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Evaluating the Scholarly Contributions of a Journal by Measuring the Discrepancy in Information Entropy Values Between Factual and Counterfactual Knowledge Systems in the Absence of the Journal

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Abstract

This study proposes a novel evaluation concept and method: assessing the value of academic journals by measuring their contributions to the knowledge system. It aims to address the limitations of traditional peer review methods and quantitative approaches based on bibliometrics and altmetrics in the practical evaluation of academic journals. The study hypothesizes that academic journals play a crucial role in the knowledge system by providing valuable information through the publication of research papers, thereby reducing uncertainty within the system. As the knowledge system evolves from disorder to order, its information entropy value tends to decrease, and the academic contributions of journals can be characterized by the negentropy derived from these publications. The study employs the concept of counterfactual research to calculate the information entropy of both the factual knowledge system and the counterfactual knowledge system in the absence of the evaluated journals. The difference in information entropy values indicates the negative entropy contributed by the evaluated journals to the knowledge system. Through empirical data, this study demonstrates that this innovative method can effectively reflect the value of journals based on their actual contributions, and it has the potential to complement traditional evaluations of journal value based on impact after further refinement. The empirical data also reveal that, in general, a small number of journals within each discipline make significant contributions to the knowledge system, while the majority of journals contribute little or nothing. This finding aligns with the nucleus zone of periodicals described by Bradford's Law.

Introduction

Academic journals serve as the primary platform for documenting innovative achievements and scientific research findings. Consequently, in the realm of scientific governance and academic communication, it is essential to design rational, scientific, and accurate evaluation methods for academic journals. Initially, the evaluation of academic journals primarily relied on peer review (Baldwin 2017). However, contemporary evaluation methods increasingly emphasize quantitative approaches, which can be broadly categorized into two types: traditional bibliometrics and forward altmetrics (Karanatsiou 2017).

It is generally believed that at the beginning of the 1900s, the development of industrial technology and the rapid emergence of academic dissemination activities led to a significant increase in the volume of academic literature and the variety of journals (Huang 2021). The economics need for evaluation to identify important journals became a priority (Lewis 1989), prompting the exploration of journal evaluation methodologies, which began in Europe. Bradford (1934) summarized the law of scattering, discovering that each subject area has a nucleus zone of periodicals that publish the majority of articles within that field. The theory of academic journal evaluation also originated from Bradford's law regarding the stratification of academic journals. In the 1950s, Garfield (1955) pioneered the establishment of a citation analysis system, gradually developing a series of citation databases and expanding their practical applications. This work led to the formulation of a comprehensive analysis system and methodology, which has had a significant impact on the field (Vinkler 2009). However, traditional scientometrics indicators based on citation analysis also present notable challenges. For instance, citation analysis often requires a lengthy post-publication period, typically taking several years to adequately assess the academic influence of journals (Feng 2023). Additionally, the evaluation data sources for traditional scientometrics indicators primarily focus on quantitative metrics, such as the number of articles or citations, while neglecting the roles and impacts that evaluated journals have in areas such as academic exchange, industrial development, and disciplinary advancement (Wang 2011). The fundamental assumption of citation analysis is that citations reflect the positive impact of academic contributions (Narin 1990); however, in practice, the motivations for citing a particular paper are more varied, and citing a work does not necessarily indicate that the citer endorses it (Dorta-Gonzalez 2013).

Priem and Taraborelli (2010) co-authored a paper titled *Altmetrics: A Manifesto*, which introduced the concept of altmetrics. The scientific and effective application of alternative metrics facilitates a more comprehensive evaluation of impact (Shuai 2012). In terms of evaluation orientation, the use of alternative metrics will foster more vibrant and efficient scientific exchanges on the Internet (Eysenbach 2011) and can lead to the development of new methods, tools, and mechanisms to enhance and optimize existing information organization and discovery processes (Priem 2012). However, a significant challenge in applying alternative metrics to the evaluation of scientific and technical journals is minimizing human interference with the metrics (Bornmann 2014). Related concerns also include the rigor and consistency of data used in alternative measures (Cronin 2014). Another important issue is how to ensure that widely dispersed and dynamic data sources are reliable (Maflahi 2016) and that the results of their statistical analyses are reproducible (Thelwall 2013).

Despite numerous explorations, an effective solution to the aforementioned limitations within the current evaluation model of academic journals remains elusive. Therefore, Ma (2022) believes that future approaches to evaluating academic journals will transcend from the traditional framework of statistical analysis focused on the journals' inherent attributes and external connections into a systematic perspective that quantitatively assesses the actual contributions of the publishing and dissemination behaviors of the evaluated journals to the evolution of the knowledge systems in which they operate.

This study posits that one of the primary roles of academic journals is to mitigate uncertainty in scientific understanding. The process of reducing uncertainties in scientific knowledge corresponds to a decrease in entropy within the knowledge system (Shannon 1963). The fundamental purpose of the academic publishing process is to enhance individuals' awareness of scientific issues and principles through the dissemination and promotion of scientific discoveries and technological innovations. Utilizing quantitative methods, this study measures the changes in information entropy within the knowledge system before and after academic publishing and develops an evaluation method to assess the contributions of scientific and technical academic journals. The degree of negentropy that an academic journal introduces to the information entropy of the knowledge system reflects its contribution to the advancement of the discipline. In this study, we propose a solution to measuring the utility of information by examining the discrepancies in information entropy values between factual and counterfactual knowledge systems, based on the concept of counterfactual thinking (Kahneman 1982).

Concepts defined in this study

Knowledge systems

The knowledge system, formed by journal articles, is defined in this study as a framework that consolidates explicit human perceptions of the objective world within specific boundaries. This system is based on various knowledge carriers and encompasses both similar and differing research perspectives. Over time, this system experiences changes, additions, and the disappearance of certain perspectives.

Uncertainty in knowledge systems

In a knowledge system, the variations in the composition of individual research perspectives are regarded as the inherent uncertainty within the system. This uncertainty can be categorized into two types: static uncertainty and dynamic uncertainty.

(1) Distribution uncertainty (static level)

Distribution state uncertainty primarily reflects, at a static level, whether the distribution of absolute indicators within a knowledge system's conclusions about academic content and the convergence of research concerns is significantly centralized or decentralized. Over time, in a given system, the more consistent and concentrated the judgments regarding knowledge viewpoints, research hotspots, and mainstream development directions are, the clearer and more coherent the knowledge system's understanding of academic issues becomes. This indicates a more complete and accurate human comprehension of the objective world. Conversely, if the exploration and understanding of knowledge within a system are more diverse, and the probabilities of different directions and conclusions are relatively similar, it suggests that human understanding of the relevant issues remains uncertain, lacking clarity and consistency.

The formulation of static uncertainty within the knowledge system, constructed from academic journal articles, can be further decomposed into three subsystems.

A1. Scalability: This term refers to the capacity of academic journals to effectively disseminate literature. As publishing and communication platforms, academic journals should aim to publish a significant number of papers that showcase the results of scientific discoveries and technological innovations, all while upholding high standards of quality and efficiency.

A2. Wideness: This term refers to the ability of an academic journal to broaden its influence. The content published and disseminated by academic journals consists of scientific research papers, which require a substantial readership to effectively share results and promote active academic communication.

A3. Sustainability: This term primarily refers to the quantity and proportion of papers funded by financial support, serving as an indicator of the alignment between journal publications and scientific and technological investments.

(2) Relation uncertainty (dynamic level)

Relation state uncertainty primarily reflects a dynamic knowledge system concerning the structure of nodes related to academic knowledge, the interactions between these nodes, and whether the relationships among different types of nodes indicate a centralized or decentralized state. Within this system, various node levels (e.g., authors, journals, keywords, individual papers) form a network of connections that represent knowledge. The relative centralization of the entire knowledge system can be inferred from the connections between knowledge nodes and their related nodes as expressed by this network. Absolute centralization implies that when people's judgments regarding knowledge perspectives, research hotspots, and mainstream development directions are highly consistent and concentrated, their understanding of academic issues within this knowledge system becomes clearer and more uniform. In other words, human comprehension of the objective world tends to be completer and more accurate. Conversely, if a system's exploration and understanding of knowledge exhibit greater diversity, and the likelihood of different directions and conclusions is relatively similar, it indicates that human understanding of the issue remains uncertain, lacking clarity and consistency.

The systematic uncertainty associated with the relatively centralized knowledge system constructed from academic journal papers can be further decomposed into four subsystems.

B1. Openness: This term refers to the transparency and accessibility of manuscript sources for journal articles. The development of manuscript sources is a critical aspect of establishing academic journals. A diverse and ample supply of high-quality manuscript sources is essential for journals to effectively fulfill their roles. Conversely, if the range of manuscript sources is overly restricted or concentrated, it may lead to a one-sided knowledge system and can diminish the communicative vitality of academic journals.

B2. Collaboration: This term refers to the capacity of journals to publish co-authored papers, including those arising from collaborative research at both national and institutional levels. Collaborative research often yields complementary advantages and generates high-quality research outcomes. Notably, the large-scale multilateral collaborations that have surged in recent years have led to the production of papers, which frequently contain key findings that can benefit the global community.

B3. Competitiveness: The capacity of a specific journal to achieve a comparative advantage over other journals within the same discipline or genre. High-competitiveness journals typically attract high-quality research, establishing authority and influence (Ma and Pan etc. 2022). This authority and influence contribute to the formation of academic consensus, thereby reducing disagreements and uncertainties regarding certain issues.

B4. Influence: This term refers to the reference value or contentious significance of the results published in a thesis by academic journals, particularly in relation to other scholarly research activities. It is primarily measured by the number of citations. The citations of a journal article serve as a key indicator of the academic impact of the paper.

Information Entropy of Knowledge Systems

It is due to the significant systemic properties of disciplinary development and dissemination that a collection of papers published in academic journals within a specific subject area can be analyzed as a relatively independent system. In this study, the information entropy of the knowledge system is defined as follows: within the closed and isolated knowledge system formed by the research papers of the journals, the measure of uncertainty regarding the knowledge and judgment of a particular scientific problem is defined as the information entropy of this knowledge system.

Counterfactual knowledge system

Counterfactual knowledge systems are virtual constructs, in contrast to real knowledge systems. This concept assumes that the evaluated journal does not exist; that is, the journal is excluded from the real knowledge system. Consequently, the volume of its published papers, references, and citations is not factored into the statistical calculations of relevant data and indicators.

Discrepancy in Information Entropy values between Factual and Counterfactual Knowledge Systems

For the evaluated journal, there is a discrepancy in information entropy values between factual knowledge systems and counterfactual knowledge systems that do not include the evaluated journal. The primary reason for this gap is the contribution of the evaluated journal, which reduces the information entropy of the knowledge system. In other words, the scholarly papers published by the evaluated academic journal contribute negentropy to the knowledge system.

Data

Sample

The sample of journals utilized for empirical evidence in this study comprises 3,713 scientific and technical academic journals, representing the vast majority of academic journals published in China. All of these journals were recognized by the state publishing administration of China in 2014. In this study, all data regarding journal articles and citations were downloaded from the China Journal Network (COJ) of Wanfang Data Co. (Ma 2008). The COJ includes over 8,000 journals and 43 million articles published in China, featuring high-quality full-text records that provide extensive information related to the articles. In this study, the analysis will be conducted using papers published between 2016 and 2019 as examples.

Disciplinary categories

The classification of 112 disciplinary categories is based on the *Chinese Science and Technology Journal Citation Reports (Core Edition)* (Pan and Ma 2018), *National Standard of PRC: Classification and Code of Disciplines (GB/T 13745-2009)* (State Bureau of Quality and Technical Supervision of PR China 2009), and the *Chinese Library Classification* (Editorial Committee of CLC 2010). The classification of these categories considers the affiliation of each discipline as well as the volume of publications, organized into six major parts of multidiscipline, basic research, agriculture, medicine, engineering and technology, and management.

High-frequency keywords

The set of high-frequency keywords was used as a framework for developing disciplinary options within each journal's subject area. The frequency of these keywords is derived from the CSTPCD, a WOS-like citation index for scientific and technical journals in China (Zhou 2007). The CSTPCD includes more than 2000 nucleus journals, representing approximately one-third of the total number of science and technology journals in China. Based on the CSTPCD, the high-frequency keywords that fall within the top 1% of usage frequency in each discipline are identified.

Method

As illustrated in Figure 1, this study aims to develop a quantitative model for calculating the information entropy of a knowledge system. In this context, academic journals are treated as a knowledge system, with high-frequency keywords serving as variables that represent system uncertainty. Additionally, we introduce measurable subsystem indicators. For the purpose of journal evaluation, we calculate the information entropy of both the factual knowledge system and the counterfactual knowledge system, which assumes the absence of the evaluated journals. The difference between these two values represents the negentropy contributed by the evaluated journal to the system, reflecting its role in reducing the uncertainty of the knowledge system. This metric can be utilized to assess the academic quality and value of journals.

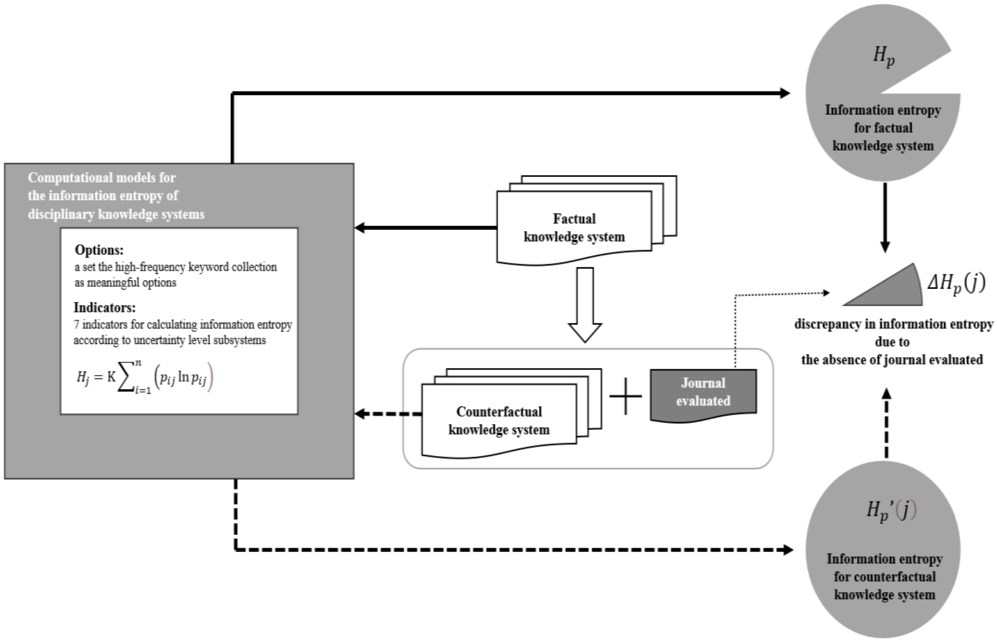

Figure 1. Research idea for this study.

To calculate the set of discipline development options

This study employs a set of high-frequency keywords for each discipline to delineate potential avenues for development within those fields. When applied to the evaluation of journals in each subject area, the model reveals varying numbers of research directions that each discipline may encompass. In other words, the number of possible options (variables) for disciplinary development differs based on the size and characteristics of each discipline.

Keywords are a set of words that express the selection, solution, technical approach, object of study, innovative ideas, application value, and other relevant aspects of a paper. According to journal publishing standards, keywords are an essential component of academic papers. They possess characteristics of standardization and universality. Typically, keywords are preferred over narrative words; that is, they should consist of semantically related and scientifically relevant terms derived from natural language vocabulary. While free words can also be utilized as keywords, it is advisable to select terms from established lexicons or widely recognized reference books and toolkits.

The keywords of a paper can reflect the direction of the chosen topic, the research methodology, or the main findings. Utilizing big data technology, the study of keywords can facilitate an intuitive understanding of the knowledge structure and the development of the field. By analyzing the evolution of the quantitative relationships among keywords, researchers can also identify and monitor the emerging hotspots within the discipline.

To set the high-frequency keyword collection as meaningful options in discipline

The keywords under consideration fall into the top 1% of all journal papers in a given discipline within the specified time window. These keywords have been sorted by word frequency from largest to smallest. The research subjects encompassed by this collection are indicative of the research focal points of the discipline within a designated time period. In practice, it is not advisable to count high-frequency words with too long a time horizon to avoid statistical errors caused by the transfer of research hotspots. The transfer of research hotspots corresponds to the rhythm of the evolution and development of each discipline; however, the time window should not be too narrow, taking into account the operability. In this study, high-frequency keywords were utilized as variables in lieu of all keywords. The principal rationale for this approach is that high-frequency words are representative, and the changes in their scope and structure can reflect the overall situation of the development of disciplines. The utilization of all keywords may result in the mixing of too much noise data. After testing and comparing, the criterion of 1% of high-frequency words was found to combine both scientific and operability.

To construct the matrix of indicators

The development of a subject area, over time, is facilitated by academic communication, which functions to accumulate and exchange knowledge. Consequently, human cognition of scientific laws and development direction becomes gradually clearer. Assuming the existence of n predetermined possible options for a specific knowledge point within a subject area, it can be posited that in the initial stage, the uncertainty surrounding these options is comparatively pronounced, resulting in a state of heightened confusion regarding knowledge cognition. Conversely, as the process progresses, the uncertainty pertaining to these options undergoes a reduction, thereby facilitating a gradual enhancement in the clarity of knowledge cognition. This progression can be conceptualized as the incorporation of effective information (negentropy) into the knowledge system.

In the framework of information entropy theory, the n preset possible options are regarded as random, and m indicators are used to describe the clarity of each preset option, i.e. to express the probability (Pi) of each option.

The hypotheses proposed in this study suggest that the probability of different predefined options becoming the dominant research direction is subject to change due to the injection of knowledge and information into this disciplinary system. As the future options of this field become gradually clearer and less uncertain, the value of the information entropy state of this disciplinary knowledge system should decrease.

The proposed indicator matrix is thus constructed as follows:

$$F = \begin{pmatrix} f_{11} & \cdots & f_{1i} & \cdots & f_{1m} \\ \vdots & & \vdots & & \vdots \\ f_{i1} & \cdots & f_{ij} & \cdots & f_{im} \\ \vdots & & \vdots & & \vdots \\ f_{n1} & \cdots & f_{nj} & \cdots & f_{nm} \end{pmatrix}$$

Where n represents n disciplinary options and m represents m indicators. Let (i=1,2,...n; j=1,2,...m), then f_{ij} is the value of the j indicator in the i disciplinary option.

To Select indicators for calculating information entropy of knowledge systems

The selection of indicators is typically undertaken using various methods, including those based on rough set theory, expert research and comment in the field, or the application of correlation coefficient and coefficient of variation methods, among others. Despite the absence of a universally accepted method for indicator screening, the role of expert review in this process remains indispensable.

In this study, the method of expert deliberation is employed for the selection of indicators. The selection process was informed by the study's objective of demonstrating the research volume, extensiveness, activity, and growth capacity of different development directions. It also took into account the scientific and accessible nature of the indicators. Following extensive adjustments and experimentation, and taking into account the research and consultation opinions of peer experts, it was determined that the following seven indicators should be used as journal evaluation guidelines and to calculate the information entropy of the knowledge system.

Table 1. Correspondence table between journal evaluation subsystems and indicators for calculating information entropy of knowledge systems.

Uncertainty level	*Subsystems*	*indicators for calculating information entropy of knowledge systems*
(1) Distribution uncertainty (static level)	A1. Scalability A2. Wideness A3. Sustainability	1) Number of published papers 2) Wide distribution of literature 3) Number of Funded Papers
(2) Relation uncertainty (dynamic level)	B1. Openness B2. Collaboration B3. Competitiveness B4. Influence	4) Ratio of international co-authored papers 5) Number of affiliations per paper 6) Growth rate of paper share 7) Number of citations per paper

To standardize indicators and calculate their probability

Due to the significant differences in the magnitudes, extreme values, etc. of the different indicators, it is necessary to standardize the transformation of the indicator matrices to form a standardized matrix A:

$$A = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix}$$

where (i=1,2,…n; j=1,2,…m), so that $a_{ij} \in [0,1]$.
The standardized formula is:

$$a_{ij} = \frac{f_{ij} - \min\{f_{1j}, f_{ij}, \ldots f_{nj}\}}{\max\{f_{1j}, \ldots f_{ij}, \ldots f_{nj}\} - \min\{f_{1j}, \ldots f_{ij}, \ldots f_{nj}\}} \quad (1)$$

For indicator j each option probability P_{ij} is defined as:

$$p_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (2)$$

where (i=1,2,…n; j=1,2,…m).
While f_{ij} is the minimum value, meaning that a_{ij} is equal to *0* and p_{ij} would have been equal to *0*, assign p_{ij} the value *0.0001* to avoid the problem of *ln(0)* in subsequent calculations and the minimal effect on the overall distribution is negligible.

To calculate the value of information entropy of a knowledge system

The information entropy of this study for each single indicator of the isolated system is calculated by the formula: (Shannon 1963)

$$H_j = K\sum_{i=1}^{n} (p_{ij} \ln p_{ij}) \quad (3)$$

where *i* represents the i of the n options that presuppose unspecified knowledge. (i=1, 2...n);
where *j* represents the j of the m indicators used to characterize uncertainty, which can be viewed as the j subsystems of the knowledge system. (j=1, 2...m);
where *K* is the normalization constant to achieve the calculation results. Since the value range of $\sum_{i=1}^{n} (p_{ij} \ln p_{ij})$ is $[\ln\frac{1}{n}, 0]$, *K* takes the value of $\ln\frac{1}{n}$. Therefore, for a single system, the value of *Hj* is distributed in the range of [0,1]. The case of H_j=0 represents the system is absolutely ordered (only one option, the realization probability is 100%, the realization probability of other options is 0); the case of H_j=1 represents the system is absolutely disordered (the realization probability of all the options is exactly the same);
By calculation, the information entropy state value of each of the m predefined possible options can be derived, then the information entropy of the whole knowledge system is the sum of the information entropy of the m subsystems.

$$H = \sum_{i=1}^{n} H_i \quad (4)$$

Since the numerical distribution of H_i is in the range of [0,1], the numerical distribution of H is in the range of [0,n]. The case of H=0 represents the system absolutely ordered (all 7 subsystems have only one option and the probability of the realization of the same option is 100%, the others are 0); the case of H=n (in this study, n=7 because of 7 subsystems) represents the system absolutely disordered (the probability of all options of all subsystems is exactly the same).

This indicator of H can be regarded as a reflection of the quantity of information and uncertainty inherent within an isolated system. To illustrate this, consider a field of research where there exist two or more divergent perspectives on human understanding of the objective world, or the future trajectory of a specific discipline, of which only a limited number of options can be predicted. At this nascent stage, the probability of the realization of each option is relatively equal, and the uncertainty is pronounced. However, as scientific research progresses, the number of feasible options decreases, thereby reducing uncertainty. Consequently, it can be posited that the probability of realizing a proportion of the possible options increases, while the probability of realizing another proportion of the possible options decreases, thus leading to a decline in uncertainty. This decline in uncertainty can be interpreted as a gradual discernment of the unknown, facilitated by the dissemination of scientific research findings, which in turn leads to a more profound understanding of the objective world by human beings.

To Calculate the discrepancy in information entropy values between factual and counterfactual knowledge systems (negentropy contributed by journal evaluated)

As a background (truth value) for the evaluation of counterfactuals, it is first necessary to calculate the information entropy value H_p of the factual knowledge system for discipline p. For the evaluated journal j as a node in the citation network with in discipline p (Chen 2004), calculate the information entropy value $H_p(j)'$ of the counterfactual knowledge system in the absence of the journal j in discipline p. The change in the values of information entropy in discipline p ($\Delta H_p(j)$) before and after removing of the journal x is the negentropy that the journal j contributes to the knowledge system of discipline p.

$$\Delta \mathrm{H}_p(\mathrm{j}) = \mathrm{H}_p{'}(\mathrm{j}) - \mathrm{H}_p \quad (5)$$

Result

Information entropy of factual knowledge systems for 112 discipline and their changes along the time dimension

In this study, the list of high-frequency keywords screened based on the papers included in CSTPCD 2016 will be utilized to calculate the annual information entropy values of each discipline in the subsequent database of 2016-2019.CSTPCD 2016 comprised approximately 565 thousand papers, utilizing around 1.5 million keywords and more than 4.1 million times. On average, each paper employed 7.3 keywords. The high-frequency keywords listed in the top 1% in terms of frequency of use for each discipline were calculated. For instance, within the discipline of

"Infectious diseases and infectious diseases", CSTPCD 2016 encompassed eight journals and published 1,093 papers in 2016, utilizing 4,349 keywords and being cited 7,876 times. The 4,349 keywords were then sorted according to their frequency of occurrence, and the 44 keywords that ranked in the top one percent (1% of 4,349) were identified as the set of high-frequency keywords for the discipline.

The information entropy values for each discipline in the database from 2016 to 2019, along with their temporal trends, are shown in Appendix 1.

The analysis of the changes in the information entropy of the knowledge system of each discipline from 2016 to 2019 (see Appendix 1) reveals a clear trend of decrease in entropy values for the majority of disciplines. A comparison of the magnitude of change in the values between 2016 and 2019, as illustrated in Figure 1, reveals that among the 112 disciplinary categories, a mere 11 categories demonstrate an increase in the direction of change in information entropy over the four-year period. The remaining categories, accounting for over 90% of the total, exhibit a decline in information entropy. Given that the numerical comparison of the information entropy of the knowledge system between individual disciplines appears to lack clear significance, the data presented in this study do not provide compelling evidence to support the hypothesis that the information entropy of the knowledge system conforms to a random distribution. This is despite the fact that the distribution state depicted in the figure bears a resemblance to a normal distribution.

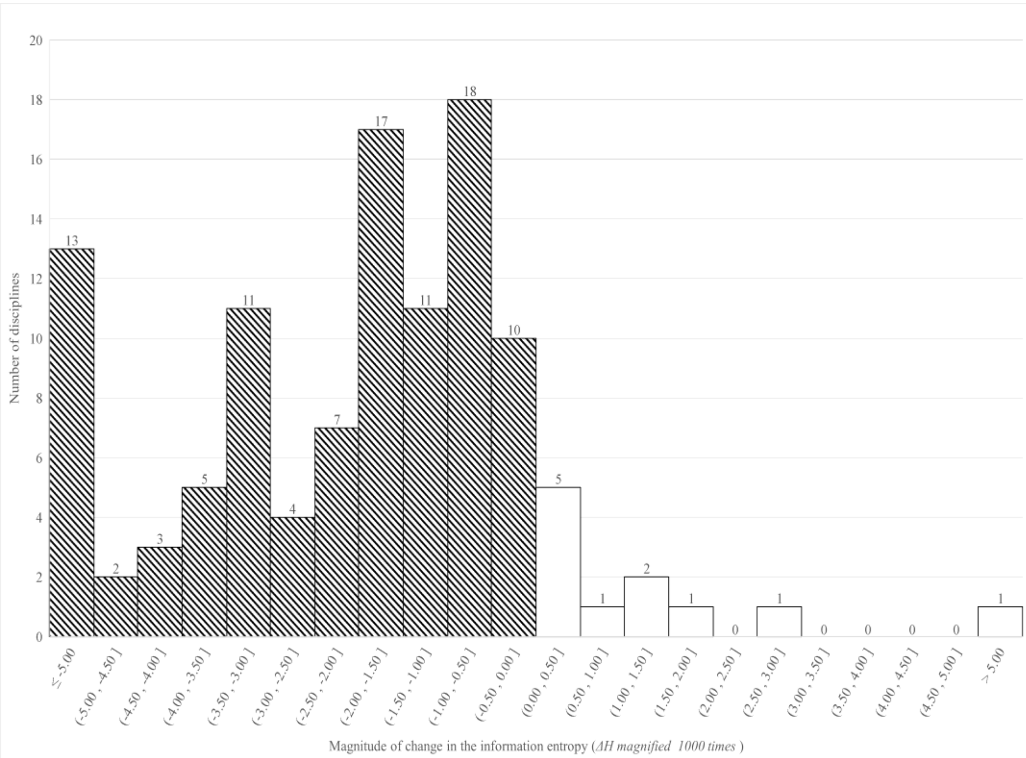

Figure 2. Distribution of the magnitude of change in the information entropy of knowledge systems 2016-2019 for 112 disciplines.

The distribution of changes in information entropy of disciplinary knowledge systems validates the hypothesis of this study: the direction of knowledge system development is evolving from chaos to order with the roles of academic journals which input valuable information and reduce uncertainty in scientific understanding. This shows that the intellectual uncertainty of most disciplines is gradually decreasing, meaning that the thematic direction of the development of a fixed range of disciplines is gradually becoming more focused and clearer, in line with the perception of the general law of disciplinary development. In this process of change, the role played by individual journals varies, that is, the size of the contribution of individual journals varies.

Contribution of evaluated journals to the knowledge system

The contribution of the evaluated journals to the knowledge system can be reflected by calculating the discrepancy in the information entropy (ΔH) between factual and counterfactuals knowledge system. Statistically, the vast majority of the sample has a positive ΔH, with 3,578 journals (96.7%) out of 3,713 journals having a positive ΔH. This indicates that the vast majority of academic journals contribute to the reduction of the chaos of the knowledge system to which they belong, that is, the academic publishing activities of journals fulfill their necessary functions.

According to the information entropy theory, the amount of information introduced into an isolated system should be non-negative, i.e., the most extreme phenomenon is that the amount of information contributed by journals to the system is zero, and the contribution of journals to the system should not have a negative value. However, in this study, the contribution ΔH of some journals to the should-knowledge system to which they belong is negative, which may indicate that these journals have published articles that have a negative effect on the development of the discipline and on the cohesion of the consensus, which increases the degree of confusion in the system.

Since the knowledge system constituted by the collection of papers obtained by using each discipline's high-frequency words as search terms is a mutually independent system in this study, there is no direct comparability between the H state values of different systems, nor between the changes in state values ΔH. However, the direction of ΔH reflects whether journals have positively or a negatively contributed to the system.

In the case of Astronomy, the calculation of the contribution of the six evaluated journals in this discipline to the knowledge system is shown in Table 2.

Table 2. Contributions to the knowledge system (negentropy provided) by six journals in the discipline of astronomy(p) in 2016.

Journal(j)	*Information entropy of factual knowledge system* H_p	*Information entropy of counterfactuals knowledge system* $H_p(j)'$	*Discrepancy as journal's contributions to the knowledge system (negentropy)* $\Delta H_p(j)$
Title 1	15.41	16.09	0.68
Title 2		15.97	0.56
Title 3		15.36	-0.05
Title 4		15.48	0.07
Title 5		15.65	0.24
Title 6		15.50	0.09

Note: The *H* data has been magnified 100 times for ease of display.

In the vast majority of academic disciplines, a small number of journals are found to make a disproportionately large contribution to the overall system in terms of the entropy of information (ΔH) compared to other journals, such as Title 1 and Title 2 in Table 2. The majority of journals, however, have entropy of information (ΔH) values that are almost negligible. This indicates that within the discipline, the distribution of the numerical values of the contribution of many journals to the information entropy of the knowledge system exhibits a distribution pattern with a small number of journals contributing more and a clear long tail of the distribution curve. This finding suggests that only a limited number of journals within the discipline are capable of fulfilling the primary function of academic publications, which is to reduce uncertainty in scientific understanding. Conversely, a greater number of journals have a negligible impact on the reduction of uncertainty in the discipline.

This pattern aligns with Bradford's Law, which posits that a limited number of pivotal core area journals predominate within each discipline. The study revealed that the number of journals contributing substantially to the discipline's knowledge system is also modest, and these journals are designated as "nucleus journals" in a broader sense. However, the study's current limitations preclude the quantification of the relationship between the number of high-contributing journals and the number of low-contributing journals.

The majority of the journals in the sample demonstrate positive ΔH, yet 41 (1.1%) journals exhibit negative ΔH, and 94 (2.5%) journals display 0. When ΔH is 0 or near to 0, it can be deduced that these journals contribute a negligible amount to the development of the discipline. The calculation method employed in this study is predicated on keyword statistics; consequently, journals that are not aligned with the subject matter of the discipline may not be adequately captured, resulting in a contribution value of 0. Additionally, the clarity of the journals' disciplinary classification may be inadequate when the ΔH is negative, resulting in a positive ΔH

for journal classification into discipline p1 and a negative *ΔH* for journal classification into discipline p2. Another possibility is that the journal publishes content that is too broadly distributed across multiple disciplines. In such cases, the journal's contribution to a specific discipline may be negligible. Statistically, the *ΔH* of journals is lower in disciplinary categories where synthesis is more pronounced.

Conclusion

In classical information theory, the measurement of the amount of information does not take into account the content importance or intrinsic significance of the information. There is no necessary connection between the amount of information and the importance of the message, and the classical information entropy only calculates a numerical value at the quantitative level, which does not directly indicate the importance of the message. Therefore, in this study, the physical meaning of the indicator values needs further discussion. Particularly for the relatively large number of medium-level journals, the values are less discriminating, leading to deficiencies in areas such as interpretability and assessment of the effectiveness of practice.

The present study operates under the assumption that the journals under review are not currently incorporated within the system. The notion of observing alterations within the system can be conceptualized as a counterfactual analytical approach, which encompasses the formulation of counterfactual assumptions, the establishment of conditions that are antithetical to established facts, and the subsequent measurement of values that are challenging to quantify using conventional descriptive methods. The notion of "counterfactual" research involves the formulation of counterfactual assumptions, the establishment of conditions that are antithetical to the established facts, and the subsequent evaluation of the causal relationship between the change of counterfactual conditions and the results derived from counterfactual reasoning. In the context of complex evaluations of relevant factors, traditional causal analysis frequently assumes that the researcher has controlled the important factors explaining the dependent variable and has not omitted important independent variables. However, the situation and variables under study often fail to satisfy this assumption, or the observed objects are not randomly occurring. This frequently generates endogeneity or sample selection bias, resulting in inaccuracy and bias, or even error, in causal analysis. The advantage of counterfactual analysis is that it can clearly identify differences in baseline or heterogeneity of causal effects among different sample groups that cannot be adequately captured by traditional regression analysis, and then conduct accurate causal analysis.

The methodology employed in this study to define disciplinary knowledge systems utilizes journal categories for classification, a process that may encounter limitations with regard to cross-disciplinary applicability. Future considerations will include the delineation of the boundaries and scope of knowledge systems at the level of the subject matter of the paper, with a view to enhancing the precision and breadth of the application of the methodology.

In this study, there may be limitations in the adequacy of the quantitative results to characterize the reality due to the relatively small number of indicators selected to describe the uncertainty of the system.

For the purpose of data acquisition, the present study employs Chinese literature databases to evaluate Chinese scientific and technical journals. In future, the intention is to adopt international literature databases with more extensive coverage to evaluate international scientific and technical journals.

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Appendix

Correspondence table between journal evaluation subsystems and indicators for calculating information entropy of knowledge systems.

Discipline(p)	*Number of options(n) (high-frequency keywords) in 2016*	*Factual value of information entropy H_p in 2016*	*Factual value of information entropy H_p in 2017*	*Factual value of information entropy H_p in 2018*	*Factual value of information entropy H_p in 2019*
Multidiscipline	182	86.55	82.07	81.32	83.69
General University Journal	532	148.62	148.24	142.93	147.21
Normal University Journal	230	60.16	61.77	63.35	61.74
Mathematics	200	30.68	31.36	30.31	28.96
Information Science and System Science	130	33.39	31.48	30.16	29.63
Mechanics	188	9.27	9.19	8.95	8.89
Physics	392	34.23	32.13	30.86	29.85
Chemistry	406	42.49	42.96	41.07	40.74
Astronomy	29	15.41	14.40	13.81	13.16
Earth Science	110	27.71	28.29	27.30	27.52
Atmospheric Sciences	101	16.00	15.58	14.77	14.23
Geophysics	162	36.93	36.51	34.26	35.12
Geography	210	24.27	23.85	23.76	22.89
Geology	261	77.90	73.06	72.08	72.43
Marine Science, Hydrography	173	51.02	52.18	50.92	47.71
Basic Biology	199	54.82	53.94	51.14	49.76
Ecology	164	29.44	29.04	28.89	27.81
Botany	92	17.78	17.99	17.79	16.89
Entomology, Zoology	83	28.11	27.16	26.11	25.06
Microbiology, Virology	92	24.72	24.61	24.84	23.82
Psychology	76	19.75	19.36	19.83	18.78
Agribusiness	557	156.32	154.65	150.90	146.34
Agricultural University Journal	305	79.41	78.79	80.56	76.20
Agronomy	152	46.95	45.13	44.40	44.95
Horticulture	92	10.49	9.96	10.16	9.80
Soil Science	70	22.69	22.67	23.05	23.15
Plant Protection	82	18.68	19.14	18.37	17.56
Forestry	225	20.42	21.01	19.76	20.27
Animal Husbandry, Veterinary Science	200	21.61	20.92	21.08	19.69

Discipline(p)	*Number of options(n) (high-frequency keywords) in 2016*	*Factual value of information entropy H_p in 2016*	*Factual value of information entropy H_p in 2017*	*Factual value of information entropy H_p in 2018*	*Factual value of information entropy H_p in 2019*
Grassland Science	60	13.67	13.02	12.78	12.64
Aquaculture	182	31.67	32.43	32.07	32.08
General Medicine	668	111.49	109.92	111.71	108.25
Medicine and Pharmacy University Journal	541	164.93	166.04	155.62	159.79
Basic Medicine	230	57.48	54.26	51.45	51.65
Clinical Medicine	452	108.06	108.10	104.23	97.47
Clinical Diagnostics	162	40.05	41.12	41.65	40.24
Health Care Medicine	106	33.14	31.93	29.92	29.98
Internal Medicine	37	18.43	17.42	16.59	17.06
Cardiovascular Disease	152	20.17	19.44	19.11	17.79
Respiratory Disease, Tuberculosis	63	18.87	17.71	18.21	17.44
Gastroenterology	100	30.50	30.84	29.96	29.31
Hematologic, Nephrology	86	20.35	20.95	19.94	18.69
Endocrinology and Metabolic Disease, Rheumatology	53	13.46	13.29	13.56	13.21
Infectious Diseases, Infectious Diseases	44	15.00	14.92	14.96	14.18
Comprehensive Surgery	148	54.97	51.18	51.90	49.61
General Surgery, Thoracic Surgery, Cardiovascular Surgery	134	44.43	43.79	41.00	39.23
Urology	47	11.05	10.79	10.77	10.19
Orthopaedic Surgery	82	19.97	20.11	19.51	19.03
Burn Surgery, Plastic Surgery	72	25.32	26.00	26.72	25.03
Obstetrics and Gynaecology	69	15.68	15.65	15.09	14.34
Paediatrics	118	18.44	17.62	17.51	17.66
Ophthalmology	95	16.49	15.73	16.16	15.99
Otolaryngology	79	22.72	21.15	21.67	21.79
Stomatology	125	36.97	37.82	38.30	36.21
Dermatology	64	13.42	13.67	13.37	12.80

Discipline(p)	*Number of options(n) (high-frequency keywords) in 2016*	*Factual value of information entropy H_p in 2016*	*Factual value of information entropy H_p in 2017*	*Factual value of information entropy H_p in 2018*	*Factual value of information entropy H_p in 2019*
Sexual Medicine	51	9.06	8.73	8.35	7.83
Neurology, Psychiatry	171	28.64	29.37	29.25	29.98
Nuclear Medicine, Medical Imaging	176	34.53	32.93	31.14	29.86
Oncology	200	44.64	42.31	41.66	41.98
Nursing	205	34.03	34.89	32.46	33.01
Preventive Medicine and Public Health	194	28.83	28.19	27.17	25.71
Epidemiology, Environmental Medicine	235	68.93	64.31	60.29	57.08
Eugenics	114	18.36	18.38	17.29	16.47
Health Management, Health Education	57	32.73	31.59	29.91	30.27
Military Medicine and Specialty Medicine	306	7.81	7.38	7.34	6.98
Pharmacy	537	116.44	114.70	117.53	119.07
Traditional Medicine	490	57.71	59.32	60.13	58.69
Tradition Medicine University Journal	184	30.35	30.55	29.53	29.75
Integrative Medicine	159	26.70	26.54	26.71	26.97
Traditional Chinese Medicine	527	80.75	79.77	74.25	73.40
Acupuncture and Moxibustion, Orthopaedics and Traumatology	57	5.39	5.38	5.39	5.28
Basic Science for Engineering and Technology	353	21.70	20.94	21.39	21.30
Engineering and Technology University Journal	959	229.03	227.63	224.11	228.55
Information and System Science Related Engineering and Technology	361	67.62	63.93	64.64	62.58
Bioengineering	84	23.52	22.77	21.85	20.55

Discipline(p)	*Number of options(n) (high-frequency keywords) in 2016*	*Factual value of information entropy H_p in 2016*	*Factual value of information entropy H_p in 2017*	*Factual value of information entropy H_p in 2018*	*Factual value of information entropy H_p in 2019*
Agricultural Engineering	324	74.10	74.29	76.17	74.58
Biomedical Engineering	132	16.43	15.42	15.01	14.37
Surveying and Mapping	175	20.86	19.64	18.45	17.39
Materials	282	73.76	73.90	71.69	72.85
Metallic Materials	213	19.75	19.13	19.01	19.52
Mining Engineering Technology	290	67.14	64.34	65.51	66.26
Metallurgical Engineering Technology	113	31.13	30.07	28.33	26.81
Mechanical Engineering Design	444	38.21	37.92	36.40	36.39
Mechanical Manufacturing Process and Equipment	380	48.60	47.41	45.37	46.35
Power Engineering	131	17.23	16.57	15.73	15.93
Electrical Engineering	514	112.97	108.87	103.52	104.77
Energy	249	44.09	42.07	39.81	39.54
Oil and Gas	330	104.23	107.04	109.40	111.46
Nuclear	75	24.08	22.70	21.80	21.07
Electronic	518	33.54	32.05	32.17	31.82
Optoelectronics and Laser	221	30.43	30.33	29.81	28.35
Communication	171	37.08	36.15	36.37	35.53
Computer	706	32.60	33.51	32.99	33.72
Chemical Engineering	399	66.99	67.54	67.23	63.10
Polymer	107	35.57	34.98	34.41	32.15
Fine Chemical Engineering	119	19.67	19.00	17.74	18.04
Applied Chemical Engineering	94	18.14	17.98	18.39	17.62
Instrumentation	249	29.41	27.86	27.72	26.32
Defence	223	50.74	50.20	49.36	46.45
Textile	95	24.88	24.26	24.22	23.10
Food	401	63.39	63.76	63.32	59.71
Building	373	33.56	32.40	32.62	31.93
Civil Engineering	129	16.43	15.74	15.25	14.74
Water Resources Engineering	285	77.99	77.05	75.41	71.06

Discipline(p)	*Number of options(n) (high-frequency keywords) in 2016*	*Factual value of information entropy H_p in 2016*	*Factual value of information entropy H_p in 2017*	*Factual value of information entropy H_p in 2018*	*Factual value of information entropy H_p in 2019*
Transportation Engineering	90	13.34	12.67	12.68	12.52
Road Transportation	135	16.08	15.19	15.06	15.47
Railroad Transportation	129	20.81	19.75	18.59	18.97
Waterway Transportation	157	26.85	26.87	26.75	25.09
Aviation, Aerospace	357	91.56	92.32	91.97	88.19
Environmental and Resource	434	61.06	62.67	59.62	57.45
Safety	150	25.20	24.50	24.02	22.52
Management	298	67.45	64.83	62.42	63.77

Note: The *H* data has been magnified 100 times for ease of display.