Interdisciplinary research: Thoughts and strategic layouts

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Interdisciplinary integration is a distinctive feature of scientific development and provides major innovation opportunities. Supporting interdisciplinary research is not only an important mission of funding agencies but also the focus and priority of the scientific and technology field. Upon the first issue of “Interdisciplinary Materials,” this paper proposes some thoughts on interdisciplinary research, for discussion with peers in the same field.

1 | STRENGTHENING INTERDISCIPLINARY RESEARCH IS A FUNDAMENTAL BASIS OF SCIENTIFIC AND TECHNOLOGICAL INNOVATIONS

Interdisciplinary integration is an important characteristic of this era of scientific research. During a speech for the Congress of the Chinese Academy of Sciences, Chinese Academy of Engineering, and National Congress of the China Association for Science and Technology, President Xi Jinping indicated that a new round of scientific and technological revolutions and industrial reforms were advancing at a rapid pace and that the paradigm of scientific research was undergoing profound changes. In addition, interdisciplinary integration has been continuously developing, and developments in science and technology and the economy and society have been progressively connecting and integrating. Throughout the history of scientific and technological development, the evolution of disciplines has undergone different stages, that is, highly integrated, highly differentiated, and highly integrated on a highly differentiated basis.[1] Modern disciplines are showing a trend of system integration, with disciplinary differentiation and integration advancing simultaneously. Accordingly, new branches of traditional disciplines have continued to emerge, and dynamic evolution has continued to advance. However, the boundaries between different disciplines have become increasingly less clear, and the concepts, knowledge, methods, and tools for a single discipline are no longer sufficient for managing major scientific issues. Cross-subject and interdisciplinary research continues to create new research fields, giving birth to new disciplinary growing points, as well as exciting revolutionary innovations. Therefore, it is necessary to deeply understand and firmly grasp the trends of interdisciplinary integration, so as to seize opportunities in future scientific and technological competition.

Interdisciplinary integration is an important driving force for the acceleration of technological innovation. During his visit to Tsinghua University, President Xi Jinping emphasized that major original innovations were mostly based on deep basic research, and have been born in the field of interdisciplinary research. New theories and inventions in science often emerge from the edges or intersections of disciplines; therefore, focusing on interdisciplinary research allows science itself to advance toward a deeper and higher level. Heisenberg, a famous physicist, once mentioned that “in the history of human thinking, the most fruitful developments frequently take place at those points where two different lines of thought meet.” At present, the creation of new disciplinary growing points, the formation of major breakthroughs in the frontiers of science, and the production of major original scientific achievements are mainly the results of interdisciplinary integration. Interdisciplinary research is also an important source of future revolutionary changes in science and technology. For example, among the Nobel Prizes in the field of natural sciences, merely 19% featured interdisciplinary characteristics between 1901 and 1920. However, since the 21st century, this proportion has
increased to more than 40%. Since 2001, approximately 2/3 of the Nobel Prizes in chemistry have featured interdisciplinary research. Major scientific and technological achievements, such as the discovery of the double helix structure of DNA molecules, quantum chemistry, nuclear magnetic resonance imaging technology, and the treatment of malaria with artemisinin, would have been impossible without interdisciplinary integration. Therefore, only by strengthening the emphasis on interdisciplinary integration and vigorously supporting interdisciplinary research can we continuously produce high-level innovation achievements.

A global consensus has been reached on the importance of interdisciplinary integration. Powerful tech countries have successively launched a series of science and technology plans and/or established interdisciplinary research centers to strengthen the support for interdisciplinary research. For example, in 2007, Japan proposed the World Premier International (WPI) Research Center Initiative, which encouraged internationally renowned high-level academic leaders to form an international research team for conducting interdisciplinary research on basic and applied basic sciences. As of December 2016, the WPI research center had won 25 scientific and technological awards, including two Nobel Prizes. In 1998, Stanford University launched the “Bio-X Project” to solve major problems in the life sciences by conducting interdisciplinary research combining various subjects such as biology and medicine, engineering, computer science, physics, and chemistry. With the support of this project, researchers have made multiple breakthroughs in the field of biological science. One example is the gene-sequencing technology developed by Professor Ronald Davis, which has become the cornerstone of genomics and has played an important role in the mapping of the human genome. In 2007, Harvard University established the first “Cross-Faculty Department,” that is, the Department of Stem Cell and Regenerative Biology. Other examples include the establishment of the Energy Research Organization and Biotechnology Processing Engineering Research Center at the Massachusetts Institute of Technology, and the joint teaching and research programs by professors from the Department of Engineering and the Faculty of Medicine at Yale University. Therefore, it is necessary to implement practical measures to support interdisciplinary research, so as to grasp the trends in technological development worldwide and seize the initiative in technological innovation.

2 | PROMOTING INTERDISCIPLINARY RESEARCH REQUIRES IMPROVED TOP-LEVEL DESIGN AND COORDINATED ADVANCEMENT

In today’s era, where interdisciplinary integration is becoming increasingly important, technology and education management departments, universities, and scientific research institutions in China have successfully implemented various practical measures. For example, the Ministry of Education established a new category of “Interdisciplinary Science” the National Natural Science Foundation of China established an Interdisciplinary Science Department, and various scientific and technological plans have introduced research projects based on interdisciplinary science. Other examples include the establishment of the Interdisciplinary Research Institute at Peking University, Frontier Interdisciplinary Research Institute in the Tsinghua University, Interdisciplinary Theoretical Research Center at the University of Science and Technology of China, and Life and Environment Interdisciplinary Platform at Shanghai Jiao Tong University. Great progress has been made in the development of interdisciplinary integration and research in China, and multiple innovations with evident interdisciplinary characteristics have emerged, including miniature two-photon fluorescence microscopy and a nano-drug delivery system. Reports have shown that the number of papers on interdisciplinary research increased from 310,353 in 2009 to 444,744 in 2013 in China, accounting for 20% of all papers worldwide. In addition, the scores of 45,051 papers were in the world’s top 10%, equivalent to that of the United States.

Despite this, the overall development of local interdisciplinary science in China is relatively behind. More specifically, interdisciplinary research in China lacks in-depth and practical integration, efforts to promote interdisciplinary integration, and long-term planning for science and technology evaluation systems; moreover, there is also a shortage of interdisciplinary talents.

Therefore, to seize the opportunities in today’s era, where there are large changes that have not been happened in a century, and in which high-quality economic and social development increasingly relies on scientific and technological innovation, it is important to strengthen scientific rationality and to fully utilize the opportunities of paradigm changes and interdisciplinary integration in scientific research, so as to facilitate the development of interdisciplinary research.
2.1 Improvement of system layout

In terms of management systems, a management department should set up individual institutions specializing in interdisciplinary research and strengthen general management, as well as providing the overall promotion of interdisciplinary integration. In terms of scientific research entities, institutions of higher learning and scientific research institutions should construct multiple scientific research centers with prominent interdisciplinary features. To seize the frontiers of science and the high ground in the future, these institutions should combine competitive resources, promote interdisciplinary integration, and recruit and train high-level talents, so as to become a strong power in scientific research. In addition, they should gather researchers from different disciplines, provide a platform for communication and cooperation, break the barriers between different disciplines, and facilitate technological innovation. In terms of subject settings, it is important to strengthen the system construction, promote the interdisciplinary integration of natural science and social science subjects, improve the integration of mathematical sciences, chemistry, information sciences, engineering materials, and life medicine, facilitate problem-oriented interdisciplinary research in the fields of energy, resources, the ecological environment, and geosciences, and help create new disciplinary growing points. These practices will help promote the interdisciplinary integration of forward-looking, strategic, and leading basic research fields.

2.2 Strengthening of key deployment plans

Scientific and technological plans should set aside dedicated channels for interdisciplinary research and focus on problem-oriented and cutting-edge projects, provided they have accurately grasped the development trends of the corresponding disciplines. In addition, the strengthening of project deployment in key interdisciplinary fields potentially leading to major original achievements should be targeted. These fields include brain science, artificial intelligence, future computing, new drug creation, synthetic biology, advanced materials, advanced manufacturing, and the ecological environment. During this process, disciplines should be encouraged to implement classification policies, create novel research paradigms, and accelerate the innovation process. Taking materials science as an example, relative to other subjects, it relies more on high-end equipment and advanced characterization technologies, has higher demands for a green full life cycle and efficient use of resources, and combines tighter with application demands. In view of the current trends, conventionally, the development of materials science in China could not keep up with the pace of technological revolutions, material performances could not meet certain special requirements, and the production of materials could not break through the traditional “stir-fry” research method, as no good methods were available to design or construct materials according to the needs. To solve these issues, the materials science community in China conducted in-depth investigations. In December 2011, the “Materials Science System Engineering” Xiangshan Science Conference was held in Beijing. During the conference, experts and scholars in the materials industry proposed to build and develop a “Materials science system engineering platform” meeting the specific needs of materials science in China by integrating theoretical computing, databases, and test platforms. Subsequently, in 2015, the Materials Genome Institute of Shanghai University was established to conduct interdisciplinary research on materials gene databases, integrated computing and software development, high-throughput material preparation and characterization, service and failure mechanisms, and so forth. All these works have pioneered high-quality developments in materials science, and therefore should be the focus of support in the next stage.

2.3 Enhancement toward the cultivation of interdisciplinary talents

We should learn from the experiences of developed countries and strengthen the training of interdisciplinary talents in all aspects. More specifically, it is recommended that educational institutions should recruit postgraduates across different disciplines, encourage professors from multiple disciplines to jointly train postgraduates, and introduce novel teaching contents and research methods that are cross-subject, integrated, and comprehensive. Furthermore, universities should be encouraged to offer courses in emerging disciplines and cutting-edge interdisciplinary disciplines as well as cross-department or cross-faculty elective courses, so as to broaden students' horizons and cultivate their interests in interdisciplinary research. Last, young scientists and doctoral students should be encouraged to participate in major interdisciplinary research projects and to conduct interdisciplinary research.
2.4 Creation of an environment conducive to interdisciplinary research

It is recommended that review and evaluation mechanisms should be thoroughly reformed to avoid linking evaluation results directly with remuneration and benefits, as this may facilitate utilitarianism. Furthermore, owing to the specialties of interdisciplinary research evaluation, an appropriate and dynamic evaluation system should be introduced, and project management and resource allocation mechanisms in line with the characteristics and laws of interdisciplinary research should be implemented. This will encourage scientists to strengthen collaboration, participate in interdisciplinary research, and strive for major scientific breakthroughs. Furthermore, efforts should be made to create a good atmosphere that encourages exploration, promotes integration, and tolerates failure, thereby creating a good research environment, as well as a sufficient development space for interdisciplinary researchers. Last, it is necessary to strengthen the construction of platforms for providing experts from different disciplines with a stage to visit, communicate, and exchange ideas.

3 Reform Measures Proposed by the National Natural Science Foundation of China to Support Interdisciplinary Research

As an important channel for funding basic research in China, the National Natural Science Foundation of China has consistently attached great importance to interdisciplinary research. After a long period of development, a supportive system for interdisciplinary integration comprising major projects, major research plans, basic science center projects, and joint fund projects has been founded. Since the “13th 5-year Plan,” 10 major projects, including “Principles and technologies for the high-pressure control of material structure and performance,” “Multi-scale structure control and function realization of advanced optical film materials,” and “High-fire safety polymer materials in confined spaces,” as well as major research plans such as “Fundamental research on high-performance materials based on functional primitive structures” and “Scientific Basis for Aeroengine High-Temperature Materials/Advanced Manufacturing and Fault Diagnosis” have been launched in the field of materials science. In recent years, Chinese researchers have made several achievements in interdisciplinary materials research, including research on the surface instability mechanisms of soft materials and biological soft tissues, and on the biological effects of nanomaterials based on synchrotron radiation. These would have been impossible without the support of the above projects.

In 2020, by firmly seizing the opportunities and challenges brought by the new round of scientific and technological revolution, as well as the ongoing paradigm changes in scientific research, the National Natural Science Foundation of China followed the law of basic research development to establish an Interdisciplinary Research Department based on opinions from different perspectives. The purpose of this department was to coordinate the overall funding of all projects in the interdisciplinary science aspects of the National Natural Science Foundation. Since its establishment, the Interdisciplinary Research Department has targeted major basic scientific issues, focused on interdisciplinary research, and coordinated and launched interdisciplinary research projects for either satisfying major national strategic needs or pioneering new scientific frontiers. In addition, it has implemented and improved the funding mechanisms for interdisciplinary integration, promoted multidisciplinary collaboration on complex scientific and technological issues, facilitated the formation of new disciplinary growing points and technological breakthroughs, explored the establishment of interdisciplinary research paradigms, cultivated interdisciplinary talents, and created an interdisciplinary research culture.

In 2021, the Interdisciplinary Research Department officially started funding projects and arranged CNY ¥560 million of funds throughout the year. These funds were distributed via the Science Fund for Outstanding Young Scholars, National Science Fund for Distinguished Young Scholars, Science Fund for Creative Research Groups, and Basic Science Center Projects, along with other major projects and major research plans. At present, the funding for 24 projects of the Science Fund for Outstanding Young Scholars, 14 projects of the National Science Fund for Distinguished Young Scholars, and four projects of the Science Fund for Creative Research Groups have already been approved. Of these 42 projects, eight are related to the materials field, accounting for 19.05% of all projects. There are also other related projects currently under review.

The Interdisciplinary Research Department has been dedicated to funding the exploration of novel scientific research paradigms and solutions to major interdisciplinary issues and has focused on the cultivation of talents, continuous optimization of project and resource allocations, and establishment of funding management mechanisms confirming the characteristics and laws of interdisciplinary research. At the
same time, it remains important to highlight problem-oriented research, guide and encourage researchers to condense interdisciplinary issues and focus on common complex principles and major scientific issues of different knowledge categories in the knowledge system. Furthermore, research should be guided by substantive integration, so as to achieve major original breakthroughs in emerging interdisciplinary fields.

As a result, the National Natural Science Foundation of China has initiated a sector-based funding layout reform. Based on a principle of “originate from the logical structure of the knowledge system, promote the integration of knowledge and applications, and focus on interdisciplinary integration,” the National Natural Science Foundation has reorganized the existing nine science departments into four sectors, namely, “Basic Science,” “Technical Science,” “Life and Medicinal Science,” and “Interdisciplinary Integration.” By reshaping the funding layout, strengthening governance capabilities, and strengthening overall planning and classification management, the National Natural Science Foundation has put greater emphasis on the support of interdisciplinary research and has continuously improved the efficiency of science funding.

The launch of “Interdisciplinary Materials” is a major event in the field of materials science in China. The journal will provide a platform for researchers in interdisciplinary materials to communicate and inspire innovative ideas, as well as offer a new impetus for the development of interdisciplinary research in the field of materials. In the last 30 years, the Wuhan University of Technology has been advocating and carrying out cross-research on materials and basic science, information science, life science, and energy technology, and has achieved fruitful results. Therefore, I firmly believe that the journal of “Interdisciplinary Materials” jointly produced by the Wuhan University of Technology and the Wiley Publishing Group will be a great success. I sincerely hope that scientific researchers can publish their research and novel ideas on this platform, so as to exchange thoughts with peers and jointly promote the production of high-quality research.

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