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Systematic Review of Interdisciplinary Research (Postprint)

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Abstract

[目的/意义] To review interdisciplinary research both domestically and internationally, summarize existing problems in current studies, provide references for evaluating interdisciplinary effectiveness, and offer insights for promoting interdisciplinary development. [方法/过程] First, relevant concepts in interdisciplinary research are distinguished and analyzed. Second, based on a survey of domestic and international studies, the research is organized and summarized from three dimensions: theoretical research on interdisciplinarity (interdisciplinary talent cultivation, types of interdisciplinarity, internal and external motivations and hindering factors), measurement research on interdisciplinarity (interdisciplinary measurement methods, interdisciplinary measurement indicators), and research on interdisciplinary patterns (bidirectional measurement of interdisciplinary impact, identification of interdisciplinary research topics). Finally, existing research deficiencies are identified and future development prospects are proposed, providing assistance for subsequent research from a perspective combining micro-level deep analysis and macro-level holistic construction. [结果/结论] Currently, interdisciplinary research exhibits the following deficiencies: faculty teams and curriculum systems require further optimization; diversity of research subjects needs improvement; interdisciplinary measurement methods and indicators still require systematization; disciplinary classification systems need further definition; bidirectional influencing factors of interdisciplinarity are not comprehensive enough; topic identification methods remain imperfect; qualitative and quantitative methods need to be combined and complement each other. Future research can conduct in-depth analysis addressing these deficiencies.

Full Text

Abstract

Purpose/Significance: This paper systematically reviews interdisciplinary research both domestically and internationally, summarizes existing research gaps, provides references for evaluating the effectiveness of interdisciplinary research, and offers insights for promoting its development.

Method/Process: First, we analyze concepts related to interdisciplinary research. Then, based on a survey of relevant studies, we organize research findings from three perspectives: theoretical research (interdisciplinary talent development, types of interdisciplinary research, internal and external motivations and obstacles), measurement research (interdisciplinary measurement methods and indicators), and pattern research (bidirectional impact measurement and topic identification). Finally, we identify current research deficiencies and propose future directions, providing a foundation for subsequent studies that combine micro-level deep analysis with macro-level construction.

Result/Conclusion: Current interdisciplinary research suffers from seven key limitations: (1) faculty and curriculum systems require further optimization; (2) research object diversity needs improvement; (3) measurement methods and indicators remain unsystematic; (4) disciplinary classification systems need clearer definition; (5) bidirectional influencing factors are inadequately comprehensive; (6) topic identification methods are incomplete; and (7) qualitative and quantitative approaches need integration and mutual reinforcement. Future research should address these deficiencies through in-depth analysis.

Keywords: interdisciplinary research; theoretical research; degree of interdisciplinarity; influencing factors; topic identification

2 Conceptual Analysis of Interdisciplinary Research

2.1 Defining Core Concepts

International discussions on cross-disciplinary research emerged in the 1940s but only gained academic attention in the 1970s. The term “interdisciplinary” was first proposed by Columbia University psychologist R.S. Woodworth to describe practices involving two or more disciplines that transcend known disciplinary boundaries [25]. In China, interdisciplinary research gained momentum in the 1980s, with some scholars adopting the translated term “cross-disciplinary” while others preferred “interdisciplinary,” notably Qian Xuesen, Qian Sanqiang, and Qian Weichang who delivered keynote speeches at the first Cross-Disciplinary Science Symposium in 1985. Although the expressions differ, both share the same English root “Interdisciplinary.”

To understand interdisciplinary research, we must first define “discipline.” The *Modern Chinese Dictionary* defines discipline as a category of knowledge, such as physics and chemistry in natural science, or school subjects like language and

mathematics [22]. Kuhn viewed a discipline as a paradigm comprising symbolic generalizations, models, and exemplars [23]. These definitions suggest disciplines possess independence from other fields and represent a social order of knowledge. However, as society evolves, single disciplines increasingly struggle to solve complex problems, giving rise to interdisciplinary research. According to Liu Zhonglin [24], if we simplify the disciplinary system into three major categories—natural sciences, social sciences, and technological sciences—the relationship between disciplines and interdisciplinary fields can be visualized as shown in [Figure 1: see original paper], where unmarked areas represent single disciplines, lined areas represent interdisciplinary fields (dashed lines indicate intra-disciplinary crossing, solid lines indicate inter-disciplinary crossing, and the central solid dot represents crossing among all three categories).

As interdisciplinary research deepens, numerous related terms have emerged, which can be categorized into four groups:

(1) Hierarchical levels of disciplinary activity: These include unidisciplinary, multidisciplinary, pluridisciplinary, crossdisciplinarity, interdisciplinary, and transdisciplinary, with increasing levels of integration. Building on Austrian scholar J. Erich’s framework [26], we summarize these terms in .

(2) Cross-disciplinary science and interdisciplinarity: Qian Xuesen [27] defined cross-disciplinary science as new disciplines emerging from the intersection of natural and social sciences. The *Dictionary of Cross-Disciplinary Science* [28] defines interdisciplinarity as the science studying the laws and methods of disciplinary crossing. While cross-disciplinary/interdisciplinary refers to activities and new disciplines formed by integrating two or more fields, cross-disciplinary science is an independent discipline examining all cross-disciplinary phenomena.

(3) Interdisciplinary research (IDR): The U.S. National Academy of Sciences defines IDR as a research mode integrating information, data, techniques, tools, perspectives, concepts, or theories from two or more disciplines to solve problems beyond single disciplinary scope [29]. I. Rafols and M. Meyer [30] emphasize that IDR’s key aspect is integrating different knowledge systems rather than violating disciplinary boundaries. Interdisciplinary research represents interactions among multiple disciplines that form interdisciplinary fields, which collectively constitute cross-disciplinary science [16].

(4) Interdisciplinarity/degree of interdisciplinarity: Li Jiang [31] suggests translating the noun form as “interdisciplinarity” or “degree of interdisciplinarity,” referring to characteristics like the breadth and intensity of knowledge integration. For consistency, this paper uniformly uses “interdisciplinary research,” “cross-disciplinary science,” “interdisciplinary research,” and “degree of interdisciplinarity.”

3 Main Research Content on Interdisciplinary Studies

This paper focuses on the practical dimension of interdisciplinary research. Based on domestic and international literature, we organize findings into three aspects: theoretical research, measurement research, and pattern research. Theoretical research provides the foundation, measurement research offers tools for assessment, and pattern research summarizes phenomena and discoveries.

3.1 Theoretical Research

3.1.1 Talent Development Traditional university departments with rigid disciplinary boundaries face challenges in cultivating interdisciplinary talent. Universities worldwide are establishing interdisciplinary research centers and restructuring curricula to include integrated courses. For example, Spanish primary and secondary schools combine history, geography, economics, and sociology into “Social and Natural Sciences,” while MIT requires engineering and liberal arts students to take cross-disciplinary courses. Scholars have analyzed curriculum design and training models: Chen Qirong [32] argues interdisciplinary education requires transformed educational philosophies; P. Hall et al. [33] emphasize comparing interdisciplinary education with traditional methods; R. Szostak [34] notes growing social demand for interdisciplinary approaches; J.K. Singleton et al. [35] examine barriers and benefits in healthcare education; M.F. Orillion [36] demonstrates through case studies that interdisciplinary courses improve student performance; Wang Dingding [37] identifies qualified faculty as the scarcest resource; and S.A. Nancarrow et al. [38] propose ten principles for supporting interdisciplinary teamwork based on interviews with 253 community rehabilitation staff.

3.1.2 Types of Interdisciplinary Research Different forms of disciplinary integration create different interdisciplinary types. Scholars have proposed various classifications: Li Chunjing et al. [40] identify three types—researcher background crossing, object crossing (“close” vs. “distant” disciplines), and paradigm crossing (language transplantation, method borrowing, theoretical integration). Jin Weiyin [41] proposes seven types including observation-comparison, discourse transplantation, complementary fusion, chain radiation, focused convergence, horizontal synthesis, and abstract sublimation. J. Klein [42] categorizes by depth from fuzzy to permeable stages, while Zhou Wenjuan [43] simplifies this to four types: transplantation, complementary fusion, chain radiation, and focused convergence. The core principle involves applying other disciplines’ methods and technologies, with further subdivisions based on dominance, mode, and degree of integration.

3.1.3 Motivations and Obstacles Understanding why interdisciplinary research emerges and what hinders it is crucial. The *Facilitating Interdisciplinary Research* report [44] identifies four drivers: inherent complexity of nature and society, fundamental research questions, social problem-solving needs, and new

technology promotion. Ma Yue et al. [45] attribute drivers to researcher curiosity, social demands, and disciplinary synergy effects. B. Shrimpton et al. [46] find that solving complex problems, producing useful results, and institutional policies motivate Australian researchers, while limited funding and time costs hinder progress. A. Milman et al. [47] survey 526 PhD students, revealing personal interest, social benefit, and enjoyment of collaboration as motivators, with longer research timelines, lack of peer support, and institutional barriers as obstacles.

We categorize promoting factors as external (major social problems, policy support, research centers) and internal (single-discipline limitations, self-improvement needs, researcher interests). Obstacles include inconsistent policies, narrow researcher perspectives, communication barriers, and lack of unified evaluation mechanisms.

3.2 Measurement Research

With rapid literature growth, scientometric methods have become essential for quantitative analysis. Measurement involves selecting literature from specific fields, journals, or disciplines, choosing appropriate classification systems, and applying indicators.

3.2.1 Measurement Methods Two primary perspectives exist:

First, researcher background/author collaboration: Methods include analyzing degrees outside one's field (e.g., Liu Zhonglin et al. [49] measuring Nobel laureates' diverse degrees; C.R. Sugimoto et al. [50] analyzing PhD advisors' backgrounds), co-authors' disciplines (G. Abramo et al. [51] using Italy's researcher classification system), institutional affiliations (Zhang Lin et al. [53]; L. Qiu [54]; A.Y.K. Chua et al. [55]), and publication-citation patterns (A.L. Porter et al. [56]; M. Gowanlock et al. [57]; J. Qin et al. [58]). However, data acquisition challenges and mismatches between backgrounds and actual research limit these approaches.

Second, target literature and its citations: This dominant approach uses reference diversity to measure knowledge integration [64]. A.L. Porter et al. [65] built on A. Stirling's [66] three-dimensional framework (variety, balance, disparity) to propose integration measures for six fields (1975-2005), showing increasing but proximate interdisciplinarity. L. Leydesdorff [67] used betweenness centrality to measure journal interdisciplinarity. L. Zhang et al. [68] developed the 2DS indicator with better discrimination than Rao-Stirling. M. Szell et al. [69] applied Gini coefficients to 108 Nobel papers, revealing persistent disciplinary boundaries. Citation analysis faces challenges with dynamic changes and journal-category mismatches, requiring combination with other perspectives [71-74].

3.2.2 Classification Systems Appropriate classification is critical. summarizes commonly used systems: WoS (254 categories), JCR (multidisciplinary categories), ESI (22 broad fields), ECOOM (16+64 categories), Scopus (4+26 categories), CWTS (5+4535 categories), NSFC (8+91 categories), Chinese Library Classification (5+22 categories), Chinese Citation Database (8+124 categories), and CSSCI (2700+ journals). Overly fine granularity creates false high interdisciplinarity, while overly coarse granularity obscures actual crossing. Selection should match research purposes and data sources.

3.2.3 Measurement Indicators A. Stirling's [66] three-dimensional framework (variety, balance, disparity) forms the basis for most indicators. summarizes existing metrics, including specialization index, integration index, diffusion index, Shannon entropy, Simpson index, Brillouin index, Gini coefficient, and network-based measures (betweenness centrality, path length, E-I index). Comprehensive metrics like Rao-Stirling, 2DS, and the Ω indicator are most robust. However, most metrics remain single-dimensional, lack systematic unification, and involve complex calculations. Some scholars use factor analysis to reduce dimensions [75-76], offering alternative approaches but maintaining computational complexity.

3.3 Pattern Research

3.3.1 Bidirectional Impact Measurement Two questions dominate: what promotes interdisciplinarity, and does it increase impact? Regarding promotion, Wang Wenping et al. [92] show international collaboration fosters interdisciplinarity but varies by field. D. Rhoten et al. [93] find women more likely to engage in interdisciplinary work due to advantages in collaboration and innovation. J. Qin et al. [58] demonstrate that multi-author papers and cross-institutional/national collaboration increase interdisciplinary citation. I. Rafols et al. [94] note instrument-sharing projects promote crossing. F.J.V. Rijnsvoever et al. [95] identify female gender, work hours, industry experience, and applied research as positive correlates.

Regarding impact, Li Dong et al. [96] find no necessary correlation between interdisciplinary collaboration and impact. T.W. Steele et al. [97] show positive correlation between interdisciplinarity and citations. L. Vincent et al. [98] find both high disciplinarity and high interdisciplinarity yield low impact. Y.Y. Alfredo et al. [99] reveal positive correlation with reference variety but negative with balance and disparity. Wang Feifei et al. [100] identify an inverted U-curve relationship. Results vary by field, measurement approach, and indicator selection.

3.3.2 Topic Identification Interdisciplinary research generates new scientific growth points. Topic identification methods include: (1) Co-word analysis using keyword intersections and networks [101-105]; (2) Co-citation analysis building dynamic networks [106-107]; and (3) Text mining employing algorithms

considering syntax and semantics [108-110]. Current limitations include small-scale data, focus on two-discipline intersections, and lack of systematic methods. Future work should leverage big data and advanced algorithms for more comprehensive topic mining.

4 Summary and Outlook

Based on our review, seven major deficiencies persist:

1. **Faculty and curriculum optimization:** Despite research centers, interdisciplinary studies lack independent disciplinary status. Faculty often specialize in single disciplines, and stable interdisciplinary teams are rare. Curricula remain discipline-centric with limited electives.
2. **Research object diversity:** Most quantitative analyses focus on journal articles, neglecting patents, monographs, and projects. This limits result completeness and scientific validity.
3. **Systematic measurement methods:** Journal categories don't perfectly represent article content; personal backgrounds don't fully reflect research; institutional collaboration doesn't guarantee interdisciplinary output. Single-dimensional indicators dominate, while multidimensional ones remain complex and unstandardized.
4. **Classification system definition:** Granularity choices significantly affect results. Coarse systems may miss major breakthroughs; fine systems may obscure actual crossing. Selection should align with research goals and data sources.
5. **Comprehensive influencing factors:** Current studies focus narrowly on collaboration and gender impacts, neglecting broader internal/external drivers and effects beyond citation impact.
6. **Topic identification methods:** Existing approaches use limited data and two-discipline intersections, requiring validation on large-scale datasets and more sophisticated algorithms.
7. **Methodological integration:** Qualitative macro-analysis and quantitative micro-analysis remain separated. Only through their integration can a coherent research system emerge.

Future research should address these deficiencies through deeper analysis and methodological innovation.

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