Constructing an Automated Evaluation Indicator System for Academic Paper Quality from a Knowledge Production Perspective: Postprint

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Abstract

[Purpose/Significance] Addressing the problem that automatic review of unpublished academic paper quality has not yet formed a unified indicator system, this paper explores and establishes a guiding, scientific, and objective indicator system for automatic paper quality review to enhance review efficiency. [Method/Process] From the perspective of knowledge production and combining elements of scientific knowledge production, an automatic paper quality review indicator system is constructed from seven aspects: paper author, references, funding project support, topic selection, innovation, scientificity, and expression form. The quantification methods and techniques are briefly elaborated, and principal component analysis is utilized to determine the weights and ranking of each automatic review indicator. [Results/Conclusion] The data results demonstrate that the weight values of paper scientificity and innovation are both relatively high. Abstract readability and length within the expression form, as well as the quality and recency of journals where references are published, are likewise important factors for automatic review. These results can provide a reference for the subsequent quantification processing of automatic review indicators.

Full Text

Preamble

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Research on the Construction of an Automatic Review Index System for Academic Paper Quality from the Perspective of Knowledge Production

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Abstract

[**Purpose/Significance**] To address the lack of a unified index system for the automatic review of unpublished academic paper quality, this study explores and establishes a guiding, scientific, and objective automatic review index system to improve review efficiency. [**Method/Process**] From the perspective of knowledge production and incorporating elements of scientific knowledge production, we construct an automatic review index system for paper quality covering seven aspects: authors, references, funding support, topic selection, innovation, scientific rigor, and expression form. We briefly explain the quantification methods and techniques for each indicator and apply principal component analysis to determine the weights and ranking of the automatic review indicators. [**Result/Conclusion**] Data results show that the scientific rigor and innovation of papers carry relatively high weight values. The readability and length of abstracts, as well as the quality and recency of journals in which references are published, are also important factors for automatic review. These results can provide references for subsequent quantitative processing of automatic review indicators.

Classification Number: G250
Keywords: knowledge production, academic papers, quality, automatic review, principal component analysis

For academic journals, especially core academic journals, editorial departments receive large volumes of submissions annually, creating an enormous workload. Each academic paper typically undergoes a rigorous review process involving initial screening by editors, peer review by experts, and final approval by chief editors—consuming substantial human resources, material resources, and time. Most importantly, this process involves numerous human interference factors, such as the subjectivity of evaluation standards and limitations of professional knowledge. Manuscript sources constitute the core of academic journals and represent important resources for periodicals. High-quality manuscript sources drive journal development, and technologies such as topic analysis can assist in automating this process.

Current evaluation methods for academic papers primarily fall into two categories: qualitative evaluation and quantitative evaluation. Qualitative evaluation includes peer review, where experts conduct subjective assessments based on their experience and knowledge. Quantitative evaluation includes citation analysis, which assesses academic impact based on post-publication citation counts. Additionally, scholars have proposed alternative metrics based on social media evaluation, improved PageRank methods, and other quantitative approaches. However, all these methods rely on external indicators and are based on subjective evaluation or target already-published papers.

The object of automatic paper quality review is submitted but unpublished manuscripts, which lack any external indicators such as citation counts or journal impact factors. Therefore, automatic review must rely solely on the internal knowledge units and content of the academic paper itself for comprehensive evaluation, distinguishing it from expert manual qualitative evaluation. Consequently, this paper distinguishes automatic review from traditional quantitative evaluation and aims to establish a guiding, scientific, and objective automatic review index system by applying knowledge mining, topic analysis, and other technologies to assist in automatic implementation.

Currently, no unified index system exists for the automatic review of unpublished academic paper quality. Therefore, this paper proposes to construct an automatic review index system for academic paper quality from the knowledge production perspective, incorporating knowledge production elements, and determine multi-indicator weights using principal component analysis with SPSS and Excel software. This exploration will provide references and a foundation for subsequent quantitative processing of automatic review indicators.

2 Construction of an Automatic Review Index System for Academic Paper Quality

2.1 Related Theory: Knowledge Production

2.1.1 Connotation of Knowledge Production In 1996, the Organisation for Economic Co-operation and Development (OECD) published the report "The Knowledge-Based Economy," defining knowledge production as the development and provision of new knowledge—an exploratory and creative intellectual activity. While no unified definition of knowledge production exists, all conceptualizations reflect its "knowledge reproduction" nature: knowledge production is the process of creating new knowledge through mental labor, a process of discovering new knowledge based on existing knowledge. The essence of knowledge production is knowledge innovation, encompassing scientific discoveries and technological inventions that can exist in various forms, including scientific papers, monographs, reports, drawings, and computer programs.

From a macroeconomic perspective, He Chuanqi et al. consider knowledge production a type of production activity undertaken by scientists, engineers, doctoral students, and assistants engaged in research and development. Scientific knowledge production is primarily original knowledge production, with academic papers representing its output. The process begins with topic selection, followed by information collection and research. Topic selection, information gathering, and information analysis constitute a process of deepening understanding and continuous improvement, while analytical research represents a crucial stage in knowledge production, involving quantitative and qualitative analysis. Writing the paper is the main process and most important link in knowledge production; upon completion, the knowledge production process concludes, forming a complete knowledge product.

Typically, knowledge production can be divided into three types: original knowledge production, replicative knowledge production, and customized knowledge production. Scientific knowledge production is mainly original, and the output of academic papers represents the outcome of this process. The general steps of scientific knowledge production are illustrated in Figure 1 [Figure 1: see original paper].

2.1.2 Elements of Knowledge Production Knowledge production involves two pathways: combination and exchange. Acquired raw materials and resources are recombined to generate new production methods, and when limited resources are owned by different actors, mutual exchange becomes a prerequisite for resource combination. Knowledge production requires a certain foundation of knowledge resources and must be completed by knowledge workers with adequate information literacy capabilities. Jiao Tong et al. identify four essential elements for knowledge production: relevant knowledge (directly or indirectly needed), intellectual workers as subjects, tools for knowledge production, and corresponding organization and management.

Li Zhengfeng notes that the sum of necessary, controllable, and usable elements for scientific knowledge production constitutes resource endowment, representing the foundation and conditions of knowledge production modes. Resources related to academic paper knowledge production include human resources, financial resources, material resources, and information resources. Human resources refer to the quantity and quality of personnel engaged in scientific knowledge production, including whether they are high-level scientists or hold senior academic titles. Financial resources refer to funds available for scientific knowledge production. Material resources refer to scientific equipment, infrastructure, and relevant condition platforms supporting scientific knowledge production. Information resources refer to basic scientific and technical data and materials generated from human scientific and technological activities, as well as various scientific data products and knowledge products processed according to different needs, typically contained in scientific literature such as books, journals, reports, papers, and archives.

Scientific knowledge production involves research subjects acting on the knowledge foundation through certain production relations, supported by research resource conditions, to create research outcomes. Based on this, we summarize knowledge production elements to construct an automatic review index system for academic paper quality comprising four aspects: research subjects and their production relations, research knowledge foundation, research resource conditions, and research outcomes themselves.

2.2 Selection and Determination of Automatic Review Indicators

A complete academic paper undergoes a standard scientific knowledge production process from conception to completion. The production elements involved in this process similarly apply to paper completion. To comprehensively consider academic paper quality evaluation indicators, this paper constructs an automatic review index system from the knowledge production perspective, incorporating the internal knowledge unit structure and content of academic papers.

2.2.1 Research Subjects and Their Production Relations Academic paper writing is a creation process whose quality depends on the author's level and effort, influenced by personal ability, knowledge level, and diligence. Therefore, evaluating paper quality should include analysis of research subjects and their production relations—that is, the authors.

Lan Hua et al. propose four factors affecting scientific journal quality, including manuscript source quality evaluation from the author perspective, assessing author academic competence and institutional distribution. Author academic competence includes reference to professional titles and education levels, such as the proportion of senior titles and doctoral degrees among authors. Institutional distribution includes reference to source institutions, such as the proportion from "985" and "211" universities and other research institutions. Author reputation and research capability should also be important evaluation references. Although a single manuscript lacks citation data, we can analyze the author's historical publication count and citation history. Additionally, J.E. Hirsch's H-index can evaluate researchers' academic output.

Multi-author collaboration has become common in research papers. F. Didegah notes that multi-author papers receive more citations than single-author papers, using correlation and regression tests to demonstrate that author count and inter-institutional collaboration correlate with higher citations. R. Sooryamoorthy also finds that international collaboration increases citation counts. Lin Deming et al. propose a formula to measure author collaboration scale: Collaboration Scale = Number of Disciplines × Number of Regions × Number of Authors / Average Authors per Discipline.

Therefore, based on the research subject and production relations element of knowledge production, this paper divides automatic review indicators into author academic competence, author research capability, author reputation, author count, author source institution, author cross-national/regional collaboration, and author cross-disciplinary collaboration. Table 1 presents detailed indicators and reference quantification methods for automatic review.

2.2.2 Research Knowledge Foundation References are crucial components of academic papers that influence paper quality. From the knowledge production perspective, references serve as information resources in production elements, and their quantity and quality reflect the author's understanding and absorption of past research. Therefore, analysis of the research knowledge foundation—that is, references—is essential.

Studies show correlations between reference count and citation frequency, and that papers citing high-impact references receive more citations. Reference quality relates to average citation count, total citations, and reference h-index. Lin Deming et al. measure reference quality through average citation frequency per reference and average impact factor of journals containing references. Reference citation half-life shows significant negative correlation with citation frequency, meaning reference recency correlates with paper citations.

Therefore, based on the research knowledge foundation element, this paper divides automatic review indicators into reference count, reference citation frequency, reference journal quality, and reference recency. Table 2 presents detailed indicators and reference quantification methods.

2.2.3 Research Resource Conditions Whether a paper receives funding support reflects its quality to some extent: (1) Project approval involves expert evaluation, demonstrating research value; (2) Funded projects have financial support for the knowledge production process; (3) Financial resources facilitate improvements in equipment, infrastructure, and conditions needed for scientific research.

Zhang Xiuhua et al. note that project funding increasingly influences modern knowledge production mechanisms, with high-level funds such as the National Natural Science Foundation of China (NSFC) and National Social Science Fund serving as important evaluation indicators for institutional research capability. Zhang Shile et al. demonstrate that SCI papers supported by NSFC have relatively high academic levels and research impact.

Therefore, based on the research resource conditions element, this paper divides automatic review indicators into funding support status and funding level. Table 3 presents detailed indicators and reference quantification methods.

2.2.4 Research Outcomes Themselves A complete academic paper comprises multiple knowledge units including title, authors, abstract, keywords, main text, and references. As the outcome of knowledge production and innovation, a paper must achieve knowledge internalization through arrangement and editing of information sources, ensuring orderly internal knowledge. Therefore, the paper's own quality is crucial, requiring scientific rigor, coherence, and logical structure.

Scholars analyzing domestic core journal review criteria emphasize evaluating topic selection, innovation, scientific rigor, writing quality, and research value. Wen Hao et al. propose evaluating scientific papers from content quality and formal quality perspectives, with content quality focusing on scientificity, innovation, and knowledge, and formal quality examining structure, formatting, and expression. Zhong Cantao et al., drawing on ISO quality concepts, suggest evaluating how well paper content and expression (readability) meet academic exchange, knowledge accumulation, and stakeholder requirements. Papers should demonstrate innovation and accuracy while maintaining standard formatting and precise expression. Innovation requires novel topics and methods with forward-looking perspectives; accuracy demands precise data, strong logic, clear hierarchy, and sufficient evidence; standard formatting requires compliance with national standards, accurate terminology, and clear figures/tables; precise expression requires high academic level and fluent writing.

Drawing on these studies and evaluation criteria for national excellent doctoral dissertations and outstanding scientific research achievements awards, which explicitly stipulate innovation and topic 前沿性, this paper identifies research outcomes themselves as a key evaluation element. From topic selection, innovation, scientific rigor, and expression form, we propose evaluation indicators detailed in Table 4 .

(1) Paper Topic Novelty: Topics should demonstrate novelty and timeliness, essential for ensuring paper quality. Topic novelty is a fundamental characteristic of academic innovation, indicating frontier research directions with pioneering significance. Topic novelty can be quantified—for instance, Yang Jianlin et al. use the KPTIDF method, while Lu Wanhui et al. apply Doc2Vec and HMM algorithms. Topic timeliness reflects current scientific frontiers, measurable through methods like LDA topic modeling.

(2) Paper Innovation: Innovation lies in new arguments and evidence, including new theories, methods, strategies, disciplines, data, and facts. Academic outcomes should demonstrate micro-level innovation in theory, technology, or research methods. Innovation measurement can employ knowledge unit theory, extracting theoretical, technical, and methodological knowledge units from papers to build respective knowledge bases. Through knowledge unit annotation, linking, and integration, we can associate, compare, and calculate knowledge units between review papers and knowledge bases to automatically evaluate theoretical, technical, and methodological innovation.

(3) Paper Scientific Rigor: Academic papers must demonstrate scientific rigor in technical level, research methods, experimental design, and data processing. Technical level can be measured using technology evolution trees to explore technological development paths. Drawing on knowledge unit theory, we can construct knowledge bases for research methods, experimental design, and data processing, enabling automatic evaluation of scientific rigor through mapping between data processing methods and rules.

(4) Paper Expression Form: Academic writing should be clear and explicit, including abstract length, keyword count, title length, 篇幅, readability of Chinese and English abstracts, and figure/table clarity. Readability can be evaluated using Chinese Flesch Reading Ease and English readability coefficients (Kincaid, ARI, Flesch Score, Fog Index), while figure/table clarity can be assessed through image recognition technology.

Based on the analysis in Sections 2.2.1–2.2.4, we establish the automatic review index system for academic paper quality, shown in Figure 2 [Figure 2: see original paper].

3 Weight Analysis of Automatic Review Indicators

Current methods for determining comprehensive evaluation indicator weights include subjective and objective weighting methods. This paper applies principal component analysis, an objective weighting method that expresses most information with fewer indicators through linear transformation. This approach establishes a weight model using the fundamental principles of principal component analysis without requiring indicator sample data, demonstrating theoretical feasibility, effectiveness, and generalizability.

3.1 Calculation Steps

(1) After determining indicator factors, experts in relevant fields score each indicator on a five-point scale: 5 (very important), 4 (important), 3 (moderately important), 2 (slightly important), and 1 (unimportant).

(2) Principal component analysis reorganizes original indicators into independent comprehensive indicators through linear combinations, expressed as:

$$\begin{aligned} F_1 &= u_{11}x_1 + u_{21}x_2 + \cdots + u_{h1}x_h \\ F_2 &= u_{12}x_1 + u_{22}x_2 + \cdots + u_{h2}x_h \\ &\vdots \\ F_m &= u_{1m}x_1 + u_{2m}x_2 + \cdots + u_{hm}x_h \end{aligned}$$

where h is the number of evaluation indicators, x represents evaluation indicators obtainable through SPSS software. In these equations, $F_1, F_2, \dots, F_m$ are m principal components, and u_{ij} are decision matrix coefficients transformed from initial factor loadings f_{ij} and eigenvalues λ_j using the calculation method in formula (2).

(3) Decision matrix coefficients u_{ij} for indicators across m principal components are weighted averaged to calculate indicator weights ω_i using formula (3), where V represents variance contribution rates of principal components.

(4) If negative weights are generated, ω_i can be transformed to ω_i' using formulas (4) and (5) with appropriate k values, translating them into structural relative numbers before normalization. If no negative weights are generated, ω_i is directly normalized.

Thus, following steps (1)–(4), principal component analysis yields indicator weights $W = (\omega_1, \omega_2, \dots, \omega_h)$.

3.2 Empirical Results

3.2.1 Descriptive Statistics We conducted a questionnaire survey of scholars and journal editorial staff in library and information science. Based on their academic review and submission experience, respondents scored the importance of 28 indicator factors for automatic review of academic paper quality. The survey was administered from May 9 to May 17, 2018, collecting 209 questionnaires. After removing questionnaires with excessively short or long completion times, 180 valid responses were obtained. The geographic distribution of respondents is shown in Figure 3 [Figure 3: see original paper]. As respondents might hold multiple roles (e.g., university faculty and journal editor), the sum of role counts exceeds the number of valid questionnaires, with detailed role distribution shown in Figure 4 [Figure 4: see original paper].

3.2.2 Weight Determination Results Using SPSS and Excel for data processing, we first tested reliability and validity. The Cronbach's alpha coefficient for all indicator items was 0.883, indicating high overall reliability. During reliability testing of dimensional subscales, we removed indicators with corrected item-total correlation (CITC) below 0.5 and whose deletion would increase the subscale's Cronbach's alpha: "author academic competence," "author research capability," "author reputation," "author count," and "paper figure/table clarity." All dimensional subscales achieved Cronbach's alpha above 0.7. Additionally, KMO value was 0.802 with significance of 0.000, confirming good construct validity.

Following the eigenvalue-greater-than-1 principle, we identified six principal components explaining 69.935% of total variance, detailed in Table 5 . Using component matrices, eigenvalues, and variance contribution rates, we calculated indicator weights shown in Table 6 , with bold values indicating weights above the average of 0.0435 (1/23).

3.3 Results Analysis and Discussion

(1) Results show that all four scientific rigor indicators and three innovation indicators rank among the highest weights, particularly scientific rigor of research methods, data processing, and experimental design reaching 0.057 and 0.056. This demonstrates that the scientific rigor and innovation of a paper's knowledge structure are crucial for automatic quality review.

(2) Abstract readability and length achieved weights of 0.049 and 0.045, indicating that expression form is also an important factor. As a distillation of the paper, the abstract is vital for both review and reader understanding, requiring precise, detailed yet concise expression. Additionally, seemingly content-unrelated factors such as keyword count, 篇幅, and title length achieved weights above 0.04, warranting attention in automatic review.

(3) Reference journal quality and recency achieved weights of 0.045 and 0.044, while reference citation frequency and count had relatively lower weights. This suggests that in the research knowledge foundation dimension, review should focus more on reference "quality" than "quantity"—the quality and recency of cited journals significantly impact automatic review.

(4) Author-related indicators showed slightly lower weights. While author information can inform initial screening to avoid misjudgment, it is not a primary review factor.

(5) Topic selection and funding support indicators had relatively lower weights, indicating that respondents did not consider topic novelty, timeliness, or funding as primary concerns. Topic novelty is not an absolute determinant of academic quality, so while these factors require consideration, they are not major review elements.

In summary, all indicators influence automatic review to varying degrees, but several high-weight factors are key, mostly concentrated in the internal structure of research outcomes: scientific rigor (experimental design, data processing, research methods, technical level), innovation (technical, methodological, theoretical), expression form (abstract readability, length), and references (journal quality, recency).

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Author Contributions

Zhu Linlin: Proposed research ideas and methods, wrote initial draft.
Du Xingye: Responsible for data collection and analysis, participated in research discussion, revised manuscript.
Li He: Responsible for writing guidance and review, finalized manuscript.

Study on the Construction of Index System for Automatic Review of Academic Paper Quality Under the Perspective of Knowledge Production

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Abstract: [Purpose/significance] The automatic review of the quality of unpublished academic papers has not yet formed a unified index system. This article explores and establishes a set of leading, scientific and objective index system for automatic review to improve review efficiency. [Method/process] From the perspective of knowledge production, combined with the factors of scientific knowledge production, the index system of academic paper quality for automatic review is constructed from seven aspects: author, reference, fund project support, topic selection, innovation, scientificity and expression form. The quantitative methods and techniques are briefly introduced, and the principal component analysis method is used to determine the weight and ranking of various automatic review indexes. [Result/conclusion] Data results show that the weight values of paper scientificity and innovation are both high. The readability and length of the abstract in the expression form, and the quality and newness of the journals where references are published are also important factors for automatic review. The results can provide references for the quantitative treatment of follow-up automatic review indexes.

Keywords: knowledge production; academic papers; quality; automatic review; principal component analysis

Note: Figure translations are in progress. See original paper for figures.