# Postprint of Research on Academic Impact Evaluation of Papers Based on Multi-Generational Citations and Knowledge Inheritance

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## Abstract

[Purpose/Significance] Academic paper evaluation plays a fundamental and radiating role in the entire scientific evaluation system. Constructing measurement indicators that can reflect the long-term academic impact of scholarly papers is an important component in improving the academic paper evaluation system. [Method/Process] This study researches and constructs an academic impact evaluation method for papers (referred to as the MGR-KI method) that comprehensively considers citation chain relationships of both direct and indirect citations, while simultaneously accounting for the continuous knowledge contribution level of academic achievements. Using 2,070 papers in the electromagnetic metamaterials field involving 7,652 citation relationships and 14,074,058 citation paths as data sources, an empirical study was conducted to verify the feasibility and effectiveness of the constructed method. [Results/Conclusions] The MGR-KI-based academic impact evaluation method constructed in this paper accounts for different citation type characteristics. Compared with citation frequency and citation h-index for evaluating academic paper impact, this method demonstrates stronger discriminative power, facilitating more refined comparison and evaluation of different papers with identical citation frequencies. Differences in text similarity calculation methods based on feature dimension and semantic dimension significantly affect results, necessitating future research on finer-grained knowledge inheritance relationship mining and inheritance intensity calculation methods to achieve more precise measurement and evaluation.

## Full Text

## Preamble

**Research on Academic Impact Evaluation of Papers Based on Multi-generation Citation and Knowledge Inheritance**

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**Abstract:** [Purpose/Significance] Academic paper evaluation plays a fundamental and radiating role in the entire scientific evaluation system. Constructing measurement indicators that can reflect the long-term academic influence of papers constitutes an important component in improving the academic paper evaluation system. [Method/Process] This paper develops and constructs an academic impact evaluation method for papers (abbreviated as MGR-KI) that comprehensively considers citation chain relationships encompassing both direct and indirect citations while accounting for the sustained knowledge contribution level of academic achievements. Using 2070 papers in the electromagnetic metamaterials field—involving 7652 citation relationships and 14,074,058 citation links—as data sources, an empirical study is conducted to verify the feasibility and effectiveness of the proposed method. [Result/Conclusion] The MGR-KI-based academic impact evaluation method constructed in this paper accounts for characteristics of different citation types and demonstrates stronger discriminative power compared to evaluation results based on citation frequency and cited h-index. This approach facilitates more refined comparisons and evaluations of different papers with identical citation frequencies. Different text similarity calculation methods based on feature dimensions and semantic dimensions significantly affect results, necessitating future research on more fine-grained knowledge inheritance relationship mining and inheritance intensity calculation methods to achieve more precise measurement and evaluation.

**Keywords:** Multi-generation citation; Knowledge inheritance; Academic chain; Academic impact; Paper evaluation
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Academic papers represent a crucial form of research output in scholarly research and serve as important carriers for the inheritance and dissemination of academic achievements. Evaluating academic papers has long been a significant focus for research institutions and universities. Academic paper evaluation plays a fundamental and radiating role in the entire evaluation system—the evaluation standards and methods not only reflect research quality and innovation orientation but also exert strong radiating effects on scholar evaluation and institutional assessment. Accurate and objective evaluation of academic papers is an essential component in constructing an academic evaluation system, and scientifically sound paper evaluation plays a vital role in promoting academic innovation and fostering positive development in scientific research. This study is supported by the National Social Science Fund Youth Project "Research on Methods for Measuring Interdisciplinarity at the Topic Level and Identifying Interdisciplinary Topics" (Project No.: 20CTQ027).

For many years, scholars both domestically and internationally have conducted systematic research on academic paper evaluation methods and indicator sys-

tems from various perspectives, focusing primarily on academic value, innovation, academic impact, and social impact. Among these, academic impact remains the central concern in current academic paper evaluation. Academia generally defines academic impact as the degree of attention a paper receives from the academic community, mainly manifested as research evaluation within its own or adjacent fields resulting from citation relationships. This has led to the emergence of various academic impact measurement indicators, such as total citation frequency, citation speed, and citation peaks.

For academic papers, generating citations quickly after publication certainly demonstrates academic impact. However, from the perspective of academic chains, a highly inspiring paper may not necessarily generate high direct citation counts, yet the academic impact of subsequent literature that achieves further innovation and development based on it can still be considered an important manifestation of that paper' s influence. Many scholars have noted this phenomenon and developed computational indicators that consider indirect citations. For instance, Schubert applied the h-index to academic achievement evaluation by calculating the citation frequency distribution of a paper' s citing literature set to obtain the paper' s cited h-index, though this method only considers the academic impact generated by first-generation and second-generation citations. Fragkiadaki et al. incorporated all direct and indirect citation information in the citation network to construct an f-value indicator reflecting paper influence, but this method essentially remains a modification of citation frequency and shows strong correlation with citation frequency indicators. From a policy perspective, the "Guiding Opinions on Improving the Evaluation Mechanism for Scientific and Technological Achievements" proposes to "strengthen medium- and long-term evaluation, post-evaluation, and achievement retrospection," representing an important task for "deepening reform of scientific and technological evaluation" and an important measure for "guiding researchers to concentrate on research and exploratory innovation." Incorporating this requirement into the elements of academic paper evaluation and constructing measurement indicators that can reflect the long-term academic impact of papers is also an important direction for building an academic paper evaluation system. Based on these two considerations, this paper will research and construct an academic paper evaluation method that comprehensively considers linear relationships between direct and indirect citations and accounts for the sustained knowledge contribution level of academic achievements, from the perspectives of multi-generation citation and knowledge inheritance, aiming to provide more diverse observation perspectives for academic paper evaluation system construction.

## 1. Literature Review

In the field of scientific research and academic evaluation, numerous methods exist for evaluating academic papers with varying dimensions and approaches, including qualitative evaluation based on peer review and quantitative evaluation employing measurement indicators. Both approaches have distinct ad-

vantages and disadvantages, making the selection of appropriate methods for specific goals and purposes to support policy decision-making an important issue in information science. This paper reviews literature from the perspective of academic paper impact, focusing specifically on academic impact evaluation methods. Academic paper impact refers to a paper' s ability to influence or change people or things through certain means. Since papers affect diverse and variable objects in multiple ways, database indexing, downloads, academic citations, online dissemination, usage, mentions, and discussions can all be considered important manifestations of impact. Consequently, paper impact has rich connotations, with existing research often dividing it into academic impact and social impact for discussion. Academic impact serves as a crucial indicator for measuring academic contribution and influence, representing scientific measurement and evaluation of an object' s academic value, contribution, and status from an impact perspective. Current research on paper academic impact evaluation primarily relies on citation indicators, with ongoing advancement in citation content mining research as algorithmic technology develops, alongside the emergence of academic paper evaluation methods based on textual content features.

In citation relationship-based academic impact evaluation systems, citation frequency and impact factor are two widely used indicators, based on the premise that factors affecting paper quality include both the overall level of the journal in which the paper is published and its own academic performance. To compensate for the time lag characteristic of citations, journal impact factor can supplementarily measure the potential impact of newly published papers that have not yet accumulated sufficient citations. However, we note that changes in journal impact factor do not equate to changes in paper academic value, making the accuracy of using journal impact factor to evaluate academic papers questionable. Meanwhile, citation frequency exhibits a strong "time accumulation effect," prompting continuous optimization efforts by scholars who have designed improved indicators such as "average annual citation frequency,""citation speed," and "weighted citation frequency based on citation time heterogeneity."Research and discussion on paper social impact primarily focus on altmetrics and related alternative metrics indicators, constructing a relatively rich evaluation system for academic paper social impact, proposing concepts of secondary impact, and examining correlations between social media indicators and citation indicators.

Although existing citation relationship-based academic impact evaluation indicator systems are relatively rich and can describe and evaluate paper academic impact from multiple perspectives, citation relationships between academic papers essentially represent the inheritance and dissemination of academic achievements and the transfer and absorption of scientific knowledge throughout the scientific innovation system. Therefore, evaluating paper academic impact must consider academic inheritance effects and construct indicators that reflect academic inheritance and knowledge transfer. Based on this objective, this paper will optimize and improve citation indicators from the perspective of knowledge inheritance. While academia has not yet formed a clear definition of knowledge

inheritance, extensive research has been conducted on knowledge inheritance phenomena accompanying scientific literature citation processes and the impact of scientific knowledge flow on innovation during inheritance. These studies have elaborated on the generation and dissemination of scientific knowledge during publication and citation processes, arguing that early scientific literature in citation networks can transmit knowledge to later literature and promote the generation and growth of new knowledge. Setting aside complex citation motivations or social influencing factors, the citation process is essentially a process of scientific knowledge flow, growth, and evolution. Knowledge carried by scientific literature is inherited and derived from predecessors, exhibiting knowledge inheritance and evolution similar to biological evolution phenomena. In the complex network formed by relevant content in scientific literature, the evolutionary process of scientific knowledge inheriting and deriving from predecessors is considered the internal driving force of knowledge selection, inheritance, and variation. Based on this, Hu Xiaojun applied the concept of "citation generation" to scientific evaluation, constructing measurement indicators for scientists or research achievements in scientific evolution networks, but only focused on calculating influence across three generations in citation networks. Ha et al. constructed a multi-generation citation-based core patent identification method from the patent citation network structure, comprehensively considering linear relationships between direct and indirect citations, achieving good application results. This paper will draw on this approach, constructing academic paper impact measurement indicators based on multi-generation citation relationships through mining paper citation networks. Simultaneously, multi-generation citation relationships of academic papers represent the selection and filtering process of research content by scholars during knowledge inheritance. The larger the generational impact a paper can achieve, the farther its content disseminates. Therefore, from the knowledge inheritance perspective, measuring sustainable knowledge contribution is also an important aspect of evaluating paper academic impact. Consequently, this paper' s main research involves constructing academic paper impact evaluation indicators from multi-generation citation and knowledge inheritance perspectives, calculating and comparing paper influence in academic evolution networks, improving the current situation of evaluating papers by journal impact factor and citation count, providing more diverse observation perspectives for academic paper evaluation system construction, and exploring and implementing paper evaluation methods based primarily on paper value and sustained knowledge contribution at the micro level.

## 2. Academic Impact Evaluation Model and Indicator Construction

A paper' s academic impact is strongly related to its citation frequency. Simultaneously, in citation networks based on citation relationships, knowledge inheritance from citing to cited literature along citation chains and a paper' s multi-generation citations—that is, its sustained knowledge contribution capability—are also important manifestations of academic impact. Based on this

fundamental assumption, this paper constructs academic impact evaluation indicators for papers that consider both knowledge inheritance capability between parent and child nodes in citation chains and sustained knowledge contribution capability across multi-generation citations, evaluating paper academic impact in academic evolution networks. The resulting Multi-generation References and Knowledge Inheritance (MGR-KI) academic paper evaluation model is shown in Figure 1 [Figure 1: see original paper].

The calculation of paper academic impact based on this model primarily includes the following steps: (1) Construct a directed network graph based on extracted paper citation relationships, extract citation chains from the citation network, and obtain parent and child node sets for each node. For example, Paper A' s child nodes are Papers C and D, while Paper D' s parent nodes are Papers A and B. (2) Construct knowledge inheritance intensity indicators along citation chains by calculating text similarity between parent and child nodes, i.e., calculating document similarity between Paper A and Paper C as the knowledge inheritance intensity value from Paper A to Paper C. (3) For each network node, calculate its child nodes' knowledge contribution intensity in the knowledge inheritance network, using knowledge inheritance intensity scores and the number of knowledge sources as base weights for calculating the parent node's knowledge contribution intensity, and allocate the node' s knowledge contribution to its parent nodes accordingly. This achieves knowledge contribution intensity indicator calculation that considers both multi-generation citations and knowledge inheritance. For instance, Paper B' s knowledge contribution calculation depends on Papers D and G. This step includes recursive calculation logic, where each node depends on its child nodes' knowledge contribution intensity.

Based on these calculation steps, this paper constructs an academic paper impact evaluation method that comprehensively considers linear citation chain relationships encompassing both direct and indirect citations from multi-generation citation and knowledge inheritance perspectives.

Figure 2 [Figure 2: see original paper] provides an example illustrating the algorithm calculation process. Arrows between nodes represent knowledge flow direction, where A $\rightarrow$ D indicates that Document D cites Document A, meaning knowledge flows from Document A to Document D, and edge weights represent content similarity between two nodes. For Node A, the knowledge contribution intensity depends on its child nodes and their subsequent knowledge inheritance relationships. Similarly, knowledge contribution intensity scores for other nodes can be obtained. The following section will collect papers in specific fields and their citation networks for empirical research to verify the feasibility of this method in evaluating paper academic impact, while comparing calculation results based on this indicator with academic impact evaluation results based on citation frequency and other indicators to verify the method' s effectiveness in supplementing and improving citation frequency-based evaluation.

## 3.1 Experimental Data and Calculation Results

This paper conducts experimental research in a specific field to compare differences in evaluation results between traditional methods using citation frequency and cited h-index versus the MGR-KI-based method constructed in this paper, thereby verifying the feasibility and effectiveness of the proposed method. For the experimental dataset, this paper retrieved and downloaded 2070 papers in the electromagnetic metamaterials field from the Web of Science database as source data, then retrieved citation information for these source papers from citation databases and downloaded citing literature to construct source and citing literature datasets, establishing accurate literature citation relationships. This dataset contains 7652 citation relationships and 14,074,058 citation links. Academic impact evaluation results based on these methods are then compared in detail. In the specific calculation process, Python programming tools are used to implement text feature similarity calculation, obtaining knowledge transmission intensity values along citation chains, and recursive calculation is employed to obtain paper impact test indicators considering multi-generation citation relationships. Table 1 presents the academic impact calculation indicators based on the above dataset and the MGR-KI method constructed in this paper, with citation frequency and cited h-index included as references for comparative analysis in the following discussion.

## 3.2 Ranking Difference Analysis

To comprehensively compare differences in academic impact measurement using different methods, this paper calculates rankings of paper academic impact under different evaluation indicators and compares how different calculation methods affect paper ranking sequences. Generally, for such ranking comparison problems, academia commonly uses the number of shared papers in the top k positions of two sequences to characterize differences between sequences, but this comparison method is insensitive to ranking positions. To address this sensitivity issue, this paper adopts the ranking difference calculation method designed by Li Siying et al. for comparative analysis of ranking differences among different academic impact evaluation indicators.

Figure 3 [Figure 3: see original paper] shows the ranking differences between the MGR-KI-based academic impact evaluation results and those based on citation frequency and cited h-index. The results clearly demonstrate that MGR-KI-based evaluation shows significant differences from the other two methods, particularly for top-ranked papers where ranking positions vary considerably under different evaluation indicators. Both comparison results show rapid increases in ranking difference measurement values within the top 60% of papers. Further comparative analysis of ranking distributions between MGR-KI-based evaluation and citation frequency/cited h-index-based evaluation in Figure 4 [Figure 4: see original paper] yields two conclusions: First, MGR-KI-based academic impact evaluation shows significant correlation with citation frequency, further demonstrating that the MGR-KI method constructed in this paper ex-

hibits strong sensitivity to citation frequency when evaluating highly cited papers while accounting for different citation types. Second, compared to citation frequency and cited h-index, the method constructed in this paper demonstrates stronger discriminative power in academic impact evaluation results—under identical citation frequencies, cited h-index evaluation results are more concentrated, while MGR-KI-based results are more dispersed, facilitating more refined evaluation and comparison of different papers with the same citation frequency.

## 3.3 Case Analysis and Discussion

To more intuitively demonstrate differences between MGR-KI-based evaluation and citation frequency/cited h-index-based evaluation, this paper selects papers with identical citation frequencies and identical cited h-index values to compare their MGR-KI differences, while illustrating different characteristics of their generational citation and knowledge inheritance networks within the overall citation network. Overall, since all these academic impact calculation methods use citation information, the resulting paper impact ranking sequences show positive correlation. However, for papers with identical citation frequencies and identical cited h-index values, their knowledge inheritance networks exhibit substantial differences. Figure 4 shows the ranking distribution of academic impact evaluation based on MGR-KI versus citation frequency and cited h-index. The figure more clearly illustrates that papers with identical citation frequencies and identical cited h-index values have different rankings under multi-generation citation and knowledge inheritance-based evaluation, further demonstrating that the method constructed in this paper provides different perspectives for academic impact evaluation and can reflect richer information about papers in citation networks.

Further illustration of individual evaluation differences through specific cases is provided in Figure 5 [Figure 5: see original paper], which presents two cases. These two papers (numbered WOS:000266381700079 and WOS:000280632000016) both have five citations within the dataset, but exhibit enormous differences in knowledge inheritance effects in the citation network. The latter paper' s citing literature does not generate strong influence in the citation network, i.e., it is inferior in citation generations compared to the former. Therefore, the MGR-KI values calculated using this paper' s method are 5.2199 and 5.1023 respectively, resulting in a 16-position difference in MGR-KI-based evaluation rankings. Two papers with identical cited h-index values (numbered WOS:000323846900020 and WOS:000275454100117) both have a cited h-index of 2, but their MGR-KI values are 10.1259 and 2.1388 respectively, resulting in a 438-position difference in MGR-KI-based evaluation rankings.

Through comparative analysis of academic impact from multi-generation citation and knowledge inheritance perspectives for papers with identical citation frequencies and identical cited h-index values, the paper academic impact measurement algorithm constructed in this paper can provide richer information and

more diverse observation perspectives for individual paper evaluation. Citation relationships in academic papers are important clues reflecting knowledge inheritance, development, application, and evaluation of a paper' s research in subsequent studies. Measuring sustained knowledge contribution from the continuity of citation chains and determining paper academic impact by combining knowledge inheritance intensity constitute the main research content of this paper. Empirical research verifies the feasibility and effectiveness of the constructed method, while also demonstrating that indirect citation relationships and different citation manifestations across multi-generation citation chains can become important features for evaluating paper academic impact. The multi-generation citation and knowledge inheritance-based academic impact evaluation indicator can serve as an important supplement to citation frequency and cited h-index indicators, providing richer information for paper evaluation.

Accurate academic impact evaluation is an important prerequisite for constructing an academic paper evaluation system and a crucial step in advancing scientific achievement evaluation system construction, playing a fundamental and radiating role in the entire academic evaluation system. Meanwhile, we must clearly recognize that the significance of academic evaluation work does not lie in evaluation itself. Striving to achieve positive interaction and resonance between academic research and scientific evaluation, mining academic inheritance contexts and dissemination patterns in evaluation, and promoting close integration between scientific research and practical problems are themselves important manifestations of evaluation orientation. From the perspective of academic inheritance, based on multi-generation citation relationships and knowledge inheritance networks among academic literature, this paper constructs a paper academic impact evaluation algorithm and verifies its feasibility and effectiveness through empirical research. This method supplements and improves upon the inability of citation frequency and cited h-index to distinguish citation forms and citation intensity, enhancing the discriminative power of paper academic impact evaluation results. Experimental results also demonstrate that this method can serve as another important dimension in paper academic impact evaluation. However, this paper also has limitations and shortcomings. For instance, in calculating knowledge inheritance intensity, this paper uses text similarity between nodes at both ends of citation chains as edge weights, but different text similarity calculation methods based on feature dimensions and semantic dimensions significantly affect results. Future research will conduct deeper investigations in this area to achieve more fine-grained knowledge inheritance relationship mining and inheritance intensity calculation, thereby providing more precise measurement for individual paper knowledge contribution and academic impact and enabling more accurate academic paper evaluation.

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