



An Open Platform for Global Engineering Initiatives: International Knowledge Centre for Engineering Sciences and Technology Under the Auspices of UNESCO

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Open science provides a bright light for global engineering and technology cooperation and promoting global sustainable development. The International Knowledge Centre for Engineering Sciences and Technology (IKCEST), a category II center under the auspices of UNESCO based in Beijing, aims at providing knowledge-based services at a global scale for policy-makers and engineering science and technology professionals in the world, with particular reference to the developing countries. IKCEST has established a platform with data resources and knowledge services at the core, which includes one general platform and several sub-platforms in its prioritized areas such as the disaster risk reduction (DRR), the intelligent city (ICITY), the engineering education (ENGEDU) and the silk road sciences and technology (SRST). Since the platform was put into operation, it has launched 38 knowledge applications (APPs), serving 3.26 million users from 220 countries and regions worldwide, and offered training for more than 18,000 persons from developing countries. In face of the pandemic, IKCEST set up a COVID-19 column which received positive feedback from users across the globe, the introductory video of which was publicized on the UNESCO official website. As a knowledge hub supporting global sustainable development goals (SDGs) and an open platform for global engineering initiatives, IKCEST will spare no efforts to make greater contributions to providing more tailored and valuable knowledge-based services for global users.

Keywords: open science, engineering science and technology, knowledge service, knowledge platform, UNESCO

INTRODUCTION

Engineering science and technology is the crystallization of human wisdom in the process of long-term scientific exploration, technology application and engineering practices. This kind of knowledge has existed in human history for a long time, but is not easily accessible in the information age yet. In the third century BC, Ptolemy I Soter initiated the building of the Library

of Alexandria, dreaming of collecting books and knowledge from all over the world. In 830 AD, Caliph Abdulla Al-Ma'moun built the magnificent House of Wisdom in Baghdad, serving the functions of a library, a research institute as well as a translation department. It was one of the crucial knowledge sources for later Renaissance in Europe. In 1408 AD, the compilation of China's Yongle Dadian (also known as Yongle Encyclopedia) was completed, with 22,937 volumes pooling together all varieties of knowledge of ancient China. It's the world's largest encyclopedia. Entering the twenty first century, the world has been changed once again by the Internet. As more data is generated in this new age, how knowledge should be acquired, disseminated and then serve the humans is a new challenge faced by us.

With this in mind, the Chinese Academy of Engineering (CAE) applied to UNESCO for establishing an International Knowledge Centre for Engineering Science and Technology, which was approved at the 37th UNESCO General Conference (2013) in November 2013 (UNESCO, 2013). On June 2, 2014, the Chinese government and UNESCO signed an agreement to establish the International Knowledge Centre for Engineering Sciences and Technology (IKCEST), a category II center under the auspices of UNESCO in Beijing. Thus, an open knowledge platform for global engineering initiatives came into being. IKCEST's long-term goal is to build a Comprehensive Knowledge Centre in Engineering Science and Technology, promote knowledge sharing of science, technology, education and cultural information relevant to global engineering, conduct technical exchanges with and provide knowledge services for the international community, establish an international network composed of professional personnel in engineering science and technology, and promote the dissemination and utilization of engineering knowledge.

In September 2015, on the occasion of the 70th anniversary of the founding of the United Nations (UN), Transforming Our World: The 2030 Agenda for Sustainable Development was adopted, which includes 17 goals, 169 targets and over 230 indicators. It's designed to integrate sustainable development in the economic, social and environmental dimensions (United Nations, 2015b). Since establishment, IKCEST has actively supported UNESCO's global priorities, contributing to the implementation of SDGs.

Some regional and global platforms of similar properties and functions have also been under construction. The European Open Science Cloud (EOSC) project creates a distributed scientific data infrastructure in Europe (Science, 2018). The National Digital Library of China (NDL) aims to build a super-large-scale database of high-quality Chinese information resources and has established an online Chinese Information Base and Service Centre (Shen, 2008). Construction of knowledge platforms and facility data in IKCEST's prioritized areas such as DRR, ICITY, ENGEDU and SRST (focusing on science and technology development in countries along the Belt and Road) at global, national and regional levels has also been under way.

In the field of the disaster risk reduction, the United Nations adopted the Sendai Framework for Disaster Risk Reduction 2015–2030 (Sendai Framework for short) in March 2015 (United Nations, 2015a), a new action framework for global

disaster reduction. The United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) (<http://www.un-spider.org>) has set up a “Links and Resources” column, which aggregates links to disaster data and software tools from several agencies, including NASA, NOAA and USGS. UNESCO has long focused on global cooperation in this area, dedicating one of its sections to disaster risk reduction under its Natural Sciences Sector (UNESCO Disaster Risk Reduction, 2018). Emergency Events Database (EM-DAT) (<https://www.emdat.be>) is a historical disaster database, created with the initial support from the World Health Organization (WHO) and the Belgian Government. EM-DAT contains essential core data on the occurrence and effects of over 22,000 mass disasters in the world from the year 1900 to present day. The Global Facility for Disaster Reduction and Recovery (GFDRR) (<https://www.gfdr.org/en>) is a global partnership that helps developing countries better understand and reduce their vulnerability to natural hazards and climate changes, and provide technical assistance as well as services in capacity building and analysis. The PREVIEW Global Risk Data Platform (<http://preview.grid.unep.ch/>) shares spatial data information about global natural disaster risks, including historical disaster data and natural disaster risk index data.

In terms of online education for intelligent city, several of the world's largest massive open online courses (MOOC) websites, Coursera and EdX, provide online courses taught by lecturers from world-renowned universities and companies. The mission of MIT Senseable City Lab is to study and predict the development of cities with digital information, develop new methods for intelligent cities and have a novel and in-depth understanding of cities (MIT School of Engineering, 2020a). Planetizen is a planning education website that provides planning-related news, information and education courses. The New Engineering Education Transformation (NEET) programme was launched by MIT in August 2017, which focuses on the new machines and systems students will build in the twenty-first century, including the Internet of Things (IoT), Big Data, Internet systems and smart cities (MIT School of Engineering, 2020b). In 2018, Tsinghua University proposed that the Engineering Education will present an “Engineering Plus” mode in the future, which will highlight “Engineering + Responsibility”, “Engineering + Innovation” and “Engineering + Communication” (Qiu, 2018). In May 2015, Xi'an Jiaotong University took the lead in establishing the “Universities Alliance of the New Silk Road” (UANSR), which was composed of 126 universities in 30 countries and regions, to give them full play in driving innovation, supporting think tanks and providing cultural guidance, and jointly create an education community under the “Belt and Road” initiative (Hao and Lu, 2015).

Domain-oriented or regional data platforms are promoting the dissemination, sharing, mining and utilization of international engineering science and technology knowledge. However, a comprehensive global knowledge center for engineering science and technology remains unbuilt. Currently, the uneven distribution of resources is a common problem for domestic and foreign knowledge platforms in some fields. Besides, most of the existing platforms focus on static data

or information portals, and a comprehensive knowledge service platform based on data-driven knowledge discovery remains unestablished. Moreover, some commercial platforms charge fees for information services, which is unfavorable to developing countries. Therefore, IKCEST, under the operation and management of the CAE, was set up to bridge the gap and provide continuous platform support for the development and prosperity of engineering science and technology in the Asia-Pacific region, the Belt and Road region and beyond.

METHODOLOGY

Overall Framework of IKCEST

IKCEST is a public data service platform that integrates various digital engineering science and technology resources, aiming to provide knowledge services such as counseling, scientific research and education for policy-makers as well as engineering science and technology professionals in the world, with particular reference to those in developing countries, help UNESCO fulfill its purpose, support its various action plans, and promote the implementation of SDGs. Currently, IKCEST has built a “1+N” integrated operation system with a general platform and several sub-platforms (as shown in **Figure 1**) in collaboration with well-known universities and scientific research institutes in China to provide continuous online knowledge services.

The framework of the IKCEST platform includes target users, platform portal, technology system, specialized knowledge service, cloud infrastructure environment, management, and operation, as shown in **Figure 2**. Under the guidance and planning of the IKCEST Governing Board and Advisory Committee, the IKCEST platform gathers a global scale knowledge resources in the field of engineering science and technology, creates an ocean of metadata, and provides general knowledge services for policy makers in UNESCO and its member states, engineering science and technology professionals (including university staff and while students) and general public. Meanwhile, IKCEST provides comprehensive and specialized knowledge services in the fields of disaster risk reduction, intelligent city, engineering education and silk road science and technology. For integrated management of the general platform and sub-platforms, operational measures and standards such as user survey, user behavior analysis and log management using ELK tools have also been formed.

Construction Process of Sub-platforms in Prioritized Fields

IKCEST has established and expanded sub-platforms in various prioritized fields according to a unified technical route and resource construction standards.

Disaster Risk Reduction Knowledge Service Sub-platform

With priority given to the use of open international technical standards and open-source web technologies, it adopts the technical architecture of an information service platform with on-demand scalability and a modular mechanism. The iterative development model is adopted, so the system can be put

into use in the system’s development life cycle. Through this system, users can gain quick access to various disaster-related knowledge resources and subject-specific knowledge services, including data, maps, literature and videos (Wang et al., 2020a). The overall method of building the sub-platform is to take the standard formulation for disaster-related metadata as the starting point to collect various knowledge resources, including a metadata-based disaster science database, disaster map resources, a disaster expert database, a disaster institution database, a disaster event database, a database of disaster open directory projects, a database of disaster-related information web mining, a disaster literature database, a disaster popular science database, and a disaster video courseware database. The semantic web method is used to associate and manage these resources, present the constructed knowledge network of disaster risk reduction in the form of the knowledge graph, provide data labels and data products, and offer in-depth analysis functions such as navigation discovery, in-depth search, knowledge reorganization, and visual interaction to improve the efficiency of resource retrieval and the accuracy of query results for mining hidden knowledge. The portal is established under development environment with an open platform to realize visualized thematic knowledge services for typical disasters such as earthquakes, droughts, flooding, freezing rain and snow, and promote knowledge sharing and application, mining, dissemination, communication and other good circulation of the entire knowledge chain, and an operation and maintenance system that can ensure long-term sustainable development (Wang et al., 2020b).

Silk Road Sciences and Technology Knowledge Service Sub-platform

It provides complete and comprehensive technical support for the Belt and Road online learning platform for international talents training. It has built a hybrid cloud computing environment that integrates multiple core technologies such as data synchronization and consistency verification of the hybrid cloud computing platform, fragmented, diversified and massive resource storage, real-time parallel transcoding of high-definition video, and big data analysis and visualization. It also combines technologies including integration of training resources, automatic construction and generation of knowledge graph, intelligent search on knowledge graph, aggregation of fragmented knowledge, as well as efficient management and retrieval of heterogeneous resources such as video and text into the platform. These functions further facilitate resource retrieval and management for courseware, studying materials, teacher background information, test bank and other training resource databases, as well as a wide range of subject resource databases covering history and culture, education and science, state of union message, policies and regulations, industrial economy, as well as population and environment. Additionally, the sub-platform integrates key technologies such as personalized navigation based on knowledge maps, learning behavior analysis and performance evaluation, interactive cloud-based live streaming and automatic aggregation of hot news. It supports online evaluation of course quality, online tests, learning progress statistics, learning behavior analysis and teaching



performance evaluation. Apart from the technical support, it provides product support to drive the promotion and application of the platform. The “product-driven” goal is empowered with AI and big data mining to fulfill the mission of “Belt and Road initiative” and talent training. With data resources, cutting-edge technologies, integrated operation and promotion, the product aims to enhance user experience and provide personalized and in-depth services for engineering and scientific personnel in B&R countries.

Intelligent City Knowledge Service Sub-platform

It is committed to disseminating engineering science and technology knowledge related to intelligent cities, focusing on the field of intelligent city, and providing data knowledge services for international practitioners in related engineering fields. The features of the core technical framework of CityIQ, an important knowledge application on the sub-platform, include the following parts. (1) The intelligent city evaluation index system is rooted in the core philosophy of “city-being,” which considering cities as living creature rather than construction. The CityIQ, therefore forming a cycle of evaluation to comprehensively evaluate how intelligent the cities are. This cycle consists of “Comprehensive Perception, Accurate Judgment, Appropriate Response and Self-learning.” First, Comprehensive Perception is using artificial intelligence technology mainly based on Natural Language Processing and Active Learning Models to dynamically obtain various types of information about the city to achieve a comprehensive perception of global cities. Secondly, Accurate Judgment is using artificial intelligence technology mainly based on Random Forest and Machine Learning to obtain the intelligent information of the city, and

perform automatic identification, data screening, and calculation judgment in real time. Then, Appropriate Response is relying on the historical performance of the city as a whole and in all dimensions to analyze shortcomings and give early warnings and suggestions in time so as to achieve minimal consumption. Lastly, Self-learning is using the text sentiment analysis technology mainly based on Active Learning to train the computer with human emotions, accurately analyzing semantics and actively learning emotions. (2) The platform could cover more cities and get larger samples by using new technologies. Therefore, more samples are being compared, the platform evaluates the position of the city in a global scale, rationally judges the status of a city as a whole and all aspects, as well as the advantages and disadvantages of intelligent city construction. In a word, the larger the sample size, the more accurate the evaluation results. (3) The platform archived dynamic intelligent city evaluation data access by introducing cutting-edge technologies. The platform realized real-time monitoring of the overall situation of the city and all dimensions, and narrowed down conventional time granularity of “annually” to “weekly,” greatly increasing the frequency of monitoring. (4) The online visualization and interaction are the priorities. It visualizes various types of data, expands the interactive function of data knowledge and maximizes data application.

Engineering Education Knowledge Service Sub-platform

It makes full use of computer and information technology and net environment, including the web technology, cloud computing technology and database technology, to build and reorganize

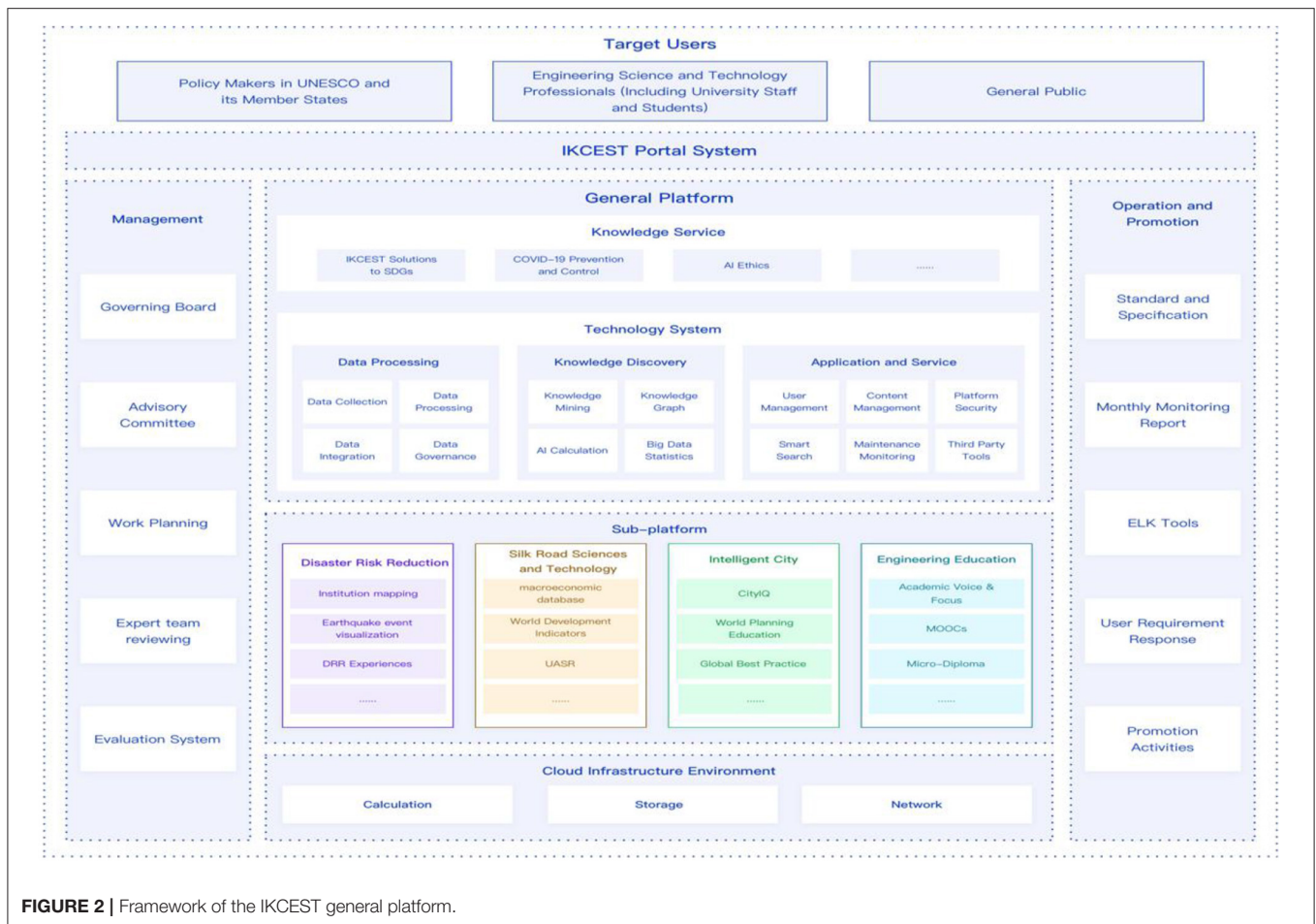


FIGURE 2 | Framework of the IKCEST general platform.

the data resources, curriculum resources and knowledge maps in the system, turn them into the knowledge service data set, build a knowledge service application to provide consulting and online learning services for target users at different levels. The framework of the sub-platform includes six parts: user layer, access layer, business layer, resource layer, technology layer and support layer. The sub-platform has launched MOOC courses in English or in Chinese with English subtitles. The contents cover electrical engineering, computer science and other professional subjects. The lectures mainly come from Tsinghua University and other engineering universities in China, and users can attend the courses online for free. On the basis of these MOOC courses, according to the latest online and offline hybrid teaching theory, the sub-platform has launched a special knowledge learning programme to provide micro-diplomas for hybrid learning.

RESULTS AND DISCUSSION

Progress

The interface of the IKCEST platform portal (<http://www.ikcest.org>) is shown in **Figure 3**. Focusing on user needs, based

on convenient international access, a six-language framework for the platform is provided. The user-level system and original content system have been developed, allowing users to upload created contents on the platform, sharing EST knowledge and data, and making contributions to SDGs. The general and sub-platforms have jointly offered knowledge service applications in various fields. The main knowledge services include IKCEST Solutions to SDGs, Public Health Security, AI Ethics, Cultural Heritage Protection, The Belt and Road Index, Macroeconomic Database, University Rank, Global Engineering Projects, Technology Trending, City IQ, Big Data Term Encyclopedia and Academic Videos.

As of December 2021, there were over 200 million pieces of data on the IKCEST platform, of which there were more than 330,000 pieces of science and technology information data, over 11 million published papers of engineering science and technology, more than 9,000 well-known experts from home and abroad, over 11 million pieces of data on English patents and 38 online knowledge applications. The number of page views of the platform had exceeded 8 million, and the number of users had surpassed 2 million. The users come from 220 countries and regions, including all countries along the “Belt and Road.”

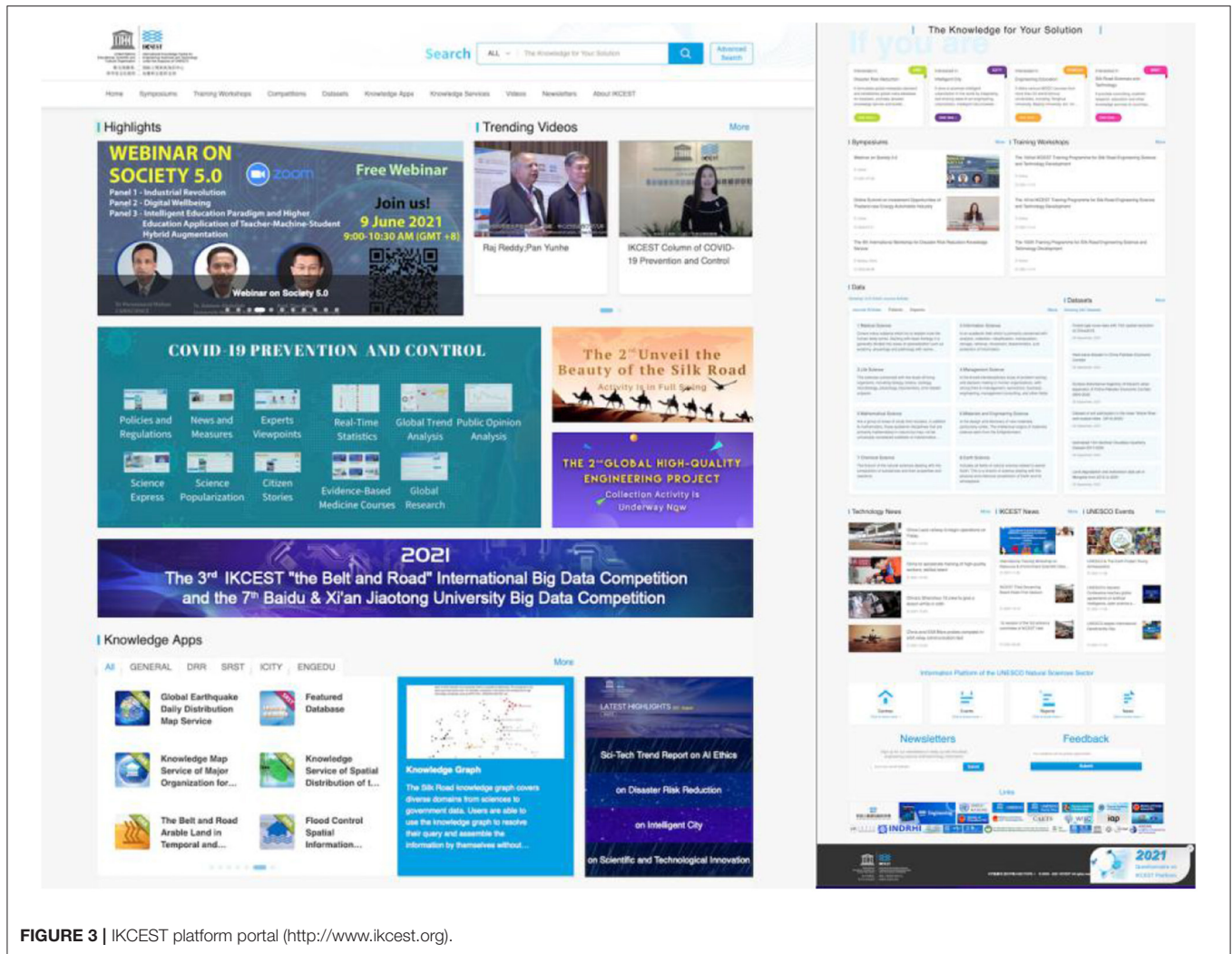


FIGURE 3 | IKCEST platform portal (<http://www.ikcest.org>).

Among the main sources of overseas visits, countries in the Asia-Pacific region include China, Japan, the Philippines, Indonesia, Thailand, Vietnam, South Korea, Singapore and Malaysia.

Achievements

- (1) Supporting the implementation of UNESCO action plans. IKCEST organized experts to compile trend analysis reports on disaster risk reduction, intelligent city, engineering education, talents cultivation, and artificial intelligence based on technological means such as bibliometric analysis. These reports became the "Sci-tech Development Trend Report" product, which received positive feedback from users from UNESCO DRR Section, UN Habitat and UN Environment Programme specialists, among many others. In 2020, IKCEST provided Chinese subtitle translation and proofreading for UNESCO's global disaster prevention and reduction science popularization video on the International Day for Disaster Reduction, which was well received by UNESCO DRR Section.
- (2) Providing support for international organizations and expanding international cooperation. IKCEST provided a working paper titled "Extraction and Analysis of Earthquake Events Information based on Web Text" and won an annual hit rate of over 6,000 times. It provided support for the mapping of global disaster prevention and mitigation capabilities, and issued the report Institution Mapping for Disaster Risk Reduction in 2020. In August 2020, the IRDR IPO and IKCEST DRR team signed a Memorandum of Understanding. In response to Thailand's urgent needs for the development of the new energy vehicle (NEV) industry, IKCEST held the "New Normal in the Post-pandemic Era-Investment Opportunities in Thailand's NEV Industry Online Summit" to provide a discussion and exchange platform for the development of Thailand's NEV industry.
- (3) Continuously organizing Big Data Competition and various high-level seminars. Since its establishment, IKCEST has been committed to building a high-level international platform for academic exchanges. By the end of November 2021, it had held 23 international high-level seminars in total, covering themes such as big data, artificial intelligence, online engineering education, etc., thus successfully serving

as a platform of academic communication for experts and scholars at home and abroad and delivering benefits to more than 16,000 people. Specifically, IKCEST has cooperated with the UNESCO DRR Section by jointly organizing four International Workshops for Disaster Risk Reduction Knowledge Service. What's more, in 2020, IKCEST, as an example of an existing open science platform, was invited to attend the webinar entitled "Inputs from Asia-Pacific region to the UNESCO Recommendation on Open Science," at which it introduced current practices of the center, and expressed the desire to cooperate with more partners in data and other aspects. In the context of the COVID-19 pandemic, the 2nd IKCEST "The Belt and Road" International Big Data Competition covered medical topics for the first time, and was themed "Forecasting the Future Incidence of Highly Pathogenic Contagious Diseases," breaking the "dimensional wall" between AI and real medicine. The competitions from 2019 to 2021 attracted more than 12,000 participants of more than 8,000 teams from over 580 universities in 22 countries on the five continents (Figure 4).

- (4) Supporting major engineering science and technology projects. IKCEST has provided support for the disaster investigation and data platform construction project of China-Pakistan Economic Corridor along the Belt and Road, and the consulting projects of the CAE, including Research on the Reliability Guarantee Strategy of Sichuan-Tibet Railway Engineering System, and Innovative Application of Artificial Intelligence 2.0 in Smart Cities. It has offered push services of academic literature in the field of disaster risk reduction according to research groups' feedback, and participated in the preliminary study of Shanghai's 14th Five-Year Plan—Research on the Goals, Ideas and Key Measures of Shanghai's Efforts to Promote the Building of a Smart City during the 14th Five-Year Plan Period, the sustainable planning and design of the Beijing City Sub-centre, the land spatial planning of Hainan Province and other projects.
- (5) Serving higher education institutions. At the invitation of Sichuan University-The Hong Kong Polytechnic University Institute for Disaster Management and Reconstruction (IDMR), IKCEST actively participated in the teaching and training of undergraduates, and providing co-teaching service for the "International Disaster Reduction and Emergency Management Innovation Class." Apart from that, IKCEST has co-organized training workshops and established cooperative ties with domestic higher education institutions such as Xinjiang University, Guizhou University, etc. and international ones such as Walailak University in Thailand and Samarkand State University in Uzbekistan, among many others.
- (6) Launching training programmes in engineering science and technology development for developing countries. With contributing to talent cultivation and capacity building in developing countries as its mission, IKCEST organized online and offline training programmes with various topics and themes at both home and abroad. From 2015 to 2021, IKCEST held 107 training sessions themed on over 30 topics, attracting more than 18,000 students from 115 countries and regions, of which 35% were female learners, and over 90% were satisfied with the training. It has developed the programme of micro-diploma of computer basics and provided hybrid learning services of MOOC-based computer basics. The programme attracted more than 2,700 online learners across the world, including college students from developing countries like Bangladesh, Kenya, Nigeria, Guinea and Pakistan.
- (7) Supporting the implementation of SDGs. In view of SDG15—the Land Degradation Suppression Target, with technical support from GIS spatial analysis module, IKCEST obtained the distribution maps of land degradation and restoration in Mongolia with 30-meter spatial resolution from 1990 to 2000, 2000 to 2010 and 2010 to 2015, displayed the land degradation trend in Mongolia in the past 25 years, and put forward countermeasures to control land degradation. The relevant achievements were successfully included in the Chinese and English versions of Big Earth Data in Support of the Sustainable Development Goals (2015). To achieve SDG4—to ensure inclusive and eligible quality education, IKCEST has launched more than 1,000 video courses and academic conference videos. To achieve SDG11—to make cities and human settlements inclusive, safe, resilient and sustainable, it has collected 500 engineering cases of excellent cities worldwide to provide high-standard references for urban construction.
- (8) Launching the Special Column on COVID-19 Prevention and Control. The column offers information services in terms of Policies and Regulations, News and Measures, Experts Viewpoints, Science Express, Science Popularization and Citizen Stories, sharing information on the pandemic and China's experience with the rest of the world in real time. Besides, it also provides knowledge services as follows. By integrating social media analysis and using GIS methods to analyse public opinions, it shows spatiotemporal changes of epidemic-related microblogs and hot topics of public discussion on an online map, providing support for the government's emergency decision-making. In addition, the column provides courses recorded by China's top medical experts and scholars, as well as resources from an evidence-based medicine database. The public can have free access to 25 courses on the Covid-19 virus, over 3,000 evidence-based medicine topics, and thousands of research papers on the Covid-19 virus. Moreover, it displays the curve of confirmed cases, mortality, cases of patients cured and growth rate of confirmed cases, and releases research reports on the effectiveness of anti-pandemic efforts in cities. On April 8, 2020, UNESCO published on its official website a video briefing on such column, providing information and knowledge services for its member states (<https://en.unesco.org/themes/building-capacity-science-and-engineering>).

Case of Knowledge Service for Disaster Risk Reduction

Land degradation is an important global ecological and environmental problem for sustainable development. Land degradation leads to a loss of available grassland resources, a

decrease in biological production, and the deterioration of the ecological environment (Li, 2018). Mongolia is a county that has suffered from severe land degradation (Hansen, 2015). IKCEST-DRR addressed this issue based on remote sensing big data. 270 Land Satellite Thematic Mapper (Landsat TM) images and 135 Land Satellite Operational Land Imager (Landsat OLI) images were acquired to retrieving the land cover map of Mongolia. With the technical support of GIS spatial analysis module, the land cover data of 2015 and 2020 are superimposed to construct the land cover transfer matrix of Mongolia, establish the land degradation and land restoration type system, and obtain the land

degradation and restoration map of Mongolia from 2015 to 2020 (shown in **Figure 5**).

The results show that the land degradation areas in Mongolia are mainly distributed in the northwest to middle, and scattered in the northeast. The land restoration areas are mainly banded in western and central-southern Mongolia, and massive in eastern Mongolia. Statistical analysis shows that the area of land degradation in Mongolia from 2015 to 2020 is about 12,679.11 square kilometers, accounting for about 8.16% of the total area of Mongolia, and the area of land restoration is about 255,638.76 square kilometers, accounting for about 16.34% of the total area

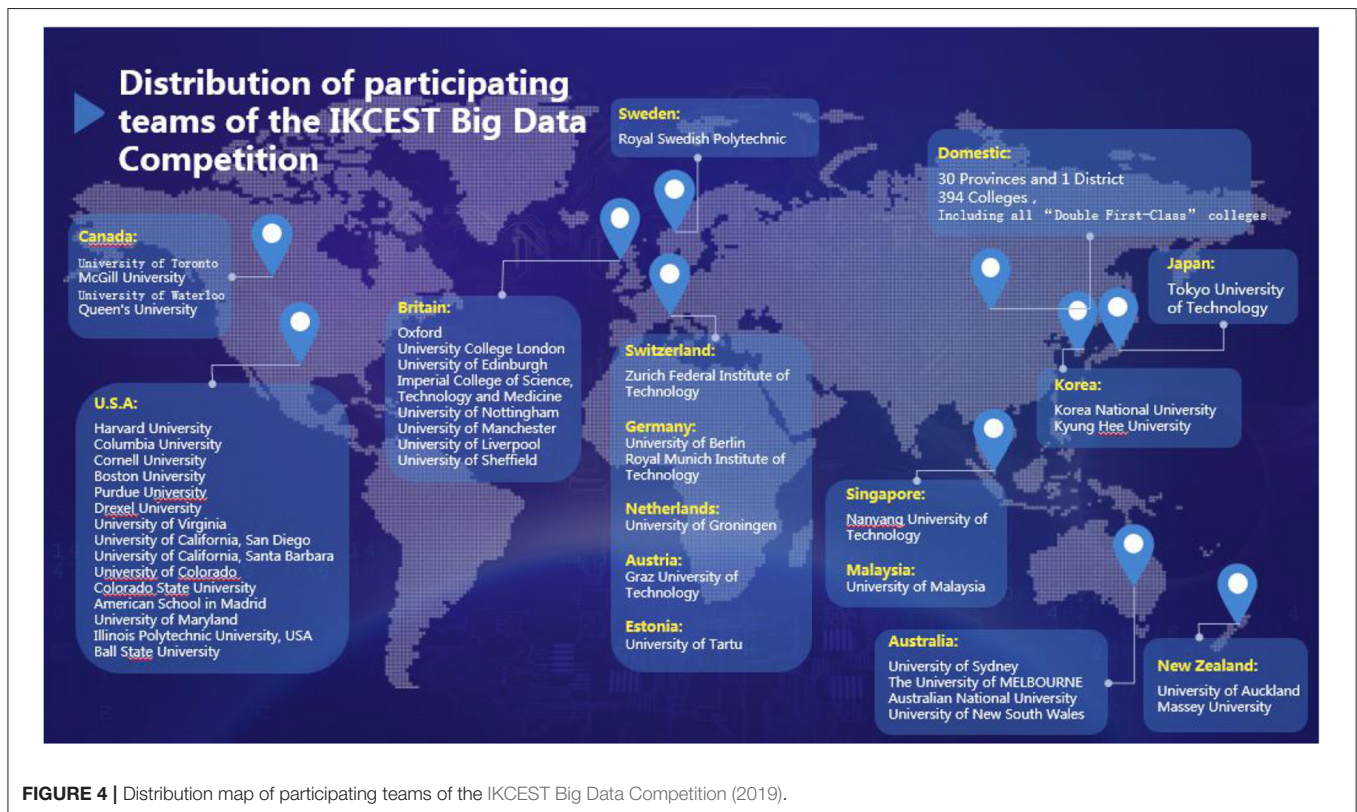


FIGURE 4 | Distribution map of participating teams of the IKCEST Big Data Competition (2019).

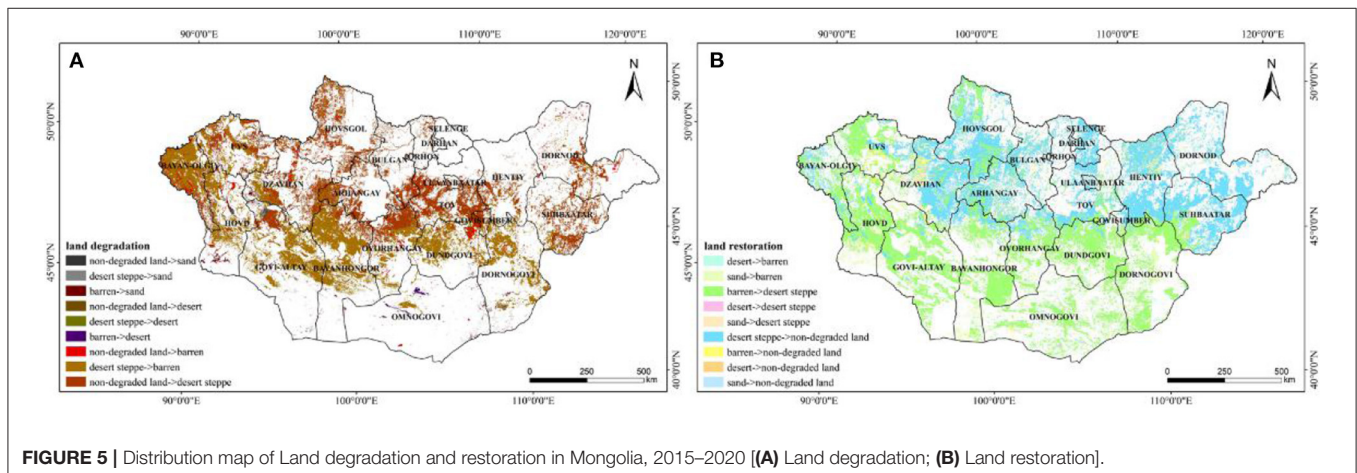


FIGURE 5 | Distribution map of Land degradation and restoration in Mongolia, 2015–2020 [(A) Land degradation; (B) Land restoration].

of Mongolia. The area of land restoration is larger than the area of land degradation. Relatively suitable temperature and sufficient precipitation promoted the growth of vegetation and created favorable conditions for land restoration. However, unregulated development of livestock, overgrazing, excessive mining, and rapid urbanization are the main causes of land degradation.

CONCLUSION

As a young and dynamic international knowledge platform, IKCEST has made remarkable progress and achievements, with the help and support of UNESCO, the Chinese Academy of Engineering and others. In response to the new demands in engineering science and technology of more developing countries in the Asia-Pacific region, the Belt and Road region and the whole world, IKCEST will continue to integrate engineering data resources, improve knowledge service capabilities, explore the correlation among data resources in various fields, so as to better realize the value of knowledge, provide specialized knowledge services in more fields and continue to support the various action plans of UNESCO and contribute to the implementation of SDGs.

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AUTHOR CONTRIBUTIONS

Under the guidance of ZC, the authors worked on this article together. All authors contributed to the article and approved the submitted version.

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