

# What Are the Possible Futures of Interdisciplinary Research in China?

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## Abstract

*The global interdisciplinary research is challenging by multi-factors. In November 29, 2020, the National Natural Science Foundation of China officially established a new "Interdisciplinary Science Department" (ISD). As a "Chinese model" for scientific research, the organizational innovation of the ISD has been highly prioritized. Two year later, the ISD has achieved preliminary success. However, some problems remain, typified by the stagnation of interdisciplinary research due to the absence of systematic national support. In order to explore the possible futures of interdisciplinary research in China and, more importantly, to respond to the global challenges of interdisciplinary research, four actions beyond ISD are discussed.*

**Keywords:** interdisciplinary science department; interdisciplinary research; STEM; Chinese model

## 1. Introduction

As shown in an investigation, 49.5% of Nobel Prizes laureates in medicine had a multidisciplinary educational background from 1901 to 2018, and 69% of them had an undergraduate major that was not directly in medicine [1]. Besides, a study published in Nature that reviewed 88,000 high-quality scientific and technical papers published globally, revealing a progressive crossover between disciplines [2]. There is no doubt that the breakthrough scientific discoveries or significant technological advancements frequently originate from interdisciplinary fields [3, 4]. The increasing complexity of scientific and social issues, such as climate, energy, water, and other challenges addressed by the United Nations Sustainable and Millennium Development Goals, requires problem-solving approaches that link multiple areas of expertise [5-7]. Accordingly, interdisciplinary research has evolved into a consensus in the academia, which is devoted to addressing grand challenges such as sustainability [8, 9]. Reflections on the experiences of these interdisciplinary attempts have produced a distinction of numerous interdisciplinary forms, including multidisciplinary, interdisciplinary, and transdisciplinary. Multidisciplinary approaches mean drawing on knowledge from multiple disciplines without exceeding their boundaries. Conversely, interdisciplinary approaches refer to analyzing, synthesizing, and coordinating the connections between disciplines into a coherent whole [10]. Transdisciplinary approaches are comprehensive frameworks that transcend the narrow scope of disciplinary worldviews through an overarching synthesis, such as general systems, policy sciences, feminism, and sustainability, etc [11].

Chinese academia concurs that as well. In recent years, China has gained significant theoretical and practical achievements in interdisciplinary research. For instance, interdisciplinary topics abound in diverse academic conferences and journals [12]. Meanwhile, a large body of world-leading scientific breakthroughs have been achieved by China in various fields such as aerospace, bioengineering, life science, information technology, new materials, and new energy, etc. Around the world, however, substantial challenges to

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interdisciplinary research have emerged, including the dearth of interdisciplinary collaboration and inadequate funding mechanisms for interdisciplinary research, etc. This is particularly salient in China, where interdisciplinary research is still in the initial stage. In November 29, 2020, the National Natural Science Foundation of China (NSFC) officially established a new “Interdisciplinary Science Department” (ISD), which consisted of the fields of physical sciences, life and health sciences, intelligence and intelligent manufacturing sciences, and integration sciences [13]. As an "experimental ground" and a "Chinese model" for scientific research, the organizational innovation of the ISD has been highly prioritized. Two year later, the ISD has made some headway in interdisciplinary research in response to the national and social demands. However, some problems remain, typified by the stagnation of interdisciplinary research due to the absence of systematic national support. In this regard, the crucial causes and approaches to mitigate the problems will be addressed in this article.

### **2. Achievement and insufficient actions**

Notably, an increasing number of Chinese universities have established interdisciplinary research institutes. For instance, the Academy of Advanced Interdisciplinary Studies (AAIS) at Peking University was officially established on April 4, 2006, pioneering interdisciplinary research in Chinese higher education institutions. Currently, AAIS has developed a coordinated and adapted management model in talent introduction and evaluation, scientific research collaboration and exchange, student training and management, cross-campus linkage and cooperation, etc. On this basis, the journal "Universities and Disciplines" and the AAIS jointly launched a special issue on interdisciplinary in 2021. Previously, the Inaugural National Frontier Interdisciplinary Forum and Joint Meeting of Frontier Interdisciplinary Research Institutes was held in December 2020, signifying the official foundation of a national exchange platform for interdisciplinary research. Driven by this trend, the Academic Degrees Committee of the State Council and the Ministry of Education (MOE) in China have initiated two interdisciplinary categories, Integrated Circuit Science and Engineering, and National Security [14], which marked a pivotal point for Chinese interdisciplinary research. Subsequently, the Academic Degrees Committee of the State Council launched a policy titled “Interdisciplinary Setting and Management Measures” to arrange interdisciplinary pilot setting and management matters [15]. Thus, interdisciplinary research in China has endured more than a decade of precipitation followed by a rapid surge over the past three years, despite the fact that the present achievements is disorganized.

Meanwhile, the ISD is also actively exploring effective ways to promote interdisciplinary collaboration. For instance, the inaugural youth academic seminar was held by the ISD on October 10-11, 2021, with the goal of developing an academic exchange platform for excellent young scientists engaged in interdisciplinary research. Additionally, adhering to the principle of "high quality, high standards, and high threshold", the reviewers successfully completed the first batch of major project reviews hosted by the ISD on November 7, 2021. As a department that is still in its infancy, the above achievements were not an easy feat. However, it is far from enough to secure the continued advancement of interdisciplinary research in China, at least for now. On the one hand, the department’s efforts are insufficiently broad. For instance, in addition to organizing

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academic seminars, what additional strategies could effectively foster interdisciplinary collaboration? How to innovate the ways of project proposal, evaluation and funding of interdisciplinary research, etc.? These issues still require sustained and in-depth exploration by the ISD. On the other hand, due to the department's limited authority, it is difficult to drive radical reforms in interdisciplinary research, such as cultivating talents adaptable to interdisciplinary research in basic education, establishing an interdisciplinary collaboration pattern oriented to the integration of diverse resources, etc. These cannot be isolated from the national policy support and cross-departmental collaboration.

Undeniably, advocacy for interdisciplinary research at the national level is ongoing. For instance, the "National Medium and Long-Term Science and Technology Development Plan (2006-2020)" issued in 2006 claimed that major scientific discoveries and emerging disciplines often arise from the intersection and integration of multiple disciplines, which require high priority and focused deployment [16]. Besides, the "Outline of National Innovation-driven Development Strategy" issued in 2016 stated that interdisciplinary strengths should be integrated to accelerate key breakthroughs [17]. In addition, the "13th Five-Year Plan for National Science and Technology Innovation" launched by the State Council in 2016 proposed to strengthen the construction of emerging disciplines such as information, biology, and nanotechnology, and encourage interdisciplinary research [18].

However, the existing policies are limited to the general descriptions rather than systematic reports or development strategies, which are not conducive to further implementation of interdisciplinary research. Comparatively, several developed countries have issued a series of national-level interdisciplinary research reports. Taking the United States for example, the National Academy of Sciences, the National Academy of Engineering, the National Academy of Medicine, and the National Research Council jointly issued "Promoting Interdisciplinary Research" in 2005, which provided a general guideline for interdisciplinary research in terms of its definition, status, institutional impediments and challenges [19]. For another instance, the Higher Education Funding Council for England and the Research Councils UK jointly published two reports on interdisciplinary research in 2016: "A Panoramic Review of Interdisciplinary Research in the UK [20]" and "A Review of Case Studies of Interdisciplinary Research in UK Higher Education Institutions [21]". The two reports have identified a range of impediments and incentives to interdisciplinary research in the UK and made policy recommendations from the viewpoints of funders, academics, and strategic leaders in higher education. By comparison, China's interdisciplinary policies continue to lag in terms of systematic top-level design. Besides, there is little coordination and integration between relevant Chinese departments, such as the MOE and the Ministry of Science and Technology (MOST), which have only formulated corresponding interdisciplinary development plans within their respective functions. Due to the lack of national development strategies, incentive mechanisms, and resource guarantees, interdisciplinary research in China is still on the margins. Given that interdisciplinary research is crucial for advancing both scientific innovation and social progress, the top-level design should be addressed.

### **3. Challenges**

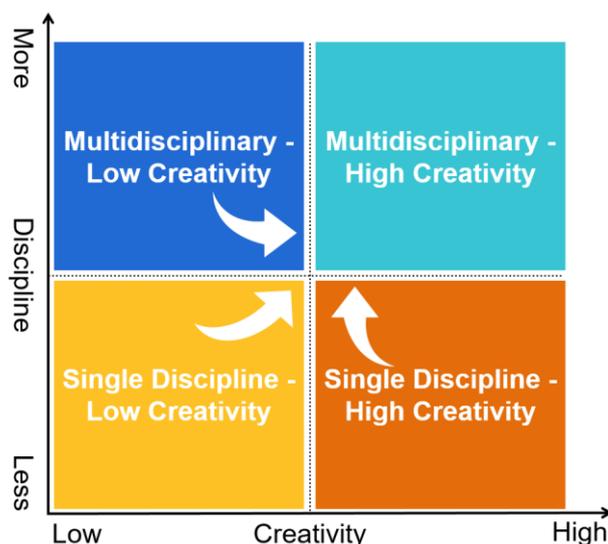
Above, we have outlined the major problems of interdisciplinary research in China. This section will explore

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the primary causes of the problems, which are also the fundamental challenges confronted by interdisciplinary research in China.

### *3.1. Discipline-centrism entrenched in K-12 education and higher education*

As a key competence of talent in the 21st century, creativity has earned enormous attention worldwide. The cultivation of creativity is differentiated not only into high and low levels, but also into disciplines. Generally, the creativity level can be defined based on the transfer degree, where low creativity and high creativity refer to students' ability to apply what they have learned to address problems similar and dissimilar to the original learning situation, respectively. It is critical to note that "low" and "high" should not be taken as absolutes, as they would change dynamically over time. According to this, the students' creativity cultivation in schools can be classified into four categories (Figure 1) namely: "Single Discipline - Low Creativity", "Single Discipline - High Creativity", "Multidisciplinary - Low Creativity" and "Multidisciplinary - High Creativity". Interdisciplinary creativity serves as the basis for interdisciplinary research, which is aligned with the "Multidisciplinary - High Creativity" perspective.



**Figure 1. Four categories of creativity cultivation in schools.**

The aforementioned settings of interdisciplinary categories represent an interdisciplinary transition in higher education. However, creativity cannot be developed overnight. As a precursor to higher education, basic education plays a pioneering and fundamental role in cultivating creative talents. Since traditional disciplinary instruction weakens the crossover of knowledge, China has maintained a general state of "Single Discipline - Low Creativity" in K-12 education. Although single-discipline education represented by mathematics, physics, chemistry competitions can enhance students' creativity (i.e., "Single-Discipline - High Creativity"), it is generally geared towards the "top students" rather than benefiting all students. Emerging STEM education is also constrained by the high demands of project-based learning (PBL), which has failed to effectively leverage its educational value (i.e., "Multidisciplinary - Low Creativity"). Coupled with the poor circumstances of colleges and organizational systems divided by disciplines in universities, it is more

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challenging for students to conduct research across disciplinary boundaries. Thus, the discipline-centered education in schools has resulted in an overall imperfect knowledge system for creative talents, which is not conducive to interdisciplinary research in China.

### *3.2. Domain inequality*

Interdisciplinary research cannot be isolated from interdisciplinary collaboration, which requires researchers from multi-disciplines to integrate their theories and methods to produce innovative results [22-24]. There may be numerous parallels between fields, but also distinct ways of knowing and thinking, which can be interesting, revitalizing, innovative, and potentially even a precursor to higher impact research [25]. Research collaborations across disciplines are frequently hampered by "domain inequality": the subtleties of familiar terms in one field are simply not appreciated by those in another [26]. Worse still, because academia tends to be self-contained, sometimes leading to a failure to recognize the value of other perspectives [27]. The field divergence between the natural and social sciences is particularly pronounced by many scholars. For instance, biophysical researchers frequently accused social scientists of spending more time conceptualizing problems than providing solutions during interdisciplinary collaboration. Conversely, social scientists were often frustrated by biophysical researchers' excessive focus on solutions, while ignoring the larger social impact of their proposed solutions [28]. This discord is also widely happened in China, which is possibly exacerbated by an inherent cultural hierarchy that frequently prioritizes the nature sciences over the social sciences. Ultimately, there is a serious asymmetry in interdisciplinary integration, which is manifested in various aspects of power, personnel numbers, funding, etc.

### *3.3. Funding for interdisciplinary research is limited*

Scientists have long suspected that interdisciplinary proposals have lower odds of being funded than those with a narrower focus [29]. The analysis of over 18,000 proposals submitted to the Australian Research Council (ARC) indicated that the higher the degree of interdisciplinarity, the lower the probability of being funded [30]. Apart from the quality considerations, it is widely believed that the existing grant-review procedure could be intrinsically skewed against interdisciplinary projects [28]. Especially in China, single disciplines continue to dominate the majority of scientific and educational resources (e.g., academic institution budgets, promotion plans, etc.). The MOE, the NSFC, and the ISD in China have not yet fully clarified the review mechanism for various interdisciplinary projects. Accordingly, interdisciplinary research has almost been measured by quantitative metrics that favor single disciplines. This is unfair to interdisciplinary research, which may require longer periods and take greater risks.

Meanwhile, when interdisciplinary research is struggling for prestige, it is also trickier for peer review [9]. In China and many other nations, peer review means judgments by those working in the same research field within a single discipline. Often, it may be challenging for independent reviewers to determine the whole value of proposals involving fields outside their expertise. For instance, Luis and Walter Alvarez et al. proposed an interdisciplinary project linking major extinction events to collisions of the Earth with objects such as asteroids. This proposal failed the peer review process in each case until the intervention of the then

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director of the Lawrence Berkeley Laboratory (LBL) led to financial support by LBL [31]. As a result, this cautionary tale is frequently cited as a lapse of the peer review system.

### **4. Actions**

Indeed, most of the above challenges are universal to interdisciplinary research worldwide, not specific to China. In order to explore the possible futures of interdisciplinary research in China and, more importantly, to respond to the global challenges of interdisciplinary research, more actions beyond ISD are necessary.

#### *4.1. Integrating interdisciplinary education across K-12 and higher education*

Key universities and research organizations are obliged to establish autonomous interdisciplinary research institutions. According to the demands of disciplines and talents development, autonomous degree authorization and accreditation unit should execute pilot interdisciplinary settings and form a high-quality faculty, a comprehensive curriculum system, and a mature cultivation mechanism. To foster a benign interaction between basic and higher education, it is imminent to advance reforms of talents cultivation in K-12 education. STEM (Science, Technology, Engineering, and Mathematics) education, as a typical sort of interdisciplinary learning, contributes to stimulating students' creativity. Due to its enormous potentials, STEM has also been extensively recognized by the Chinese government and the publics since 2011. China's K-12 education curriculum reform has also advocated the paradigm shift from the current discipline-based to an integrated orientation, but with limited effects. One of the leading causes lies in the lack of scaffold on how to integrate the curriculum, specifically, what is the anchor for integration? How to represent and assess the objectives and effectiveness of integration? To address these problems, engineering education deserves to be considered as the interdisciplinary glue that connects various disciplines [32]. The visual artifacts produced by engineering practice could inspire and sustain students' sense of learning motivation and achievement, more importantly, promote their future development in the field of STEM [12].

In addition, the lack of national development strategies, social linkage mechanisms, and faculty training guidelines all risk impeding the effectiveness of STEM education in China. Correspondingly, the following aspects should be approached. First, given that STEM education has risen to a national strategic level in major developed countries, represented by the United States (US), Chinese governments are expected to launch a set of related systematic proposals and promotion plans. Second, STEM development is a social matter which involves in-depth integration of diverse resources [33]. Accordingly, a multi-party (e.g., schools, families, government, universities, enterprises, etc.) collaborative service mechanism should be established. Third, it is critical to build a school culture and environment (e.g., dedicated STEM curriculum, tool, research and learning communities, etc.) that supports the integrated implementation of STEM education [34, 35]. Last but not least, the Chinese education sector has to launch relevant curriculum guidelines, resource building programs, teacher training plans, evaluation programs, etc [12].

#### *4.2. Embracing interdisciplinary research at different levels*

Enabling interdisciplinary research has long been a global challenge. For a latecomer to science like China,

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interdisciplinary research is even more difficult. According to the degree of intersection between different disciplines, interdisciplinary research can be classified into three levels: (1) Realize knowledge production and innovation in this discipline by employing the theoretical frameworks and research methodologies from others. (2) Experts with diverse academic backgrounds collaborate to address the same issues from multidisciplinary perspectives. (3) Experts effectively integrate methodologies and theories from multidisciplinary disciplines to address complex theoretical or practical challenges. In this process, a variety of interdisciplines have emerged at disciplinary boundaries, which can be further divided into distant interdisciplines and neighboring interdisciplines, such as computational mechanics, chemical physics, philosophy of science and technology, ethics of technology, mathematical linguistics, etc [36].

In comparison to the previous two levels, the third level remains challenging on a practical level, as it requires a new system tailored to interdisciplinary research, including hiring, management, assessment, and motivation, as well as the attribution and evaluation of interdisciplinary research results. However, interdisciplinary research cannot cease at the first two levels. Generally, major scientific progress originates in the third level of interdisciplinary research, which is widely recognized as the most essential strategy for addressing the grand challenges. For instance, Roger Penrose, a mathematical physicist, was awarded the 2020 Nobel Prize in Physics for his contributions on black holes. He pioneered the application of a variety of sophisticated mathematical techniques to several branches of physics, providing a fresh perspective on research. Therefore, the third-level interdisciplinary research should be consistently nurtured on the basis of the previous two. Correspondingly, when establishing projects, the ISD might embrace varying levels of interdisciplinary research with certain inclusiveness, support, and expectations.

### *4.3. Encouraging interdisciplinary research collaboration*

Interdisciplinary research and collaboration in many developed countries are more driven by top-down forces. Through the promotion of the central government and research institutions, the enthusiasm of scholars for cooperation has been raised to the level of standardized management. For instance, the National Science Foundation (NSF) of the United States has set up specialized management departments for interdisciplinary research, such as the Comprehensive Activities Bureau, the Multidisciplinary Activities Bureau, and the Emerging Frontier Research Science Office. Besides, a bunch of interdisciplinary research centers, such as Independent Industry and Academia, Collaborative Research Centers, Engineering Research Centers, have been established to promote interdisciplinary research. Comparatively, the related strategic planning, policy support, and resource guarantee in China are insufficient. To break through the limitations of “domain inequity” in interdisciplinary collaborative research, endeavors can be performed in the following aspects.

First, the MOE, the MOST and other departments of China should strengthen cooperation, formulate a systematic national strategy for promoting interdisciplinary research, and continue to integrate multi-party forces of interdisciplinary integration to address major problems.

Second, a favorable climate for interdisciplinary research throughout society should be fostered. Specifically, in addition to holding high-level interdisciplinary seminars on a regular basis, relevant administrative departments and academic institutions can expand the types of interdisciplinary journals, which

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is dedicated to fostering interactions between experts from various interdisciplinary cultures. Moreover, Chinese universities and research institutes should be encouraged to engage actively in research programs funded by credible international organizations (e.g., the European Union), which can enhance international collaboration between academics from diverse disciplines. Notably, it is vital to further clarify the attribution and responsibility of interdisciplinary collaborative research results. Only in this way can the outputs of interdisciplinary collaborative research be incorporated in the evaluation indicators of research universities and institution. Meanwhile, corresponding managements mechanisms should be established to ensure the coordination and efficiency of the interdisciplinary cooperation process.

Third, the Chinese government should make concerted efforts to construct a variety of effective interdisciplinary research platforms and data sharing spaces. On the one hand, this contributes to the development of an environment that fosters the knowledge analysis, communication, creation, and dynamic interaction. On the other hand, it may break the restrictions of physical space and content classification, provide varied pathways for scientific data exchange. Naturally, the operation of the platform and space is inextricably linked to the necessary guidance and supervision.

Last but not least, it is crucial to further strengthen financial security at the national level. Given the intrinsic cultural hierarchy that prioritizes the natural sciences above the social sciences, the China Science Fund system needs to tailor the funding structure considering the differences between natural sciences and social sciences. Especially, a project funding structure that allocates and segregates funding for the social sciences component from the outset should be promoted [37]. Additionally, extensive and specialized educational backgrounds should be required before researchers submit grant applications or awardees sign contracts [38].

### *4.4. Optimizing interdisciplinary research reviews*

Funding agencies play a key role in shaping interdisciplinary research. To develop a balanced and extensive interdisciplinary research funding system, the ISD, as well as other relevant ministries and commissions, should improve their evaluation procedures for interdisciplinary research. Current interdisciplinary metrics are constrained by single-discipline measurement conventions, such as textual references or bibliometric analysis, with the former detecting the usage of terms such as "interdisciplinary" [39], and the latter tracking the affiliations and citations of authors [40]. However, the interpretation of terms such as "multidisciplinary," "interdisciplinary," "transdisciplinary" varies widely, which would affect the labeling results of interdisciplinary research [41]. Additionally, bibliometric analyses may not be applicable for evaluating grant proposals where outputs have not yet been published or citations formats cannot be analyzed. Therefore, it is critical to propose a quantitative measure that escapes the above limitations. In this vein, Lindell Bromham et al. employed evolutionary biology methods to analyze the information presented in the grant application to determine the differences and balance of the constituent disciplines of each proposal [30]. This evaluation measure could also be considered by the relevant funding departments in China.

In addition, research papers are the product of lengthy discussions between authors and reviewers — guided by editors. To lessen the probability of high-quality interdisciplinary research being rejected by narrow

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evaluation, it is vital to carefully select a panel of interdisciplinary experts as gatekeepers to ensure the robustness and clarity of papers. Besides, since interdisciplinary research has a certain threshold, it is more challenging to review its results. Therefore, an incentive mechanism should be established to motivate more experts to participate in interdisciplinary research reviews. Meanwhile, there is a need to opening up the peer review for interdisciplinary proposals funding. More transparency not only benefits researchers who study peer-review systems, but also deters potential misconduct while mitigating the cost of oversight [42]. Moreover, interdisciplinary research poses challenges for editors, too. They are sometimes burdened with the arduous responsibility of making integrative judgments regarding the value of interdisciplinary research [26]. Therefore, it is also crucial to form an editorial board with interdisciplinary expertise, who are devoted to fostering fast and fair peer review to select research that reflects the boundaries of new knowledge [43].

## **5. Conclusions**

Interdisciplinary research has evolved into a consensus in the academia, which is devoted to addressing grand challenges such as sustainability. Although China has gained significant theoretical and practical achievements in interdisciplinary research, some problems remain, typified by the stagnation of interdisciplinary research due to the absence of systematic national support. In this regard, the crucial causes are speculated as follows: (1) Discipline-centrism entrenched in K-12 education and higher education. (2) Domain inequality. (3) Funding for interdisciplinary research is limited. Coupled with the above root causes, the following endeavors may be performed: (1) Integrating interdisciplinary education across K-12 and higher education. (2) Embracing interdisciplinary research at different levels. (3) Encouraging interdisciplinary research collaboration. (4) Optimizing interdisciplinary research reviews. Frankly, a top-level design is the first step and most critical step to advance interdisciplinary research in China. It is crucial to emphasize that the perspectives presented in this paper are a conceptual vision, not a definitive solution, but rather a starting point for a productive dialogue about possible futures of interdisciplinary research in China.

## **Data Availability**

All data are available in the main text or the references.

## **Declaration of Conflicting Interests**

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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