ACCSCIENCE PUBLISHING

INNOSC Theranostics and Pharmacological Sciences

REVIEW ARTICLE

Leveraging bibliometric analysis competencies for improved postgraduate pharmaceutical education in China

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Abstract

Postgraduate pharmaceutical students are at the forefront of drug development and application in China. In recent years, global pandemics, demand for the research and development of new drugs, and college and university requirements of outcome-based education (OBE) indicate that major reforms in postgraduate pharmaceutical education are essential. A currently neglected aspect of OBE in Chinese pharmaceutical education is bibliometric analysis. To establish a framework for bibliometric analysis training, the researchers searched the top 50 research works in major academic databases using the keywords "Pharmacy education" and "Framework." Ten papers were selected that were closest to the desired paradigm. The procedures, theoretics, and goals of the frameworks in these papers were combined with the researchers' teaching and research experience to construct a bibliometric analysis competency (BAC) framework. The BAC framework, which was created to fill current gaps in postgraduate pharmaceutical education, constitutes three levels: (A) knowledge; (B) familiarization; and (C) mastering. The three levels require graduate students to (A) have a preliminary understanding of the steps of bibliometrics, (B) comprehend the literature on bibliometrics, and (C) independently apply the steps to perform bibliometric analysis, respectively. This paper also describes the theoretical setup of the BAC framework and a potential assessment system. The BAC framework provides a useful reference for the reform of Chinese pharmaceutical graduate education, and its future implementation is urgently anticipated.

Keywords: Bibliometric analysis competencies; Framework; Pharmaceutical education; Postgraduate education; China

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Citation: Huang J, Wang X, Luo R, *et al*. Leveraging bibliometric analysis competencies for improved postgraduate pharmaceutical education in China. *INNOSC Theranostics and Pharmacological Sciences.* 2025;8(1):59-70. doi: 10.36922/itps.4734

Submitted: September 2, 2024

Revised: November 4, 2024

Accepted: November 20, 2024

Published online: January 31, 2025

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1. Introduction

Since ancient times, China has attached great importance to the research, development, and application of medicines, forming a unique traditional Chinese medicine (TCM) system that involves botanic (such as the roots and seeds of *Arctium Lappa*[1]), animal (such as the musk of *Moschus berezovskii Flerov*, *Moschus sifanicus Przewalski*, or

Moschus moschiferus Linnaeus[2]), fungal (such as *Cordyceps sinensis*[3]), and mineral (such as cinnabar[4]) ingredients. Before the introduction of Western medicine, TCM was the main means of disease treatment in China. Since the introduction of the Western medicine system into China, China has also begun to advance the development and application of modern drugs, including small molecule chemical drugs,[5] biological macromolecular drugs (proteins, polysaccharide, nucleic acid, etc.),[6] and vaccines.[7] In recent years, the concept of biotherapy has also received increased attention in China. For instance, the most famous biotherapy approaches, chimeric antigen receptor (CAR)-T-cell therapy and CAR-NK cell therapy, are promising new methods of cancer treatment.[8]

The development and application of both TCM and modern medicine require pharmaceutical knowledge, which substantially depends on the cultivation of pharmaceutical talent. This cultivation is realized mainly through pharmaceutical education. Throughout history, Chinese culture has attached importance to pharmaceutical education, training numerous talented Chinese pharmacists. Sun Simiao, who presided over the world's first national pharmacopeia, *Tang Xin Materia Medica*, is well known in China to this day.[9] Furthermore, Li Shizhen's *Compendium of Materia Medica* is known as the "great book of oriental medicine."[10]

In ancient times, the cultivation of pharmaceutical talents mainly depended on the master–apprentice system. In modern China, however, the training of pharmaceutical talent has gradually shifted to the formal modern college pharmaceutical education system. In this system, postgraduate education occupies a very important position. This is because its key focus is to train masters and doctors with independent scientific research abilities and provide fresh forces for the field of drug design and development.[11] However, other components of the modern college pharmaceutical education system – that is, vocational and undergraduate education – do not focus on this aim (Figure 1). Postgraduate education is indispensable and irreplaceable for future pharmacists.

Nowadays, the main curricula for pharmacy postgraduates in China constitute some theoretical courses (such as pharmacology or pharmaceutics), experimental curricula (such as drug analysis and medicinal chemistry experimentation), and practical courses (such as internships); however, no course focuses on bibliometrics training specifically. As a result, students' abilities to analyze the existing literature and understand the status of current research, hotspots, and development trends in the pharmaceutical field are not being efficiently cultivated.

2. Background

2.1. Why propose a new framework?

With the development of the economics and technologies, the demand for health in human society is increasing, which puts forward higher requirements for the field of drug research and development. In this context, improving the training quality of postgraduate pharmaceutical students is necessary to cultivate stronger independent scientific research capabilities. This growing need is manifested at the following three levels (Figure 2):

(1) Societal level. In the context of the continuous recent increase in the incidence of tumors, cardiovascular diseases, and neurodegenerative diseases – as well as epidemics and pandemics such as COVID-19,[12] influenza A,[13] and monkeypox[14] – the demand for safe, effective, and quality-controlled drugs is increasing. With the discovery of new therapeutic targets for known diseases and the emergence of new infectious diseases, the pace of drug research and development is accelerating, and the demand for new drug development capabilities has increased significantly.

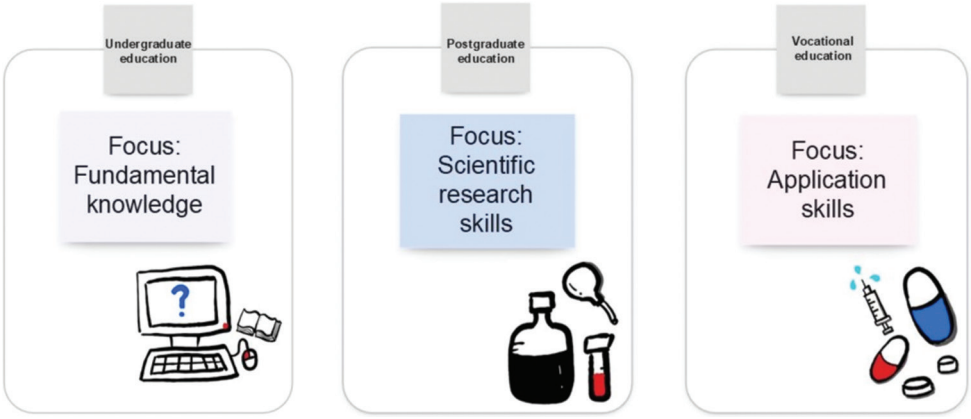


Figure 1. Key focus of each component of the modern college pharmaceutical education system

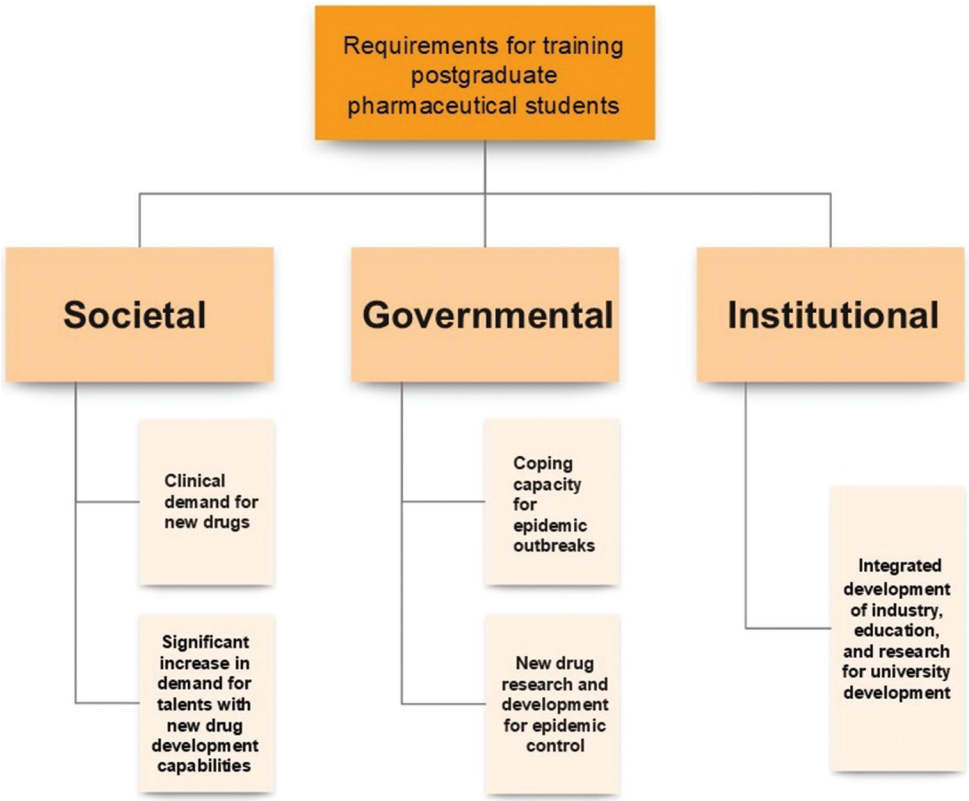


Figure 2. Requirements for training postgraduate pharmaceutical students at various levels

(2) Governmental level. Under the current situation, the ability of countries and regions to respond quickly and effectively to public health emergencies has become an important component of national system, and it is also a concrete manifestation of soft power. Taking the fight against the COVID-19 epidemic as an example, the research and development process of preventive vaccines,[15] diagnostic reagents,[16] and therapeutic drugs[17] has largely determined the effectiveness of epidemic and pandemic control. This also requires the support of new drug research and development.

(3) Institutional level. The integrated development of industry, education, and research is one of the mainstream ideas in the contemporary development of colleges and universities.[18] In the context of the growing industrial demand for drug research and development capabilities, and based on the teaching concept of outcome-based education, colleges and universities should pay more attention cultivating the independent scientific research abilities of postgraduate pharmaceutical students.

To improve the quality of postgraduate pharmaceutical training, effective education reforms are necessary to enable the cultivation of students' independent scientific research abilities and improve their competitiveness in the job market. Such reform will also hold significance for teachers as it will enhance their teaching skills. In this context, a new framework should be proposed as a theoretical guide for the corresponding pedagogical reform.

2.2. What is bibliometric analysis?

Bibliometric analysis competencies (BAC) must be part of the above-mentioned education reform and can assist in the proposal of a corresponding framework. Bibliometrics is an interdisciplinary approach in library and information management that uses both qualitative and quantitative analysis to describe and analyze the current status of scientific research in specific fields, including the number of papers, high-yield institutions, high-frequency hot words, research frontiers, and future trends. The results of bibliometric research are usually expressed in the form of graphs.[19,20] Correspondingly, bibliometric analysis refers to the following processes: (1) determination of research aim; (2) establishment of retrieval strategy; (3) literature survey; (4) software processing; (5) data interpretation; and (6) description of the knowledge domain[21] This process is illustrated in Figure 3.

Bibliometric analysis was first applied to the field of library science and information management. After years of

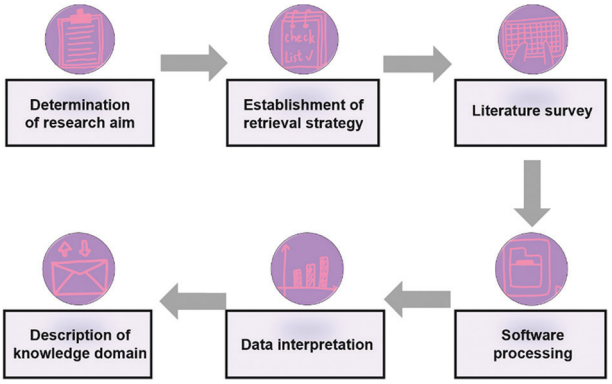


Figure 3. Bibliometric research process flowchart

development, bibliometric analysis has been widely applied to several sub-disciplines in the medical field, including physiology,[22] toxicology,[23] clinical medicine,[24] clinical chemistry,[25] public health,[26] nursing,[27] and pharmacy.[28] In the field of pharmacy, bibliometric analysis can be applied to research on various aspects of drug development, such as drug discovery,[29] medicinal chemistry,[30] natural product extraction,[31] biopharmaceutics,[32] pharmaceutical analysis,[33] pharmacology,[34] pharmaceutics,[35] pharmaceutical engineering,[36] and pharmaceutical management.[37]

Bibliometric analysis has positive implications for the field of drug discovery, and the use of bibliometric principles to evaluate, analyze, and provide historical perspective on journal evaluation has become widespread.[38] Bibliometrics has also positively influenced drug development. Bibliometric methods can be used to analyze the research status, hotspots, and development trends of drugs already on the market, which, in turn, can illuminate new directions for further research and development.[39,40] Pharmacy postgraduates, as future drug developers and researchers, should therefore master this skill to help them in their work. This article, therefore, proposes a new BAC framework as a theoretical guide to implement bibliometric training in pharmaceutical education.

3. Methods

Based on the above background, this paper proposes a framework for bibliometric analysis training. The researchers have developed the BAC framework to improve this aspect of graduate-level pharmacy education in China. The objective of this paper was to systematically analyze the existing educational resources and research findings using this framework to identify the key issues and potential areas of improvement in pharmacy postgraduate education and provide a scientific basis and guidance for future educational policies and curriculum design.

To this end, the researchers searched the literature in academic databases and search engines, including Web of Science, PubMed, Scopus, and Google Scholar on January 8, 2024, at 10 a.m. (Beijing time) using the keywords "Pharmacy education" and "Framework." Access to these databases was provided by Jinan University. The retrieved literature was sorted by relevance, and the research team downloaded the top 50 relevant papers from each search engine and read them after deduplication. The 10 papers[41-50] that were closest to the expected research paradigm of this paper (Table 1) were selected and the approaches, theoretics, and goals of these frameworks were analyzed. The team then constructed the BAC framework based on the findings as well as their own years of experience as educators and researchers.

4. Framework proposal

4.1. Tabular and schematic summary

Regarding the proposed framework, tabular and schematic summaries are provided in Table 2 and Figure 4, respectively.

4.2. Description

In this subsection, the BAC framework is explained in detail to provide some reference for the reform of pharmaceutical graduate education in China.

Based on the six technical steps of bibliometric analysis mentioned above (the determination of a research aim; the establishment of a retrieval strategy; the literature survey; software processing; data interpretation; and the description of the knowledge domain), the BAC framework is divided into three levels: A, knowledge; B, familiarization; and C, mastering (Table 2).

The internal logical relationship of the BAC framework is shown in Figure 4. Levels A–C are progressive, aligning with the principles of human cognition and higher education, and exhibit high rationality. In addition, Figure 4 shows the expected progress of the implementation of the BAC framework, which is based on a 3-year, six-semester postgraduate pharmaceutical program. In Semester 1, the pedagogy for Level A of competency is carried out as early as possible. In Semesters 2 and 3, the staff helps develop Level B competencies among postgraduate students. Based on this foundation, the remaining Semesters 4 – 6 can be used to implement the Level C training plan. Postgraduate students in other long-term study programs can make appropriate adjustments in the above schedule. A shorter study program would shorten the overall training cycle, especially Levels A and B, but should guarantee adequate training for Level C competencies. Meanwhile, a longer

Table 1. Previous studies on pharmaceutical education frameworks

No.	Journal	Title	Year of Publication	Framework Proposed	Reference
1	*Journal of Pharmaceutical Policy and Practice*	Clinical preceptor competencies for a better pharmacy education: a suggested framework for Lebanon	2020	Clinical preceptor competencies framework	Zeitoun *et al.*[41]
2	*Research in Social and Administrative Pharmacy*	Using critical realism as a framework in pharmacy education and social pharmacy research	2012	Critical realism framework	Oltmann *et al.*[42]
3	*American Journal of Pharmaceutical Education*	Entrustable professional activities as a novel framework for pharmacy education	2018	Entrustable professional activities framework	Jarrett *et al.*[43]
4	*British Pharmacological Society*	Design of a foundational sciences curriculum: applying the ICAP framework to pharmacology education in integrated medical curricula	2021	ICAP framework	Quesnelle *et al.*[44]
5	*Pharmaceutical Education*	Framework for action to implement interprofessional education and collaborative practice in pharmacy and allied health sciences programs in India	2016	Interprofessional and collaborative practice framework	Rajiahand Maharajan *et al.*[45]
6	*Pharmacy*	Development and refinement of a matrix competency framework, with associated entrustable professional activities, to support initial pharmacy education in Kuwait	2023	Matrix competency framework	Moreau *et al.*[46]
7	*Pharmacy*	Exploring the implications of a needs-based pharmacy education framework modeled on population health: perspective from a developing country	2019	Needs-based pharmacy education framework	Bheekie *et al.*[47]
8	*Nurse Education Today*	Pharmacology education: a theoretical framework of applied pharmacology and therapeutics	2003	Pharmacology education framework	Banning[48]
9	*Research in Social and Administrative Pharmacy*	Pharmacy emergency preparedness and response (PEPR): A proposed framework for expanding pharmacy professionals' roles and contributions to emergency preparedness and response during the COVID-19 pandemic and beyond	2020	PEPR framework	Aruru *et al.*[49]
10	*American Journal of Pharmaceutical Education*	Moving from injustice to equity: a time for the pharmacy profession to take action: the Rx-heart framework to address health equity and racism within pharmacy education	2021	Rx-HEART framework	Butler *et al.*[50]

Notes: There was no specified timespan for the publication search; all publications predating January 8, 2024, were eligible.
Abbreviation: ICAP: Interactive, constructive, active, and passive.

program could appropriately extend the overall training cycle.

Postgraduates should be instructed in the use of various bibliometric software (VOSviewer, CiteSpace, R, Biblioshiny, COOC, SATI, SPSS, etc.), which offer a wealth of practical tools to conduct bibliometrics research. Postgraduates' ability to evaluate and analyze the hot spots in drug research publications can be promoted after they grasp the basics of bibliometrics software. In summary, through the three-level division paradigm, we proposed the BAC framework. According to the above description, the BAC framework has a richer connotation and a more rigorous logic and, and has strong feasibility.

4.3. Significance

Through the above three-level division paradigm, the BAC framework has richer connotations for research training, a more rigorous logic, and strong practical feasibility. In the scientific research process, project initiation research is very important, and the ability to conduct such research must therefore be emphasized for the cultivation of independent scientific research abilities in postgraduate pharmaceutical students. The information obtained from bibliometric analysis can be used to explore new directions for scientific research and evaluate project feasibility. The quality of a bibliometric study may even determine the success or failure of the project. Therefore, the construction of the

Table 2. Tabular summary of the BAC framework

Level	Competency	Objective	Outcomes
A. Knowledge	Fundamental knowledge of bibliometrics	To gain basic understanding of bibliometric analysis	(1) Knowing what a research aim is and how to determine it; (2) Knowing what a retrieval strategy is and how to establish it; (3) Knowing what databases can be used for a literature survey and how to conduct a survey; (4) Knowing what software can be used for bibliometric analysis and how to process data using that software; (5) Knowing what methodologies can be used for data interpretation and how to implement them; (6) Knowing what the knowledge domain is and how to describe it.
B. Familiarization	Real-world material understanding	To independently understand the practical process of bibliometric analysis	(1) Understanding the reason for research aim determination in existing materials; (2) Understanding the logic of retrieval strategy establishment in existing materials; (3) Understanding literature survey procedures in existing materials; (4) Understanding software processing in existing materials; (5) Understanding the logic of data interpretation in existing materials; (6) Understanding the described knowledge domain in existing materials.
C. Mastering	Conducting bibliometric analysis	To independently conduct bibliometric analysis	(1) Mastering the ability to determine the research aim; (2) Mastering the ability to establish a retrieval strategy; (3) Mastering the ability to survey the literature; (4) Mastering the ability to use software for bibliometric analysis; (5) Mastering the ability to interpret bibliometric data; (6) Mastering the ability to describe the knowledge domain.

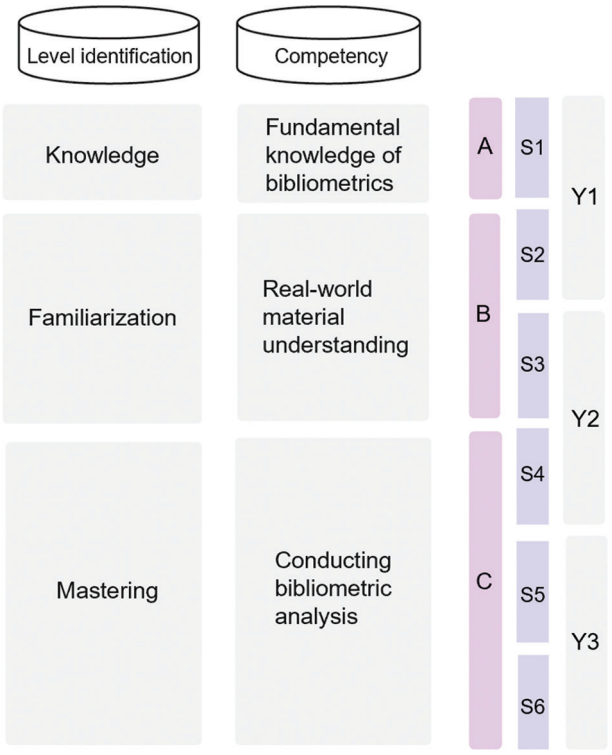


Figure 4. Graphical summary of the bibliometric analysis competencies framework
Abbreviations: S: Semester; Y: Year.

BAC framework will improve postgraduate pharmaceutical students' readiness to conduct independent scientific research in the future by optimizing their approach to project initiation.

Furthermore, the BAC framework meets the aforementioned developmental needs at the societal, governmental, and institutional levels. Society requires pharmacists with drug development capabilities to realize local governments' responses to public health emergencies along with the integrated development of industry, education, and research. In particular, the BAC framework complements the characteristics of contemporary postgraduate pharmaceutical training, which will help institutions enhance their uniqueness and academic reputation. Therefore, it is reasonable, scientific, and meaningful to implement BAC as a framework for planning, training, examining, and evaluating the independent scientific research abilities of postgraduate pharmaceutical students.

4.4. Implementation

Having proposed the BAC framework, the next consideration is its implementation. Based on the contents of Levels A-C as laid out in Table 2 and Figure 4, we propose the following implementation procedures:

(1) In Level A (knowledge), which corresponds to Semester 1 in a 3-year, six-semester postgraduate pharmaceutical program, lectures and individual asynchronous, facilitated pedagogy should be introduced. Postgraduate students will engage in bibliometrics courses, lectures, training, and

instructor-led cloud classroom learning and online discussions. Teaching Level A will primarily rely on a passive learning pedagogy.

(2) In Level B (familiarization), which corresponding to Semesters 2 and 3 of a 3-year, six-semester postgraduate pharmaceutical program, individual, asynchronous (non-facilitated), application-based learning exercises, and a team-based learning pedagogy should be introduced. Postgraduate students can join massive open online courses and study reference books independently. They will conduct independent research and group discussions according to their teachers' pre-determined questions on the six technical steps of bibliometric analysis and present their interpretations of these steps based on the materials they read in seminars. Level B can be achieved through active and constructive learning pedagogies.

(3) At Level C (mastering), which corresponds to Semesters 4 – 6 of a 3-year, six-semester postgraduate pharmaceutical program, problem-based learning, small group (non-facilitated), and simulation pedagogy should be introduced. Postgraduate students should be able to evaluate and critique the six technical steps of bibliometric analysis material provided in advance by the instructor, form small groups for self-directed learning, and use computers to conduct simulated bibliometric analyses on given research topics in communication sessions. Postgraduate students can achieve Level C through interactive learning (Table 3).[44]

The relevant elements are summarized in Table 3, based on the paradigm outlined in a previous study.[44]

Notably, Levels A and B in the above proposed implementation may need to be shortened for shorter programs; however, the training provided for Level C competencies should be retained, with an emphasis on achieving this level of competencies.

4.5. Assessment

Based on the BAC framework, the researchers developed an assessment system that focuses on the quantitative evaluation of the participating postgraduate students. The total proposed score was 100 points, including 10 points (10%) for a mentor interview, 40 points (40%) for a written report, and 50 points (50%) for a group presentation. A total score of <60 will be recorded as FAILED; 60 – 69 will be recorded as PASS; 70 – 79 will be recorded as MODERATE; 80 – 89 will be recorded as GOOD; 90 – 99 will be recorded as EXCELLENT; and 100 will be recorded as PERFECT. In this case, grades of PASS and above are considered as passing the BAC framework training, while students who receive FAILED grades require additional training.

The specific proposed grading rules are as follows:

(1) Mentor interviews. The main function of the interviews conducted by the instructor is to examine postgraduate students about their overall awareness of bibliometric analysis. The mentor determines what level (A – C) the postgraduate student's cognition has achieved, with 0 – 2 points for not achieving Level A, 3 – 4 points for achieving Level A without achieving Level B, 5 – 7 points for achieving Level B without achieving Level C, and 8 – 10 points for achieving Level C.

(2) Written report. The main content of the written report is a bibliometric analysis of a postgraduate student's

Table 3. Implementation of the BAC framework

Level code	Pedagogy	Examples	ICAP designation
A	Lectures	Bibliometrics courses, lectures, and training	Passive
	Individual asynchronous, facilitated learning	Instructor-led cloud classrooms and online discussions	Passive
B	Individual asynchronous, non-facilitated learning	Postgraduate students independently study MOOCs, literature, and references	Active
	Application-based learning exercises	Faculty members ask preset discussion questions on the six technical steps of bibliometric analysis, and postgraduate students conduct their own research and group discussions	Active
	Team-based learning	During seminars, postgraduate students develop interpretations of the bibliometric analysis material they have read based on the six technical steps	Constructive
C	Problem-based learning	Postgraduate students evaluate and critique the six technical steps of the bibliometric analysis material provided in advance by faculty members	Interactive
	Small groups (non-facilitated)	Postgraduate students form self-directed small groups	Interactive
	Simulations	After being given a research topic, postgraduate students use computers to conduct simulated bibliometric analyses	Interactive

Abbreviations: ICAP: Interactive, constructive, active, and passive; MOOCs: Massive open online courses.

self-selected research topic. Each technical step of the bibliometric analysis is scored according to both understanding and presentation, with each technical step being graded from 0 to 6 points, including 0 – 1 point for not reaching Level A, 2 – 3 points for reaching Level A without reaching Level B, 4 – 5 points for reaching Level B without reaching Level C, and 6 points for reaching Level C. In addition, the academic writing style and format of the academic report is scored from 0 to 4 points.

(3) Group presentation. The main form of the group presentation is a multimedia presentation report on a bibliometric analysis of a self-selected research topic by the postgraduate students in small groups, with each member of the group being scored equitably. The scoring module is synthesized from (1) and (2) above. First, the grader determines what level the group's cognition reaches from A to C. From here, 0 – 2 points are given for not reaching Level A, 3 – 4 points for reaching Level A without reaching Level B, 5 – 7 points for reaching Level B without reaching Level C, and 8 – 10 points for reaching Level C. Scoring is also conducted based on the understanding and presentation of the six technical steps, with 0 – 6 points given for each technical step. Here, 0 – 1 point is given for not reaching Level A, 2 – 3 points are given for reaching Level A without reaching Level B, 4 – 5 points are given for reaching Level B without reaching Level C, and 6 points are given for reaching Level C. In addition, the standardization of academic presentation style and format is given 0 – 4 points.

For simplicity, the above details are summarized in Table 4.

Based on the authors' teaching experience and the assessment system described above, a postgraduate student's assessment level can theoretically be assessed with a total score based on the contents of Table 4. For those who have not achieved Level A, the total score will be 0 – 24. For those who have achieved Level A but not Level B, the total score will be 30 – 52. For those who have achieved Level B but not Level C, the total score will be 50 – 83. Finally, for those who have achieved Level C, the total score will be 88 – 100. Based on these scores, those who have not achieved Level B will be categorized as FAILED and in need of supplemental training. Those who have achieved Level B but not Level C may be categorized as FAILED, PASSED, MODERATE, or GOOD, depending on the specific circumstances, and may need further training. Those who have reached Level C will be categorized as GOOD, EXCELLENT, or PERFECT, passing the training without further requirements.

Table 4. Assessment system grading rules for the BAC framework

Total score	Section	Achievement	Score
100	Mentor interview (10)	<A	0 – 2
		>A, <B	3 – 4
		>B, <C	5 – 7
		>C	8 – 10
	Written report (40)	<A (for each technical procedure)	0 – 1
		>A, <B (for each technical procedure)	2 – 3
		>B, <C (for each technical procedure)	4 – 5
		>C (for each technical procedure)	6
		Normalization	0 – 4
	Group presentation (50)	<A (overall understanding)	0 – 2
		>A, <B (overall understanding)	3 – 4
		>B, <C (overall understanding)	5 – 7
		>C (overall understanding)	8 – 10
		<A (for each technical procedure)	0 – 1
		>A, <B (for each technical procedure)	2 – 3
		>B, <C (for each technical procedure)	4 – 5
		>C (for each technical procedure)	6
		Normalization	0 – 4

4.6. Framework refinement

This framework is not a static system, and major and minor revisions should be conducted as necessary. First, a 3-year trial period should be conducted for this framework, tracking the BAC achievement of the subject postgraduate students from their 1st-year enrollment to their 3rd-year graduation. During this period, discussions should be held with postgraduate mentors to learn which parts the mentors feel need further optimization. The parts in need of optimization will also be determined based on the assessment results of the postgraduates. In addition, the international and domestic research reports on postgraduate pharmaceutical education should be continuously tracked, and the desirability of related frameworks should be appropriately evaluated and incorporated into optimization plans. The changes and trends in public health and the pharmaceutical industry should also be noted to improve the effectiveness of the BAC framework for all types of contingencies. Major and minor revisions will thus be made to the framework in several ways, as described above; the degree of concrete revisions will be determined and adjusted to ensure a constant and dynamic reform process.

4.7. Limitations

This framework has certain natural limitations. From a top-level design perspective, this framework is largely based on the teaching and research experience of the authors and their team; however, due to limited capacity and time, it was not possible to ensure the desirability of the established teaching and research experience. Thus, as there may be fallacies, the feasibility of the framework should be further validated.

From a practical implementation perspective, although this framework has theoretical basis and is guided by experience, it has not been piloted in a graduate pharmacy student population; therefore, its implementation requires further testing. The developed framework is expected to provide a useful reference for the reform of postgraduate pharmaceutical education in China. We plan to conduct an empirical study to test its efficacy and outcome.

The final limitation is in scope of application. The postgraduate training needs and ideas considered in designing this framework are mainly pertinent to China (and countries or regions with similar national conditions, especially some developing countries[51]) and may not be applicable to other countries or regions with different national conditions. Therefore, the potential of using the BAC framework in postgraduate pharmaceutical education in these other countries or regions should be assessed.

Despite these limitations, this framework still has significance for the reform and improvement of postgraduate pharmaceutical education. Through continuous real-world framework refinement, the potential problems in the top-level design and practical implementation can gradually be resolved. Furthermore, if there is a need to extend the framework to other countries and regions, the authors are eager to collaborate with interested institutions in those countries or regions. The core ideas of this framework can even help to establish the current situation of postgraduate pharmaceutical education in those countries or regions. Subsequently, the teaching and research experience from foreign institutions can be incorporated and an amended or new framework can be proposed.

5. Conclusion

Nowadays, there are three levels of demand for independent research skills in the pharmaceutical enterprise: these demands are from societies, from governments, and from institutions. This article proposed the integration of bibliometrics into Chinese postgraduate pharmaceutical program to establish a new framework as a theoretical guide for education reform. The BAC framework was designed by performing three levels of classification using a detailed assessment system. Institutions should carry out major and minor revisions to this framework to promote the reform of their postgraduate pharmaceutical programs. This framework could have great significance for postgraduate education through its continuous optimization using regular communication and real-time attention to developments in the domestic and international pharmaceutical industries. The continuous optimization and promotion of the framework will not only solve the problems of top-level design implementation and execution but also improve on China's current postgraduate pharmaceutical education system by enhancing the independent scientific research abilities of postgraduate pharmaceutical students, thus promoting the overall development of China's pharmaceutical industry.

Based on the findings, this study makes the following suggestions. First, it is necessary to incorporate professional bibliometrics training into the compulsory or elective courses of postgraduate students and combine theory with practice by studying real-world cases. Second, such training should be conducted by experts in bibliometrics, and advanced database resources and econometric tools should be introduced to facilitate students' econometrics learning and practice. Finally, promotional tools should be used to increase students' awareness about and interest in bibliometrics. Econometrics competitions or specific practical projects can also be conducted to strengthen students' practical skills.

Acknowledgments

None.

Funding

The authors would like to thank the financial support from Major Funding of the National Natural Science Foundation of China (Grant No. 82330112) and Guangdong Universities Keynote Regions Special Funded Project (Grant No. 2022ZDZX2002).

Conflict of interest

The authors declare that they have no competing interests.

Author contributions

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Writing – review & editing: Chuanbin Wu, Xin Pan, Xuejuan Zhang

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

Not applicable.

References

1. Chan YS, Cheng LN, Wu JH, *et al*. A review of the pharmacological effects of *Arctium lappa* (burdock). *Inflammopharmacology*. 2011;19(5):245-254.

   doi: 10.1007/s10787-010-0062-4

2. Lv S, Lei Z, Yan G, Shah SA, Ahmed S, Sun T. Chemical compositions and pharmacological activities of natural musk (*Moschus*) and artificial musk: A review. *J Ethnopharmacol*. 2022;284:114799.

   doi: 10.1016/j.jep.2021.114799

3. Chen YC, Chen YH, Pan BS, Chang MM, Huang BM. Functional study of *Cordyceps sinensis* and cordycepin in male reproduction: A review. *J Food Drug Anal*. 2017;25(1):197-205.

   doi: 10.1016/j.jfda.2016.10.020

4. Jain A, Sarsaiya S, Wu Q, Shi J, Lu Y. New insights and rethinking of cinnabar for chemical and its pharmacological dynamics. *Bioengineered*. 2019;10(1):353-364.

   doi: 10.1080/21655979.2019.1652491

5. Sanghai N, Vuong B, Burak Berk A, Afridi MSK, Tranmer GK. Current small molecule-based medicinal chemistry approaches for neurodegeneration therapeutics. *ChemMedChem*. 2024;19(9):e202300705.

   doi: 10.1002/cmdc.202300705

6. Agrahari V, Agrahari V, Mitra AK. Nanocarrier fabrication and macromolecule drug delivery: Challenges and opportunities. *Ther Deliv*. 2016;7(4):257-278.

   doi: 10.4155/tde-2015-0012

7. Liu Y, Yan Q, Zeng Z, Fan C, Xiong W. Advances and prospects of mRNA vaccines in cancer immunotherapy. *Biochim Biophys Acta Rev Cancer*. 2024;1879:189068.

   doi: 10.1016/j.bbcan.2023.189068

8. Sterner RC, Sterner RM. CAR-T cell therapy: Current limitations and potential strategies. *Blood Cancer J*. 2021;11(4):69.

   doi: 10.1038/s41408-021-00459-7

9. Wilms S. Nurturing life in classical Chinese medicine: Sun Simiao on healing without drugs, transforming bodies and cultivating life. *J Chin Med*. 2010;93:5-13.

10. Li M, Liang Y. Li Shizhen and the grand compendium of materia medica. *J Tradit Chin Med Sci*. 2015;2(4):215-216.

    doi: 10.1016/j.jtcms.2016.01.015

11. Liu F, Qu S, Fan Y, Chen F, He B. Scientific creativity and innovation ability and its determinants among medical postgraduate students in Fujian province of China: A cross sectional study. *BMC Med Educ*. 2023;23(1):444.

    doi: 10.1186/s12909-023-04408-9

12. Abd El-Aziz TM, Stockand JD. Recent progress and challenges in drug development against COVID-19 coronavirus (SARS-CoV-2)-an update on the status. *Infect Genet Evol*. 2020;83:104327.

    doi: 10.1016/j.meegid.2020.104327

13. Boltz DA, Aldridge JR, Webster RG, Govorkova EA. Drugs in development for influenza. *Drugs*. 2010;70:1349-1362.

    doi: 10.2165/11537960-000000000-00000

14. Almehmadi M, Allahyani M, Alsaiari AA, *et al*. A glance at the development and patent literature of tecovirimat: The first-in-class therapy for emerging monkeypox outbreak. *Viruses*. 2022;14(9):1870.

    doi: 10.3390/v14091870

15. Han X, Xu P, Ye Q. Analysis of COVID-19 vaccines: Types, thoughts, and application. *J Clin Lab Anal*. 2021;35(9):e23937.

    doi: 10.1002/jcla.23937

16. Filchakova O, Dossym D, Ilyas A, Kuanysheva T, Abdizhamil A, Bukasov R. Review of COVID-19 testing and diagnostic methods. *Talanta*. 2022;244:123409.

    doi: 10.1016/j.talanta.2022.123409

17. Wu R, Wang L, Kuo HCD, *et al*. An update on current therapeutic drugs treating COVID-19. *Curr Pharmacol Rep*. 2020;6:56-70.

    doi: 10.1007/s40495-020-00216-7

18. Wang HY. Research on the construction of integrated education mechanism of industry and education in applied undergraduate colleges. In: Patnaik S, Paas F, editors. *Recent Trends in Educational Technology and Administration. EduTA 2022. Learning and Analytics in Intelligent Systems*. Vol 31. Cham: Springer; 2023.

    doi: 10.1007/978-3-031-29016-9_22

19. Wu H, Cheng K, Guo Q, *et al*. Mapping knowledge structure and themes trends of osteoporosis in rheumatoid arthritis: A bibliometric analysis. *Front Med* (*Lausanne*). 2021;8:787228.

    doi: 10.3389/fmed.2021.787228

20. Lin H, Wang X, Huang M, *et al*. Research hotspots and trends of bone defects based on Web of Science: A bibliometric analysis. *J Orthop Surg Res*. 2020;15:463.

    doi: 10.1186/s13018-020-01973-3

21. Huang Y, Chang Z, Xia X, *et al*. Current and evolving

knowledge domains of cubosome studies in the new millennium. *J Nanopart Res*. 2023;25(9):176.

doi: 10.1007/s11051-023-05823-1

22. Ye S, Xing R, Liu J, Xing F. Bibliometric analysis of Nobelists' awards and landmark papers in physiology or medicine during 1983-2012. *Ann Med*. 2013;45(8):532-558.

doi: 10.3109/07853890.2013.850838

23. Nascimento F, de Melo E Silva D, Nunes H, Parise M. Evaluation of DNA damage and toxicological methodology development: A bibliometric study. *Hum Exp Toxicol*. 2020;39(6):870-880.

doi: 10.1177/0960327120903481

24. Batooli Z, Mohamadloo A, Nadi-Ravandi S. Relationship between altmetric and bibliometric indicators across academic social sites in article-level: The case of Iranian researchers' "Top Papers" in clinical medicine. *Libr Hi Tech*. 2021;39(4):1025-1042.

doi: 10.1108/LHT-12-2020-0319

25. Annesley TM. Gender authorship in the field of clinical chemistry. *J Appl Lab Med*. 2020;5(5):869-876.

doi: 10.1093/jalm/jfaa096

26. Wu L, Yang J, Wang D, Cheng Q, Lu W. Scientists' response to global public health emergencies: A bibliometrics perspective. *J Inf Sci*. 2023;49(4):911-931.

doi: 10.1177/01655515211030866

27. Doyon O, Raymond L. Surveillance and patient safety in nursing research: A bibliometric analysis from 1993 to 2023. *J Adv Nurs*. 2024;80(2):777-788.

doi: 10.1111/jan.15793

28. Huang Z, Zhang X, Wu L, *et al*. Progress on pharmaceutical sciences/pharmacy postgraduate education: A bibliometric perspective. *J Pharm Innov*. 2022;17(4):1360-1372.

doi: 10.1007/s12247-021-09611-z

29. Cheng T, Pan Y, Hao M, Wang Y, Bryant SH. PubChem applications in drug discovery: A bibliometric analysis. *Drug Discov Today*. 2014;19(11):1751-1756.

doi: 10.1016/j.drudis.2014.08.008

30. Zhang H, Gao Y, Fu G, Liu J, Jiao Q. Trends and hotspots for European Journal of Medicinal Chemistry: A bibliometric study. *Eur J Med Chem*. 2023;247:115041.

doi: 10.1016/j.ejmech.2022.115041

31. Yeasmen N, Bhuiyan MHR, Orsat V. Unravelling scientific research towards the green extraction of phenolic compounds from leaves: A bibliometric analysis. *Int J Food Sci Technol*. 2021;56(10):4893-4906.

32. Fabiano G, Marcellusi A, Favato G. Public-private contribution to biopharmaceutical discoveries: A bibliometric analysis of biomedical research in UK. *Scientometrics*. 2020;124:153-168.

doi: 10.1007/s11192-020-03429-1

33. Zhang J, Zhou Z, Kong Q. Progress in the electrochemical analysis of flavonoids: A scientometric analysis in citespace. *Curr Pharm Anal*. 2022;18(1):43-54.

doi: 10.2174/1573412917666210525153519

34. Zhu J, Liang Q, He S, *et al*. Research trends and hotspots of neurodegenerative diseases employing network pharmacology: A bibliometric analysis. *Front Pharmacol*. 2023;13:1109400.

doi: 10.3389/fphar.2022.1109400

35. Robert C, Wilson CS, Venuta A, Ferrari M, Arreto CD. Evolution of the scientific literature on drug delivery: A 1974-2015 bibliometric study. *J Control Release*. 2017;260:226-233.

doi: 10.1016/j.jconrel.2017.06.012

36. Daughton CG. Pharmaceuticals and the Environment (PiE): Evolution and impact of the published literature revealed by bibliometric analysis. *Sci Total Environ*. 2016;562:391-426.

doi: 10.1016/j.scitotenv.2016.03.109

37. Sinaa A-A, Mendes AM, Taisir H, Fernandez-Llimos F. International collaboration in pharmacy practice research: A bibliometric analysis. *Res Soc Adm Pharm*. 2020;16(11):1513-1518.

doi: 10.1016/j.sapharm.2020.05.019

38. Wenjie Z, Jun Z. Development history of bibliometrics in China and its application in evaluation of scientific and technological journals. *Tianjin Sci Technol*. 2024;51(1): 109-112+117. Article in Chinese.

doi: 10.14099/j.cnki.tjkj.2024.01.038

39. Jiaqi S, Huiying L. A bibliometric analysis of drug repositioning research hotspots. *China Modern Doctor*. 2022;60(19):71-76. Article in Chinese.

40. Jian G. *Study on the prediction of drug approved for marketing based on multi-dimensional characteristics of literature-taking the field of neoplasm as an example. Master*; 2023. [Article in Chinese].

41. Zeitoun A, Sacre H, Hallit S, Zeenny RM, Sili G, Salameh P. Clinical preceptor competencies for a better pharmacy education: A suggested framework for Lebanon. *J Pharm Policy Pract*. 2020;13(1):21.

doi: 10.1186/s40545-020-00217-3

42. Oltmann C, Boughey C. Using critical realism as a framework in pharmacy education and social pharmacy research. *Res Soc Adm Pharm*. 2012;8(4):333-337.

doi: 10.1016/j.sapharm.2011.07.005

43. Jarrett JB, Berenbrok LA, Goliak KL, Meyer SM, Shaughnessy AF. Entrustable professional activities as a

novel framework for pharmacy education. *Am J Pharm Educ*. 2018;82(5):6256.

doi: 10.5688/ajpe6256

44. Quesnelle KM, Zaveri NT, Schneid SD, *et al*. Design of a foundational sciences curriculum: Applying the ICAP framework to pharmacology education in integrated medical curricula. *Pharmacol Res Perspect*. 2021;9(3):e00762.

doi: 10.1002/prp2.762

45. Rajiah K, Maharajan M. Framework for action to implement interprofessional education and collaborative practice in pharmacy and allied health sciences programs in India. *Indian J Pharm Educ Res*. 2016;50(2):238-245.

doi: 10.5530/ijper.50.2.3

46. Moreau P, Qaddoumi M, Al-Taweel D, *et al*. Development and refinement of a matrix competency framework, with associated entrustable professional activities, to support initial pharmacy education in Kuwait. *Pharmacy* (*Basel*). 2023;11(5):149.

doi: 10.3390/pharmacy11050149

47. Bheekie A, Van Huyssteen M, Coetzee R. Exploring the implications of a needs-based pharmacy education framework modelled on population health: Perspective from a developing country. *Pharmacy* (*Basel*). 2019; 7(3):116.

doi: 10.3390/pharmacy7030116

48. Banning M. Pharmacology education: A theoretical framework of applied pharmacology and therapeutics. *Nurse Educ Today*. 2003;23(6):459-466.

doi: 10.1016/s0260-6917(03)00064-9

49. Aruru M, Truong HA, Clark S. Pharmacy Emergency Preparedness and Response (PEPR): A proposed framework for expanding pharmacy professionals' roles and contributions to emergency preparedness and response during the COVID-19 pandemic and beyond. *Res Soc Adm Pharm*. 2021;17(1):1967-1977.

doi: 10.1016/j.sapharm.2020.04.002

50. Butler LM, Arya V, Nonyel NP, Moore TS. The Rx-HEART framework to address health equity and racism within pharmacy education. *Am J Pharm Educ*. 2021;85(9):8590.

doi: 10.5688/ajpe8590

51. Khan MT, Ahmad R, Liu G, *et al*. Potential environmental impacts of a hospital wastewater treatment plant in a developing country. *Sustainability*. 2024;16(6):2233.

doi: 10.3390/su16062233