than to the quality and the intrinsic value of their content.

### Degree of agreement between assessors

The agreement between the three assessors was calculated using Cohen's kappa for interrater correlation.[19,20] The scores were in the range of 0.78 to 0.96 for articles in List B (articles identified via keyword search).

## Results

### Top-cited articles in the 13 medical education journals (List A)

Appendix 1 summarizes the top-cited articles published in the 13 medical education journals (List A). Articles are listed in descending order by rank from 1 to 50 based on the number of citations obtained by each article as of the day of the search.[21–76] List A includes 56 articles, not 50, because some articles shared the same absolute number of citations. A denominator of 56 was used in the calculation of percentages. All articles were published in the English language.

The majority of these articles were reviews (n = 27; 48.2%) and articles (n = 19; 33.9%). Eight (14.3%) were research papers, and 2 (3.6%) were educational guides. The topics covered included problem-based learning (n = 9; 16.1%); clinical competency and assessment (n = 8; 14.3%); professionalism and professional competence/practice (n = 6; 10.7%); medical simulation and standardized patients (n = 4; 7.1%); faculty development (n = 4; 7.1%); and cross-cultural education, interprofessional education, and ethical environment (n = 4; 7.1 %). Table 1 summarizes other topics covered and topic distribution by article type.

These articles were published in five journals: *Academic Medicine* (n = 34; 60.7%), *Medical Education* (n = 16; 28.6%), *Medical Teacher* (n = 4; 7.1%), *Journal of Continuing Education in the Health Professions* (n = 1; 1.8%), and *Advances in Health Sciences Education: Theory and Practice* (n = 1; 1.8%).

The most frequently cited article was "Problem-based learning: A review of literature on its outcomes and implementation issues" by Albanese and Mitchell,[21] which was published in *Academic Medicine* in 1993 and cited 861 times over 21 years. The article ranked 50th was "The New Mexico experiment: Educational innovation and institutional change" by Kaufman et al,[76] which was published in *Academic Medicine* in 1989 and cited 141 times over 25 years. Most papers originated from academic institutions, with first authors from the United States (n = 31; 55.3%), Canada (n = 11; 19.6%), the United Kingdom (n = 6; 10.7%), the Netherlands (n = 5; 8.9%), Australia (n = 2; 3.6%), and Israel (n = 1; 1.8%).

All of the articles were published during a 28-year period (1979–2007) (see Table 2). The number of highly cited articles increased significantly after 1990, and the majority (n = 47; 83.9%) were published in the period from 1991 to 2007. No correlation was found between the year of publication and the number of citations obtained by an article ($R^2 = 0.054$) (see Supplemental Digital Figure 1A, available at http://links.lww.com/ACADMED/A285).

Some authors contributed to more than one article in this list. Schmidt authored two of the most frequently cited articles[33,46] and coauthored with Norman three others[23,24,43] (see Appendix 1). These articles focused on problem-based learning (four articles) and cognitive perspectives on medical experts (one article). Norman was also the author[55] or coauthor[62] of two other articles on clinical reasoning and cognitive psychology in relation to professionalism, respectively. Irby authored two articles[36,59] and coauthored a third.[48] These articles were on teaching and learning in the ambulatory care setting, clinical teachers, and strategies for improving teaching practices, respectively. Hafferty authored an article on the hidden curriculum[31] and coauthored another on the same topic.[29] Van der Vleuten authored[35] or coauthored[44] two articles, both on assessment of professional competence. Harden was the first author of two articles.[28,57] The first was a famous article on objective structured clinical examinations, and the second was on outcome-based education.

### Top-cited articles identified by keyword search (List B)

Appendix 2 summarizes the top-cited medical education articles identified by keyword search across all journals (List B).

Table 1

**The Top-Cited Articles in Medical Education Identified by Searching Medical Education Journals (List A) or by Searching by Keyword Across All Journals (List B), by Article Type and Topic[a]**

| Topic by list | Article type: no. of articles[references] | | | | Total no. (%) |
|---|---|---|---|---|---|
| | Review | Article | Educational guide | Research paper | |
| **List A[b]** | | | | | |
| Problem-based learning | 5[21,23,25,33,70] | 4[32,34,43,46] | — | — | 9 (16.1) |
| Clinical competency skills and their assessment | 4[30,35,44,55] | 1[28] | — | 3[37,45,72] | 8 (14.3) |
| Professionalism and professional competence/practice | 3[54,61,51] | 1[60] | — | 2[47,73] | 6 (10.7) |
| Medical simulation and standardized patient | 2[22,53] | 2[38,64] | — | — | 4 (7.1) |
| Curriculum and educational innovation | 0 | 3[29,31,76] | — | — | 3 (5.4) |
| Students' stress | 1[50] | — | — | — | 1 (1.8) |
| Ambulatory/primary care | 2[36,58] | — | — | — | 2 (3.6) |
| Communication skills | — | 1[42] | — | 1[41] | 2 (3.6) |
| Medical experts and performance | 2[24,67] | 1[26] | — | — | 3 (5.4) |
| E-learning | 1[39] | — | — | — | 1 (1.8) |
| Knowledge translation | 1[27] | — | — | — | 1 (1.8) |
| Teachers' skills and mentoring skills | 2[68,62] | 1[66] | — | 1[75] | 4 (7.1) |
| Error in diagnosis | — | 1[40] | — | — | 1 (1.8) |
| Cross-cultural education, interprofessional education, and ethical environment | 1[69] | 1[74] | 1[65] | 1[71] | 4 (7.1) |
| Faculty development | 2[52,59] | 2[48,63] | — | — | 4 (7.1) |
| Learning style and learning outcomes | 1[56] | 1[49] | 1[57] | — | 3 (5.4) |
| Total | 27 | 19 | 2 | 8 | 56 (100) |
| **List B[c]** | | | | | |
| Problem-based learning | 7[21,81,23,25,33,94,101] | 4[32,34,43,46] | — | — | 11 (19.6) |
| Clinical competency skills and their assessment | 6[30,35,44,99,96,95] | 2[28,97] | — | 5[90,93,37,45,106] | 13 (23.2) |
| Professionalism and professional competence/practice | 3[79,85,100] | 1[80] | — | — | 4 (7.1) |
| Medical simulation and standardized patient | 3[22,92,98] | 1[38] | — | 1[84] | 5 (8.9) |
| Curriculum and educational innovation | 1[108] | 2[29,31] | — | 1[102] | 4 (7.1) |
| Academic motivation | 1[89] | 1[88] | — | — | 2 (3.6) |
| Ambulatory/primary care | 1[36] | — | — | — | 1 (1.8) |
| Communication skills | 1[91] | 1[42] | — | 3[100,41,78] | 5 (8.9) |
| Medical experts and performance | 1[24] | 1[26] | — | 2[83,104] | 4 (7.1) |
| E-learning | 1[39] | — | — | — | 1 (1.8) |
| Knowledge translation | 1[27] | — | — | — | 1 (1.8) |
| Teachers' skills and mentoring skills | 1[86] | — | — | — | 1 (1.8) |
| Cross-cultural education, interprofessional education, and ethical environment | — | — | — | 1[47] | 1 (1.8) |
| Learning style skills, learning outcomes, and feedback | 2[82,87] | — | — | — | 2 (3.6) |
| Evidence-based medicine | 1[77] | — | — | — | 1 (1.8) |
| Total | 30 | 13 | 0 | 13 | 56 (100) |

[a]A category search and a keyword search were conducted from March 1 to 12, 2014, using the Web of Knowledge (1900–2014) to identify the 50 top-cited articles in medical education. See Method section for definitions of article types. Percentages may not add to 100 because of rounding.
[b]For a summary of the articles in List A, see Appendix 1. Because 6 articles shared the same numbers of citations, the list comprised 56 articles. Articles with the same citation counts had the rank numbers 24, 32, 34, 35, 39, and 46.
[c]For a summary of the articles in List B, see Appendix 2. Because 6 articles shared the same numbers of citations, the list comprised 56 articles. Articles with the same citation counts had the rank numbers 18, 43, 44, 48, and 50.

Articles are listed in descending order by rank from 1 to 50 based on the number of citations received by each article as of the day of the search.[21–39,41–47,77–106] List B includes 56 articles, not 50, because some articles shared the same absolute number of citations. A denominator of 56 was used in the calculation of percentages. All articles were published in the English language.

The majority of these articles were reviews (n = 30; 53.6%). The rest were articles (n = 13; 23.2%) or research papers (n = 13; 23.2%). There were no educational guides identified. The

Table 2

**The Top-Cited Articles in Medical Education Identified by Searching Medical Education Journals (List A) and by Searching by Keyword Across All Journals (List B), by Article Type and Year of Publication[a]**

| Article type by list | Year of publication: no. of articles[references] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1975–1980 | 1981–1985 | 1986–1990 | 1991–1995 | 1996–2000 | 2001–2005 | 2006–2007 | Total no. (%) |
| **List A[b]** | | | | | | | | |
| Article | 1[28] | — | 2[32,76] | 4[29,38,46,63] | 5[31,34,43,48,60] | 7[26,40,42,49,64,66,74] | — | 19 (33.9) |
| Educational guide | — | — | — | — | 1[57] | — | 1[65] | 2 (3.6) |
| Review | — | 1[33] | 4[24,30,56,70] | 8[21,23,25,36,51,58,59,67] | 3[35,62,68] | 7[22,44,53,54,55,61,69] | 4[27,39,50,52] | 27 (48.2) |
| Research paper | — | 1[45] | — | 1[47] | 3[37,72,75] | 3[41,71,73] | — | 8 (14.3) |
| Total | 1 | 2 | 6 | 13 | 12 | 17 | 5 | 56 (100) |
| **List B[c]** | | | | | | | | |
| Article | 1[28] | — | 1[32] | 4[29,88,38,46] | 4[97,31,34,43] | 3[80,26,42] | — | 13 (23.2) |
| Educational guide | — | — | — | — | — | — | — | 0 (0.0) |
| Review | — | 1[33] | 2[24,30] | 9[77,21,23,25,82,86,89,91,36] | 4[85,92,35,103] | 7[79,22,94,98,99,101,44] | 7[81,27,87,95,96,39,105] | 30 (53.6) |
| Research paper | — | 1[45] | — | 3[78,90,47] | 4[84,93,37,102] | 4[100,41,104,106] | 1[83] | 13 (23.2) |
| Total | 1 | 2 | 3 | 16 | 12 | 14 | 8 | 56 (100) |

[a]A category search and a keyword search were conducted from March 1 to 12, 2014, using the Web of Knowledge (1900–2014) to identify the 50 top-cited articles in medical education. See Method section for definitions of article types.
[b]For a summary of the articles in List A, see Appendix 1. Because 6 articles shared the same numbers of citations, the list comprised 56 articles. Articles with the same citation counts had the rank numbers 24, 32, 34, 35, 39, and 46.
[c]For a summary of the articles in List B, see Appendix 2. Because 6 articles shared the same numbers of citations, the list comprised 56 articles. Articles with the same citation counts had the rank numbers 18, 43, 44, 48, and 50.

topics covered included problem-based learning (n = 11; 19.6%); clinical competency and assessment (n = 13; 23.2%); professionalism and professional competence (n = 4; 7.1%); medical simulation and standardized patients (n = 5; 8.9%); curriculum and educational innovation (n = 4; 7.1%); communication skills (n = 5; 8.9%); and medical experts and performance (n = 4; 7.1%). There were no articles on faculty development or error in diagnosis. Table 1 summarizes other topics covered and topic distribution by article type.

These articles were published in 21 journals. Twenty-seven (48.2%) of the articles were published in 5 medical education journals (2012 Journal Impact Factor; no. of articles): *Academic Medicine* (3.292; n = 17), *Medical Education* (3.546; n = 7), *Medical Teacher* (1.824; n = 1), *Journal of Continuing Education in the Health Professions* (1.321; n = 1), and *Advances in Health Sciences Education: Theory and Practice* (2.061; n = 1).

The remaining articles were published in two groups of journals. Nineteen (33.9%) were published in the group of 10 general medicine and surgery journals (2012 Journal Impact Factor; no. of articles): *JAMA–Journal of the American Medical Association* (29.978; n = 7), *CMAJ–Canadian Medical Association Journal* (6.465; n = 1), *Annals of Internal Medicine* (13.976; n = 2), *Archives of Internal Medicine* (10.579; n = 1), *BMJ–British Medical Journal* (17.215; n = 1), *Journal of the American College of Surgeons* (4.500; n = 1), *NEJM–The New England Journal of Medicine* (51.658; n = 3), *The Lancet* (39.060; n = 1), *BJA–British Journal of Anaesthesia* (4.237; n = 1), and *Annals of Surgery* (6.329; n = 1).

The other 10 articles (17.9%) were published in the second group of journals, which included 4 higher education and 3 educational psychiatry journals (2012 Journal Impact Factor; no. of articles): *Review of Educational Research* (4.229; n = 2), *Journal of the Learning Sciences* (3.036; n = 1), *Studies in Higher Education* (1.036; n = 1), *Learning and Instruction* (3.337; n = 1), *Educational Psychologist* (3.289; n = 3), *Educational Psychology Review* (2.154; n = 1), and *Assessment* (2.430; n = 1).

The most frequently cited article was "Evidence-based medicine: A new approach to teaching the practice of medicine" by the Evidence-Based Medicine Working Group, published in *JAMA–Journal of the American Medical Association* in 1992 and cited 1,278 times over 22 years.[77] Two articles shared the rank of 50th: "Do clinical clerks suffer ethical erosion? Students' perceptions of their ethical environment and personal development" by Feudtner et al,[47] which was published in *Academic Medicine* in 1994 and cited 213 times over 20 years, and "The mini-CEX: A method for assessing clinical skills" by Norcini et al,[106] which was published in *Annals of Internal Medicine* in 2003 and cited 213 times over 11 years. Most articles originated from academic institutions, with first authors from the United States (n = 35; 62.5%), Canada (n = 8; 14.3%), the Netherlands (n = 6; 10.7%), the United Kingdom (n = 4; 7.1%), Australia (n = 1; 1.8%), Belgium (n = 1; 1.8%), and New Zealand (n = 1; 1.8%).

The articles were published within a 28-year period (1979–2007) (see Table 2). The number of highly cited articles increased significantly after 1990, and the majority (n = 50; 89.3%) were published in the period from 1991 to 2007 (Table 2). There was no correlation between the year of publication and the number of citations obtained by an article ($R^2 = 0.0033$) (see Supplemental Digital Figure 1B at http://links.lww.com/ACADMED/A285).

Further assessment of the articles in List B revealed that 20 of the top-cited medical education articles published in non-medical-education journals were also among their respective journals' 50 top-cited articles: *JAMA–Journal of the American Medical Association*,[77,84,85,92,97] *CMAJ–Canadian Medical Association Journal*,[78] *Annals of Internal Medicine*,[80] *BMJ–British Medical Journal*,[91] *Journal of the American College of Surgeons*,[93] *BJA–British Journal of Anaesthesia*,[100] *Educational Psychologist*,[81,88,89] *Review of Educational Research*,[82,87] *Assessment*,[83] *Journal of the Learning Sciences*,[86] *Educational Psychology Review*,[94] *Studies in Higher Education*,[95] and *Learning and Instruction*.[101]

Again in List B, the two articles Schmidt authored[33,46] and the three articles Schmidt coauthored with Norman[23,24,43] were among the top-cited articles, as were the two papers on the hidden curriculum authored or coauthored by Hafferty.[29,31] List B included three articles by Van Der Vleuten on assessment,[35,44,99] two of which were also included in List A.[35,44] Epstein authored two articles[85,96] and coauthored two articles[79,97] on assessing professional competence and mindful practice of assessment. Also, Papadakis coauthored two articles[71,104] on unprofessional behavior and disciplinary action by medical boards (see Appendix 2).

### Articles included in both lists

Comparison of the top-cited articles included in the two lists—articles identified by searching medical education journals (category search; List A) or by searching using keywords (List B)—revealed that there were 26 articles identified by both searches.[21–39,41–47]

## Discussion

The aim of this study was to identify the 50 most frequently cited articles in medical education and to examine their characteristics in order to gain insight into the history and main developments of the medical education field. To ensure that articles published in journals other than journals that specialized in medical education were identified, two searches were conducted in the Web of Knowledge. The first search was a category search covering 13 medical education journals (List A), and the second search used keywords related to major medical education topics covered under medical education to search across all journals listed in the Web of Knowledge (List B). In both searches, most of the top-cited articles identified originated from the United States, Canada, the United Kingdom, or the Netherlands, and the top-cited articles were published in the English language. Similar findings have been reported in other fields.[16,107]

The findings from this study show that there were 26 articles included in both lists, but the rankings of these articles differed in List A (Appendix 1) and List B (Appendix 2). The keyword search revealed that there were top-cited papers on medical education published in journals other than those that specialized in medical education: 29 (51.8%) of the 56 articles included in List B were not published in medical education journals. These non-medical-education journals had 2012 Journal Impact Factors ranging from 1.036 (*Studies in Higher Education*) to 51.658 (*The New England Journal of Medicine*), and they covered a range of disciplines including general medicine, surgery, higher education, and educational psychology. The finding that more than half of the articles in List B were published in non-medical-education journals is consistent with the integrated nature of medical education and the breadth of its subspecialties. It also shows the interest of general medicine journals and some surgery journals in publishing articles on topics related to medical education.

It is of interest to note that articles published in general medicine journals attracted more citations than those published in medical education journals. However, the range of numbers of citations for medical education articles was considerably lower than the range of numbers of citations obtained by classic articles in other disciplines such as surgery, medicine, and pediatrics.[9,11,14]

The finding that 20 of the top-cited medical education papers published in general medicine, educational psychology, and higher education journals were also among the 50 top-cited papers in their respective journals shows the ability of these articles to compete with subject-based articles published in these specialized journals.

The topics covered by the articles in List A and List B were nearly the same, although the number of articles in each topic varied. Interestingly, in both lists, the majority of the articles were not research papers: Only 8 articles (14.3%) in List A and 13 articles (23.2%) in List B were research papers (see Table 1). Four research papers were included in both lists.[37,41,45,47] Most of the research papers were qualitative studies (n = 5 in List A, n = 8 in List B); the others were quantitative studies (n = 3 in List A, n = 5 in List B). The methods used in qualitative studies in both lists included face-to-face interviews, questionnaires, observations, and anonymous mailed surveys with follow-up letters and/or telephone surveys. Only 3 research papers used a randomized controlled study design,[84,90,93] and 2 were case–control studies.[71,104] The small number of randomized controlled and case–control studies in medical education research is related to the difficulty in designing such studies in an educational program.[108]

Two other studies are of interest to this work.[109,110] Sampson et al[109] examined the characteristics of medical education studies published in five general and internal medicine (GIM) journals and five medical education journals. They reported that medical education journals had a concentration of studies targeting medical students, whereas GIM journals had a concentration of studies targeting residents. Lee et al[110] aimed at assaying the nature and context of growth in publications in the medical education field from 1960 to 2010 by searching MEDLINE for articles on medical education. They found that the annual publications in medical education increased from 279 in 1960 to 3,760 in 2010. They concluded that the increases in the number of medical education publications and in the number of journals publishing medical education articles suggest growth in the field.

The present work and the study by Sampson et al[109] each found similarities in the themes of publications in both groups of journals, while the distributions for each topic or category were different. The findings of Lee et al[110] are in agreement with the present study. The numbers of citations obtained by the top-cited articles in List A and List B and the finding that articles on medical education were among the top-cited articles published in general medicine journals are indications of the increasing number of publications in

medical education and the development of new investigations in the field. Lee and colleagues'[110] findings that authors from the United States, Canada, and the Netherlands dominated the authorship are also consistent with this study's findings.

This study provides insight into knowledge generation processes that are vital in medical education practices and research work. It also honors the research leaders in the field by identifying their work that has been frequently cited by other researchers over three decades.

### Limitations and strengths

There are a few limitations of this study. First, the search methods used were based on journals with impact factors and articles published in the English language. This may have contributed to the high number of articles from Western countries, especially the United States, Canada, the Netherlands, and the United Kingdom. Therefore, influential articles in languages other than English that may have global impact were not included. Second, factors that may affect the citation rates of an article were not carefully addressed. For example, authors' self-citations were not excluded from the total number of citations, and the absolute number of citations was used to determine rank.[111] Third, the searches were conducted using only one database, the Web of Knowledge, and there is the possibility that the database's filters are not sensitive enough. For example, the article by the Medical School Objectives Writing Group[103] published in *Academic Medicine* was not identified when the search was conducted for articles published in that journal, but it was identified in the keyword search; therefore, it was included in List B but not List A. The opposite was the case for the paper by Croskerry,[40] which was included in List A but not List B. Fourth, focusing on the 50 top-cited articles represents an arbitrary number. Finally, the articles included in this study represent the search outcomes at the time the searches were conducted.

One of the strengths of this study is the use of two search methods to identify the top-cited articles. The keyword search enabled the identification of top-cited papers in medical education that were published in non-medical-education journals.

### Conclusions

This bibliometric study identified the most frequently cited medical education papers published in medical education journals (List A) and across all journals listed in the Web of Knowledge (List B). The results show the impact that the articles have had on the scientific community and the field of medical education. The "classic" articles identified in this study are landmark papers that have contributed greatly to the field. Evidence of influential scholarship such as what is shown in this study could be considered as one criterion for awards in medical education scholarship such as the Karolinska Institutet awards.

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*Other disclosures:* None reported.

*Ethical approval:* Reported as not applicable.

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# Appendix 1

**Top-Cited Medical Education Articles Published in Medical Education Journals, Identified by Category Search in the Web of Knowledge, Ranked From 1 to 50 (List A)[a]**

| Rank[b] | Authors, year[reference] | Article (journal) | Category | No. of citations | Origin: First author's organization, location (country) |
|---|---|---|---|---|---|
| 1 | Albanese and Mitchell, 1993[21] | Problem-based learning: A review of literature on its outcomes and implementation issues (*Academic Medicine*) | Review | 861 | University of Iowa College of Medicine, Iowa City, Iowa (United States) |
| 2 | Issenberg et al, 2005[22] | Features and uses of high-fidelity medical simulations that lead to effective learning: A BEME systematic review (*Medical Teacher*) | Review | 596 | University of Miami School of Medicine, Miami, Florida (United States) |
| 3 | Norman and Schmidt, 1992[23] | The psychological basis of problem-based learning: A review of the evidence (*Academic Medicine*) | Review | 533 | McMaster University, Hamilton, Ontario (Canada) |
| 4 | Schmidt et al, 1990[24] | A cognitive perspective on medical expertise: Theory and implication (*Academic Medicine*) | Review | 523 | University of Limburg, Maastricht (The Netherlands) |
| 5 | Vernon and Blake, 1993[25] | Does problem-based learning work? A meta-analysis of evaluative research (*Academic Medicine*) | Review | 493 | University of Missouri–Columbia School of Medicine, Columbia, Missouri (United States) |
| 6 | Ericsson, 2004[26] | Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains (*Academic Medicine*) | Article | 478 | Florida State University, Tallahassee, Florida (United States) |
| 7 | Graham et al, 2006[27] | Lost in knowledge translation: Time for a map? (*The Journal of Continuing Education in the Health Professions*) | Review | 472 | University of Ottawa, Ottawa, Ontario (Canada) |
| 8 | Harden and Gleeson, 1979[28] | Assessment of clinical competence using an objective structured clinical examination (OSCE) (*Medical Education*) | Article | 470 | Ninewells Hospital and Medical School, Dundee (United Kingdom) |
| 9 | Hafferty and Franks, 1994[29] | The hidden curriculum, ethics teaching, and the structure of medical education (*Academic Medicine*) | Article | 445 | University of Minnesota, Duluth School of Medicine, Duluth, Minnesota (United States) |
| 10 | Miller, 1990[30] | The assessment of clinical skills/competence/ performance (*Academic Medicine*) | Review | 418 | University of Illinois, Urbana–Champaign, Urbana–Champaign, Illinois (United States) |
| 11 | Hafferty, 1998[31] | Beyond curriculum reform: Confronting medicine's hidden curriculum (*Academic Medicine*) | Article | 388 | University of Minnesota–Duluth School of Medicine, Duluth, Minnesota (United States) |
| 12 | Barrows, 1986[32] | A taxonomy of problem-based learning methods (*Medical Education*) | Article | 387 | Southern Illinois University School of Medicine, Springfield, Illinois (United States) |
| 13 | Schmidt, 1983[33] | Problem-based learning: Rationale and description (*Medical Education*) | Review | 355 | University of Limburg, Maastricht (The Netherlands) |
| 14 | Colliver, 2000[34] | Effectiveness of problem-based learning curricula: Research and theory (*Academic Medicine*) | Article | 328 | Southern Illinois University School of Medicine, Springfield, Illinois (United States) |
| 15 | Van Der Vleuten, 1996[35] | The assessment of professional competence: Developments, research and practical implications (*Advances in Health Sciences Education: Theory and Practice*) | Review | 294 | Maastricht University, Maastricht (The Netherlands) |
| 16 | Irby, 1995[36] | Teaching and learning in ambulatory care settings: A thematic review of the literature (*Academic Medicine*) | Review | 283 | University of Washington School of Medicine, Seattle, Washington (United States) |
| 17 | Regehr et al, 1998[37] | Comparing the psychometric properties of checklists and global rating scales for assessing performance on an OSCE-format examination (*Academic Medicine*) | Research paper | 276 | Faculty of Medicine, University of Toronto, Toronto, Ontario (Canada) |
| 18 | Barrows, 1993[38] | An overview of the uses of standardized patients for teaching and evaluating clinical skills (*Academic Medicine*) | Article | 260 | Southern Illinois University School of Medicine, Springfield, Illinois (United States) |
| 19 | Ruiz et al, 2006[39] | The impact of E-learning in medical education (*Academic Medicine*) | Review | 257 | University of Miami Miller School of Medicine, Miami, Florida (United States) |

(*Appendix continues*)

# Appendix 1
(Continued)

| Rank[b] | Authors, year[reference] | Article (journal) | Category | No. of citations | Origin: First author's organization, location (country) |
|---|---|---|---|---|---|
| 20 | Croskerry, 2003[40] | The importance of cognitive errors in diagnosis and strategies to minimize them (*Academic Medicine*) | Article | 246 | Dalhousie University Faculty of Medicine, Halifax, Nova Scotia (Canada) |
| 21 | Sutcliffe et al, 2004[41] | Communication failures: An insidious contributor to medical mishaps (*Academic Medicine*) | Research paper | 233 | University of Michigan Business School, Ann Arbor, Michigan (United States) |
| 22 | Makoul, 2001[42] | Essential elements of communication in medical encounters: The Kalamazoo consensus statement (*Academic Medicine*) | Article | 232 | Northwestern University Medical School, Chicago, Illinois (United States) |
| 23 | Norman and Schmidt, 2000[43] | Effectiveness of problem-based learning curricula: Theory, practice and paper darts (*Medical Education*) | Article | 223 | McMaster University, Hamilton, Ontario (Canada) |
| 24 | van der Vleuten and Schuwirth, 2005[44] | Assessing professional competence: From methods to programmes (*Medical Education*) | Review | 221 | University of Maastricht, Maastricht (The Netherlands) |
| 24 | Newble and Jaeger, 1983[45] | The effect of assessments and examinations on the learning of medical students (*Medical Education*) | Research paper | 221 | University of Adelaide, Adelaide, South Australia (Australia) |
| 25 | Schmidt, 1993[46] | Foundations of problem-based learning: Some explanatory notes (*Medical Education*) | Article | 216 | University of Limburg, Maastricht (The Netherlands) |
| 26 | Feudtner et al, 1994[47] | Do clinical clerks suffer ethical erosion? Students' perceptions of their ethical environment and personal development (*Academic Medicine*) | Research paper | 213 | University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania (United States) |
| 27 | Wilkerson and Irby, 1998[48] | Strategies for improving teaching practices: A comprehensive approach to faculty development (*Academic Medicine*) | Article | 212 | University of California, Los Angeles, Los Angeles, California (United States) |
| 28 | Downing, 2003[49] | Validity: On meaningful interpretation of assessment data (*Medical Education*) | Article | 209 | University of Illinois at Chicago (United States) |
| 29 | Dyrbye et al, 2006[50] | Systematic review of depression, anxiety, and other indicators of psychological distress among U.S. and Canadian medical students (*Academic Medicine*) | Review | 208 | Mayo Clinic, Rochester, Minnesota (United States) |
| 30 | Gordon, 1991[51] | A review of the validity and accuracy of self-assessments in health professions training (*Academic Medicine*) | Review | 205 | University of Washington School of Medicine, Seattle, Washington (United States) |
| 31 | Steinert et al, 2006[52] | A systematic review of faculty development initiatives designed to improve teaching effectiveness in medical education: BEME guide no. 8 (*Medical Teacher*) | Review | 202 | Faculty of Medicine, McGill University, Montreal, Quebec (Canada) |
| 32 | Ziv et al, 2003[53] | Simulation-based medical education: An ethical imperative (*Academic Medicine*) | Review | 198 | Chaim Sheba Medical Center, and Israel Center for Medical Simulation (MSR), Tel-Hashomer (Israel) |
| 32 | Carraccio et al, 2002[54] | Shifting paradigms: From Flexner to competencies (*Academic Medicine*) | Review | 198 | University of Maryland, Baltimore, Baltimore, Maryland (United States) |
| 33 | Norman, 2005[55] | Research in clinical reasoning: Past history and current trends (*Medical Education*) | Review | 197 | Michael De Groote Centre for Learning and Discovery, McMaster University, Hamilton, Ontario (Canada) |
| 34 | Newble and Entwistle, 1986[56] | Learning styles and approaches: Implications for medical education (*Medical Education*) | Review | 193 | University of Adelaide, Adelaide, South Australia (Australia) |
| 34 | Harden et al, 1999[57] | AMEE guide no. 14: Outcome-based education: Part 5—From competency to meta-competency: A model for the specification of learning outcomes (*Medical Teacher*) | Educational guide | 193 | Centre for Medical Education, Dundee (United Kingdom) |
| 35 | Bland et al, 1995[58] | Determinants of primary care specialty choice: A non-statistical meta-analysis of the literature (*Academic Medicine*) | Review | 186 | University of Minnesota Medical School, Minneapolis, Minnesota (United States) |

(*Appendix continues*)

## Appendix 1
(Continued)

| Rank[b] | Authors, year[reference] | Article (journal) | Category | No. of citations | Origin: First author's organization, location (country) |
|---|---|---|---|---|---|
| 35 | Irby, 1994[59] | What clinical teachers in medicine need to know (*Academic Medicine*) | Review | 186 | University of Washington School of Medicine, Seattle, Washington (United States) |
| 36 | Swick, 2000[60] | Toward a normative definition of medical professionalism (*Academic Medicine*) | Article | 184 | Institute of Medicine and Humanities, Saint Patrick Hospital, Missoula, Montana (United States) |
| 37 | Arnold, 2002[61] | Assessing professional behavior: Yesterday, today, and tomorrow (*Academic Medicine*) | Review | 181 | University of Missouri–Kansas City School of Medicine, Kansas City, Missouri (United States) |
| 38 | Regehr and Norman, 1996[62] | Issues in cognitive psychology: Implications for professional education (*Academic Medicine*) | Review | 177 | University of Toronto Faculty of Medicine, Toronto, Ontario (Canada) |
| 39 | Massaro, 1993[63] | Introducing physician order entry at a major academic medical center: II. Impact on medical education (*Academic Medicine*) | Article | 166 | University of Virginia (UVA), School of Medicine, Charlottesville, Virginia (United States) |
| 39 | Kneebone, 2003[64] | Simulation in surgical training: Educational issues and practical implications (*Medical Education*) | Article | 166 | Imperial College London, London (United Kingdom) |
| 40 | Hammick et al, 2007[65] | A best evidence systematic review of interprofessional education: BEME guide no. 9 (*Medical Teacher*) | Educational guide | 165 | University of Central England, Birmingham, West Midlands (United Kingdom) |
| 41 | Eva, 2005[66] | What every teacher needs to know about clinical reasoning (*Medical Education*) | Article | 163 | McMaster University, Hamilton, Ontario (Canada) |
| 42 | Samkoff and Jacques, 1991[67] | A review of studies concerning effects of sleep deprivation and fatigue on residents' performance (*Academic Medicine*) | Review | 159 | Keystone Peer Review Organization, Pennsylvania Medical Society, Harrisburg, Pennsylvania (United States) |
| 43 | Kilminster and Jolly, 2000[68] | Effective supervision in clinical practice settings: A literature review (*Medical Education*) | Review | 160 | University of Sheffield, Northern General Hospital, Sheffield (United Kingdom) |
| 44 | Hall and Weaver, 2001[69] | Interdisciplinary education and teamwork: A long and winding road (*Medical Education*) | Review | 156 | University of Ottawa Institute of Palliative Care, Ottawa, Ontario (Canada) |
| 45 | Walton and Matthews, 1989[70] | Essentials of problem-based learning (*Medical Education*) | Review | 155 | University Medical School, Edinburgh, Scotland (United Kingdom) |
| 46 | Papadakis et al, 2004[71] | Unprofessional behavior in medical school is associated with subsequent disciplinary action by a state medical board (*Academic Medicine*) | Research paper | 152 | University of California, San Francisco, San Francisco, California (United States) |
| 46 | Faulkner et al, 1996[72] | Validation of an objective structured assessment of technical skill for surgical residents (*Academic Medicine*) | Research paper | 152 | University of Toronto Faculty of Medicine (UTFM), Toronto, Ontario (Canada) |
| 47 | Hojat et al, 2004[73] | An empirical study of decline in empathy in medical school (*Medical Education*) | Research paper | 149 | Center for Research in Medical Education and Health Care, Jefferson Medical College, Philadelphia, Pennsylvania (United States) |
| 48 | Betancourt, 2003[74] | Cross-cultural medical education: Conceptual approaches and frameworks for evaluation (*Academic Medicine*) | Article | 144 | Massachusetts General Hospital, Boston, Massachusetts (United States) |
| 49 | Palepu et al, 1998[75] | Junior faculty members' mentoring relationships and their professional development in U.S. medical schools (*Academic Medicine*) | Research paper | 143 | Boston Medical Center, Boston University School of Medicine, Boston, Massachusetts (United States) |
| 50 | Kaufman et al, 1989[76] | The New Mexico experiment: Educational innovation and institutional change (*Academic Medicine*) | Article | 141 | University of New Mexico School of Medicine, Albuquerque, New Mexico (United States) |

[a]The articles in List A were identified via a category search conducted from March 1 to 12, 2014, of the 13 medical education journals in the category "Education, Scientific Discipline" in the Web of Knowledge (1900–2014). See the Method section for definitions of article types.

[b]Because 6 articles shared the same numbers of citations, List A comprised 56 articles. Articles with the same citation counts had the rank numbers 24, 32, 34, 35, 39, and 46. References 21–39 and 41–47 were included in both this list and List B (see Appendix 2) but with different rank numbers.

# Appendix 2

**Top-Cited Medical Education Articles Published Across All Journals Listed in the Web of Knowledge, Identified by Keyword Search, Ranked From 1 to 50 (List B)[a]**

| Rank[b] | Authors, year[reference] | Article (journal) | Category | No. of citations | Origin: first author organization, location (country) |
|---|---|---|---|---|---|
| 1 | Evidence-Based Medicine Working Group, 1992[77] | Evidence-based medicine: A new approach to teaching the practice of medicine (*Journal of the American Medical Association*) | Review | 1,278 | McMaster University, Hamilton, Ontario (Canada) |
| 2 | Stewart, 1995[78] | Effective physician–patient communication and health outcomes: A review (*Canadian Medical Association Journal*) | Research paper | 1,210 | University of Western Ontario, London, Ontario (Canada) |
| 3 | Albanese and Mitchell, 1993[21] | Problem-based learning: A review of literature on its outcomes and implementation issues (*Academic Medicine*) | Review | 861 | University of Iowa College of Medicine, Iowa City, Iowa (United States) |
| 4 | Epstein and Hundert, 2002[79] | Defining and assessing professional competence (*Journal of the American Medical Association*) | Review | 677 | University of Rochester School of Medicine and Dentistry, Rochester, New York (United States) |
| 5 | ABIM Foundation et al, 2002[80] | Medical professionalism in the new millennium: A physician charter (*Annals of Internal Medicine*) | Article | 669 | ABIM Foundation, Philadelphia, Pennsylvania (United States) |
| 6 | Issenberg et al, 2005[22] | Features and uses of high-fidelity medical simulations that lead to effective learning: A BEME systematic review (*Medical Teacher*) | Review | 596 | University of Miami School of Medicine, Miami, Florida (United States) |
| 7 | Kirschner et al, 2006[81] | Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching (*Educational Psychologist*) | Review | 576 | Open University of the Netherlands, Heerlen (The Netherlands) |
| 8 | Norman and Schmidt, 1992[23] | The psychological basis of problem-based learning: A review of the evidence (*Academic Medicine*) | Review | 533 | McMaster University, Hamilton, Ontario (Canada) |
| 9 | Schmidt et al, 1990[24] | A cognitive perspective on medical expertise: Theory and implication (*Academic Medicine*) | Review | 523 | University of Limburg, Maastricht (The Netherlands) |
| 10 | Vernon and Blake, 1993[25] | Does problem-based learning work? A meta-analysis of evaluative research (*Academic Medicine*) | Review | 493 | University of Missouri-Columbia School of Medicine, Columbia, Missouri (United States) |
| 11 | Butler and Winne, 1995[82] | Feedback and self-regulated learning—A theoretical synthesis (*Review of Educational Research*) | Review | 482 | University of British Columbia, Vancouver, British Columbia (Canada) |
| 12 | Ericsson, 2004[26] | Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains (*Academic Medicine*) | Article | 478 | Florida State University, Tallahassee, Florida (United States) |
| 13 | Graham et al, 2006[27] | Lost in knowledge translation: Time for a map? (*Journal of Continuing Education in the Health Professions*) | Review | 472 | University of Ottawa, Ottawa, Ontario (Canada) |
| 14 | Harden and Gleeson, 1979[28] | Assessment of clinical competence using an objective structured clinical examination (*Medical Education*) | Article | 470 | University Department of Surgery and Centre for Medical Education, Ninewells Hospital and Medical School, Dundee (United Kingdom) |
| 15 | Baer et al, 2006[83] | Using self-report assessment methods to explore facets of mindfulness (*Assessment*) | Research paper | 469 | University of Kentucky, Lexington, Kentucky (United States) |
| 16 | Peabody et al, 2000[84] | Comparison of vignettes, standardized patients, and chart abstraction: A prospective validation study of 3 methods for measuring quality (*Journal of the American Medical Association*) | Research paper | 461 | University of California, Oakland, California (United States) |
| 17 | Epstein, 1999[85] | Mindful practice (*Journal of the American Medical Association*) | Review | 457 | University of Rochester School of Medicine and Dentistry, Rochester, New York (United States) |
| 18 | Anderson et al, 1995[86] | Cognitive tutor: Lessons learned (*Journal of the Learning Sciences*) | Review | 449 | Carnegie Mellon University, Pittsburg, Pennsylvania (United States) |
| 18 | Hattie and Timperley, 2007[87] | The power of feedback (*Review of Educational Research*) | Review | 449 | University of Auckland, Auckland (New Zealand) |

(*Appendix continues*)

## Appendix 2
(Continued)

| Rank[b] | Authors, year[reference] | Article (journal) | Category | No. of citations | Origin: first author organization, location (country) |
|---|---|---|---|---|---|
| 19 | Hafferty and Franks, 1994[29] | The hidden curriculum, ethics teaching, and the structure of medical education (*Academic Medicine*) | Article | 445 | University of Minnesota, Duluth School of Medicine, Duluth, Minnesota (United States) |
| 20 | Deci et al, 1991[88] | Motivation and education—the self-determination perspective (*Educational Psychologist*) | Article | 436 | University of Rochester, Rochester, New York (United States) |
| 21 | Miller, 1990[30] | The assessment of clinical skills/competence/performance (*Academic Medicine*) | Review | 418 | University of Illinois, Urbana–Champaign, Urbana–Champaign, Illinois (United States) |
| 22 | Schunk, 1991[89] | Self-efficacy and academic motivation (*Educational Psychologist*) | Review | 408 | University of North Carolina at Greensboro, Greensboro, North Carolina (United States) |
| 23 | Roter et al, 1995[90] | Improving physicians' interviewing skills and reducing patients' emotional distress. A randomized clinical trial (*Archives of Internal Medicine*) | Research paper | 406 | Johns Hopkins University, Baltimore, Maryland (United States) |
| 24 | Hafferty, 1998[31] | Beyond curriculum reform: Confronting medicine's hidden curriculum (*Academic Medicine*) | Article | 388 | University of Minnesota–Duluth School of Medicine, Duluth, Minnesota (United States) |
| 25 | Barrows, 1986[32] | A taxonomy of problem-based learning methods (*Medical Education*) | Article | 387 | Southern Illinois University School of Medicine, Carbondale and Springfield, Illinois (United States) |
| 26 | Simpson et al, 1991[91] | Doctor–patient communication: The Toronto consensus statement (*British Medical Journal*) | Review | 363 | University of Toronto, Toronto, Ontario (Canada) |
| 27 | Schmidt, 1983[33] | Problem-based learning: Rationale and description (*Medical Education*) | Review | 355 | University of Limburg, Maastricht (The Netherlands) |
| 28 | Issenberg et al, 1999[92] | Simulation technology for health care professional skills training and assessment (*Journal of the American Medical Association*) | Review | 352 | University of Miami School of Medicine, Miami, Florida (United States) |
| 29 | Colliver, 2000[34] | Effectiveness of problem-based learning curricula: Research and theory (*Academic Medicine*) | Article | 328 | Southern Illinois University School of Medicine, Springfield, Illinois (United States) |
| 30 | Scott et al, 2000[93] | Laparoscopic training on bench models: Better and more cost effective than operating room experience? (*Journal of the American College of Surgeons*) | Research paper | 327 | University of Texas Southwestern Medical Center, Dallas (United States) |
| 31 | Hmelo-Silver, 2004[94] | Problem-based learning: What and how do students learn? (*Educational Psychology Review*) | Review | 315 | The State University of New Jersey, New Brunswick, New Jersey (United States) |
| 32 | Van Der Vleuten, 1996[35] | The assessment of professional competence: Developments, research and practical implications (*Advances in Health Sciences Education*) | Review | 294 | Maastricht University, Maastricht (The Netherlands) |
| 33 | Nicol and Macfarlane-Dick, 2006[95] | Formative assessment and self-regulated learning: A model and seven principles of good feedback practice (*Studies in Higher Education*) | Review | 284 | University of Strathclyde, Glasgow (United Kingdom) |
| 34 | Irby, 1995[36] | Teaching and learning in ambulatory care settings: A thematic review of the literature (*Academic Medicine*) | Review | 283 | University of Washington School of Medicine, Seattle, Washington (United States) |
| 35 | Epstein, 2007[96] | Assessment in medical education (*The New England Journal of Medicine*) | Review | 277 | University of Rochester School of Medicine and Dentistry, Rochester, New York (United States) |
| 36 | Regehr et al, 1998[37] | Comparing the psychometric properties of checklists and global rating scales for assessing performance on an OSCE-format examination (*Academic Medicine*) | Research paper | 276 | Faculty of Medicine, University of Toronto, Ontario (Canada) |
| 37 | Novack et al, 1997[97] | Calibrating the physician. Personal awareness and effective patient care. Working Group on Promoting Physician Personal Awareness, American Academy on Physician and Patient (*Journal of the American Medical Association*) | Article | 265 | Allegheny University of the Health Sciences, Philadelphia, Pennsylvania (United States) |

(*Appendix continues*)

## Appendix 2
(Continued)

| Rank[b] | Authors, year[reference] | Article (journal) | Category | No. of citations | Origin: first author organization, location (country) |
|---|---|---|---|---|---|
| 38 | Gallagher et al, 2005[98] | Virtual reality simulation for the operating room: Proficiency-based training as a paradigm shift in surgical skills training (*Annals of Surgery*) | Review | 263 | Emory University School of Medicine, Atlanta, Georgia (United States) |
| 39 | Barrows, 1993[38] | An overview of the uses of standardized patients for teaching and evaluating clinical skills (*Academic Medicine*) | Article | 260 | Southern Illinois University School of Medicine, Springfield, Illinois (United States) |
| 40 | Ruiz et al, 2006[39] | The impact of E-learning in medical education (*Academic Medicine*) | Review | 257 | University of Miami Miller School of Medicine, Miami, Florida (United States) |
| 41 | Wass et al, 2001[99] | Assessment of clinical competence (*The Lancet*) | Review | 255 | Guy's, King's and St Thomas' School of Medicine, Weston Education Centre, London (United Kingdom) |
| 42 | Fletcher et al, 2003[100] | Anaesthetists' Non-Technical Skills (ANTS): Evaluation of a behavioural marker system (*British Journal of Anaesthesia*) | Research paper | 243 | University of Aberdeen, King's College, Aberdeen (United Kingdom) |
| 43 | Dochy et al, 2003[101] | Effects of problem-based learning: A meta-analysis (*Learning and Instruction*) | Review | 237 | University of Leuven, Afdeling Didactiek, Leuven (Belgium) |
| 43 | Wetzel et al, 1998[102] | Courses involving complementary and alternative medicine at U.S. medical schools (*Journal of the American Medical Association*) | Research paper | 237 | Harvard Medical School, Boston, Massachusetts (United States) |
| 44 | Sutcliffe et al, 2004[41] | Communication failures: An insidious contributor to medical mishaps (*Academic Medicine*) | Research paper | 233 | University of Michigan Business School, Ann Arbor, Michigan (United States) |
| 44 | Medical School Objectives Writing Group, 1999[103] | Learning objectives for medical student education—Guidelines for medical schools: Report I of the Medical School Objectives Project (*Academic Medicine*) | Review | 233 | Association of American Medical Colleges, Washington, DC (United States) |
| 45 | Makoul, 2001[42] | Essential elements of communication in medical encounters: The Kalamazoo consensus statement (*Academic Medicine*) | Article | 232 | Northwestern University Medical School, Chicago, Illinois (United States) |
| 46 | Papadakis et al, 2005[104] | Disciplinary action by medical boards and prior behavior in medical school (*The New England Journal of Medicine*) | Research paper | 230 | University of California, San Francisco, San Francisco, California (United States) |
| 47 | Norman and Schmidt, 2000[43] | Effectiveness of problem-based learning curricula: Theory, practice and paper darts (*Medical Education*) | Article | 223 | McMaster University, Hamilton, Ontario (Canada) |
| 48 | van der Vleuten and Schuwirth, 2005[44] | Assessing professional competence: From methods to programmes (*Medical Education*) | Review | 221 | University of Maastricht, Maastricht (The Netherlands) |
| 48 | Newble and Jaeger, 1983[45] | The effect of assessments and examinations on the learning of medical students (*Medical Education*) | Research paper | 221 | University of Adelaide, Adelaide, South Australia (Australia) |
| 48 | Cooke et al, 2006[105] | American medical education 100 years after the Flexner report (*The New England Journal of Medicine*) | Review | 221 | University of California, San Francisco, San Francisco, California (United States) |
| 49 | Schmidt, 1993[46] | Foundations of problem-based learning: Some explanatory notes (*Medical Education*) | Article | 216 | University of Limburg, Maastricht (The Netherlands) |
| 50 | Feudtner et al, 1994[47] | Do clinical clerks suffer ethical erosion? Students' perceptions of their ethical environment and personal development (*Academic Medicine*) | Research paper | 213 | University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania (United States) |
| 50 | Norcini et al, 2003[106] | The mini-CEX: A method for assessing clinical skills (*Annals of Internal Medicine*) | Research paper | 213 | Foundation for Advancement of International Medical Education and Research and American Board of Internal Medicine, Philadelphia, Pennsylvania (United States) |

[a]The articles in List B were identified via a keyword search conducted from March 1 to 12, 2014, across all journals listed in the Web of Knowledge (1900–2014). See the Method section for keywords searched and definitions of article types.

[b]Because 6 articles shared the same numbers of citations, List B comprised 56 articles. Articles with the same citation counts had rank numbers 18, 43, 44, 48, and 50. References 21–39 and 41–47 were included in both this list and List A (see Appendix 1) but with different rank numbers.