

Power of Math to Expand Human Understanding

Dialogue

By LONG Yun & BI Weizi

Mathematics, often described as the universal language of science, has shaped our understanding of the natural world and modern technology. Experts like Professor Kenji Fukaya, a trailblazer in symplectic geometry and a Shaw Prize winner, show us just how beautiful mathematics can be and how deeply one can fall in love with it.

In an exclusive interview at Tsinghua University's Yau Mathematical Sciences Center, where he now serves as a professor, Fukaya shared his mathematical journey with characteristic academic rigor and precision.

Academic breakthroughs
For Fukaya, the decision to pursue mathematics was made when he entered university, driven by a lifelong dream to become a scientist. But he wasn't very good at hands-on experiments and he tended to work independently. This preference toward deep thought proved to be an asset in his career.

"A major part of the job is simply to sit down and think," he says, emphasizing that the essence of his discovery often lies in sustained, focused contemplation.

One of Fukaya's groundbreaking contributions is his conceptualization of the "Fukaya category" in symplectic geometry, an achievement recognized by the 2025 Shaw Prize in Mathematical Sciences.

According to the award citation, he "anticipated the existence of the Fukaya category formed by Lagrangian submanifolds in symplectic manifolds, and accomplished the formidable task of its construction."

To make this abstract concept more



Professor Kenji Fukaya. (PHOTO: YMSC)

accessible, he draws an analogy with classical geometry: "In Euclidean geometry, you study triangles, rectangles, and lines. In non-Euclidean geometry, you study similar objects, but their properties differ. For example, the angles of a triangle may not add up to 180 degrees. What's interesting is that the space itself defines these relationships."

Building on this foundation, the Fukaya category examines not just individual geometric objects but the entire space and the interactions between objects within it. This approach was partly inspired by physics, particularly the work of mathematical physicist Maxim Kontsevich, who proposed that certain geometric spaces that appear different could produce equivalent physical theories.

"Physicists found that two very different spaces could give rise to the same quantum field theory," Fukaya explains. "This suggested that our classical notion of space might be incomplete."

By formalizing these relationships using the category theory, Fukaya has provided mathematicians with a powerful

tool to explore deep questions in symplectic topology, mirror symmetry, and beyond.

Beauty of mathematical discovery
Beyond the technical achievements, Fukaya also reflects on the deeper satisfactions of mathematical discovery. When asked about the most rewarding aspects of being a mathematician, he highlights aesthetic intuition: "In many sciences, importance is often tied to utility, which is valuable. But in mathematics, great discoveries may take centuries to find applications. We have to recognize what is important without knowing how it will be applied."

This requires an independent mindset. "Every mathematician must develop their sense of which problems are interesting and worth pursuing."

Fukaya's career is marked by intellectual flexibility. Initially trained in Riemannian geometry, he shifted to symplectic geometry in the 1990s, influenced by emerging connections between physics and advanced mathematics. "I was at the Max Planck Institute for Mathematics

in Bonn, where I had the freedom to explore new areas," he recalls. "I started reading about gauge theory and spent months immersing myself in physics."

This interdisciplinary curiosity proved transformative. "Physicists and mathematicians often see the same formulas but interpret them very differently," he remarks. "Collaboration isn't always easy, but these interactions can lead to surprising insights."

Advice for aspiring mathematicians

Fukaya encourages students considering a career in pure mathematics. "Applied mathematics is often driven by concrete goals, but pure mathematics is freer. You're exploring ideas that might shape the next century," he says. He cites group theory as an example: Initially developed to solve polynomial equations, it later became fundamental to quantum mechanics, chemistry and beyond.

"The key is persistence and trust in your judgment," he says. "Mathematical problems often require months or years of work, and you'll face many setbacks. But if you believe a problem is worth solving, you have to keep going."

Asked how his work might benefit society, Fukaya remains characteristically modest. "I study abstract notions of space, ideas that go beyond our everyday experience," he says. However, from his perspective, mathematics expands human understanding beyond the limits of physical experimentation.

"Mathematics is about seeing patterns, making connections, and discovering structures that feel inevitable once you understand them," he says. "That moment of clarity, when something abstract suddenly makes sense, is what keeps me going."

NIU Yun and WANG Yiting from YMSC also contributed to this article.

Tech+Culture

Tech Makes Ancient Crown Glorious Again

By WANG Fei & ZHANG Tianfu

The gleaming star attraction at the Haixi Prefecture Ethnic Museum in Qinghai province is perfectly described by the museum's director Zhu Youzhen. "Even by modern standards, this crown is absolutely stunning," he told *Science and Technology Daily*, referring to the return home of the eighth-century Tibetan royal crown, meticulously restored in Beijing and now recognized as China's first fully reconstructed complex crown from the Tubo Kingdom era.

Visitors marvel at the transformative restoration when comparing pre- and post-repair images. It's once again a reminder of the role science and technology plays in preserving cultural heritage and how it helped to preserve this treasure from archaeological excavation to pristine conservation.

Laser precision meets ancient craftsmanship

In 2019, archaeologists conducted an excavation of Tomb No. 1 in Qangu, Ulan County, Haixi. This tomb, the first mural-adorned Tubo-era burial site on the Qinghai-Xizang Plateau, holds significant value for understanding the integration and exchanges of Han and Tibetan cultures.

Despite repeated looting, a hidden compartment in the tomb's rear chamber remained intact. Inside a wooden box within this compartment lay the golden crown. "Royal crowns from ancient China are exceptionally rare in archaeological findings," said Tong Tao, an expert from the Chinese Academy of Social Sciences. "The tomb's hidden compartment shows the meticulous care taken by its builders."

The crown features winged dragons on the front and back, standing phoenixes on the sides, and a neck guard decorated with twin lions. It is also adorned with gemstones, lined with silk, and embellished with a pearl-studded fringe.

Though still dazzling after a millennium underground, parts of the crown were severely fragmented. In March 2023, it arrived at the Key Laboratory of Archaeometry and Cultural Heritage Conservation, Chinese Academy of Social Sciences, where restorers faced an immense challenge.

"The difficulty was immediately apparent," said Huang Xi, an assistant researcher at the lab. "Gold and silver artifacts are typically thin, emphasizing their delicate nature. This crown's body was as thin as three stacked A4 sheets. Parts had been crushed by falling debris and suffered electrochemical corrosion from alkaline soil, leaving the lower section nearly disintegrated."

As the saying goes, science and technology can "turn stone into gold." Huang



The restored eighth-century Tibetan royal crown. (PHOTO: The Chinese Academy of History)

Xi and her team ultimately found a solution. They employed an annealing method of heat treatment, with independent intellectual property rights to restore the crown's framework through recrystallization, thereby recovering its structural strength for reshaping. Simultaneously, they utilized modern laser welding techniques, meticulously securing tens of thousands of weld points to ensure the main body of the crown retained its original appearance in the restoration.

Today, the crown with its coiled dragons, spread-winged phoenixes, and lions clutching auspicious grass draws regular crowds at the Haixi museum. Enhanced by digital displays, visitors get a first-hand look at a relic of the ancient Silk Road's cultural exchange.

Reconstruction of the pearl fringe
The crown's pearl fringe composed of over 2,000 pearls and other decorations was initially a jumbled mess.

"The original silk threads had decayed, and falling debris further shattered the fragile fringe," Huang recalled. "It was like a puzzle smashed on the ground, with missing pieces." Fortunately, archaeologists used menthol consolidation to extract the fringe intact.

Through CT scanning and spectroscopic analysis, Huang's team deciphered the fringe's original arrangement. After months of painstaking work, they reassembled 2,581 beads, only missing one garnet. Fortunately, a colleague of Huang's found it when sifting through plant remains. Five months later, the fringe was restored.

"Advanced techniques — 3D microscopy, infrared spectroscopy, X-ray diffraction, metallography, and scanning electron microscopy are revolutionizing heritage conservation," Huang said. "We want these technologies to 'bring relics back to life,' allowing more people to appreciate China's historical legacy."

Taijiquan: The Flow of Energy

Traditional Eastern Wisdom

By BI Weizi

Taijiquan is a traditional physical exercise characterized by smooth, circular motions that harmonize with breath control and the cultivation of a neutral mind. Commonly known as "meditation in motion," taiji seeks to focus and balance the body's purported qi (vital energy), providing benefits for both mental and physical well-being.

Emerging in the mid-17th century in Wenxian county, Henan province, central China, the practice is now embraced nationwide by individuals of all ages and ethnic backgrounds. The fundamental movements of Taijiquan focus on wubu (five steps) and bafa (eight techniques) along with a variety of routines, exercises and tuishou (hand-pushing

techniques practiced with a partner).

Chinese philosophy, especially Taoist and Confucian ideas, serves as the conceptual foundation for taijiquan. An essential element of taiji philosophy is to engage with the balance of yin (softness) and yang (hardness) forces. When two forces exert equal strength against each other, neither side budges. Movement cannot take place until one side gives way.

Consequently, an essential principle in taiji is to refrain from applying force directly against force (hardness versus hardness). Laozi, founder of Taoism, established the model for this in the *Tao Te Ching* (a Chinese classic text) with his statement, "The soft and the pliable will defeat the hard and strong."

Inspired by Taoist and Confucian ideas and concepts from traditional Chinese medicine, taijiquan has evolved into various schools (or styles) designated by a clan or a master's personal

name. The element is conveyed via clan-centered transmission or the master-apprentice model.

In 2020, UNESCO inscribed Taijiquan on the Representative List of the



American Jake Pinnick practices Taijiquan in the Jade Void Temple in Shiyan city in Hubei province. (PHOTO: XINHUA)

Intangible Cultural Heritage of Humanity. It is estimated that the number of Taijiquan practitioners is around 500 million, distributed across over 150 countries and regions.

Xin Hong Zhuan: China's Solution to Intelligent Sailing

From page 1

Data pertaining to the ship's condition and equipment operation are captured by the 15,000 sensors installed in the vessel, and are seen on screens at the shore-based center.

Thanks to this center, when the sailing and controlling mode of the ship at sea changes, the shore-based navigator can remotely control sailing and steer the ship to shore, or the autonomous sailing mode can be switched on to enable the ship to recognize its route and avoid obstacles autonomously, said Yin Yong, professor at DMU and chairman of the board of Zhilong (Dalian) Marine Technology Co. Ltd.

There are more challenges to face in autonomous control of a vehicle at sea than on land, said Zeng Hong, a professor at DMU. Key technologies like AI models, development of the core system and application of sensing systems were given as examples.

Based on a comprehensive automation system, DMU built a digital base via a unified integration platform, ensuring deep integration of sailing, engine and electric systems. Extensive research on emergencies and risks of narrow channels has been conducted to enhance the capacity of risk identification.

Research and onboard practice
Xin Hong Zhuan is also a maritime

experiment vessel, which will provide crucial support for research on the basic, pioneering and key technologies of intelligent sailing.

The first batch of trainees have boarded the ship and participated in practical training via the digital twin technology system developed by DMU. The digital twin technology can establish a high-fidelity numerical simulation model of the ship and highly realistic virtual scenes, Zeng said, adding that trainees can monitor and operate equipment in the digital twin ship.

Sun Feng, director of the R&D department of COSCO Shipping Heavy Industry (Dalian) Co., Ltd., said the digital

twin technology reduced the time needed for maritime testing by more than half.

The Dalian Science and Technology Bureau will build the first mobile pilot test base for domestic ship equipment and a sea-based technology validation platform based on Xin Hong Zhuan, Wang said.

Through practical simulation and scenario-based application, the platform aims to attract domestic and international research teams to conduct verification of technical equipment in maritime communications and navigation and underwater robots, accelerating the transfer of sci-tech achievements to real productivity, Wang said.

Photo News

Global Mayors Dialogue: SCO Summit Cities opened in north China's Tianjin on July 8. Guests including mayors, diplomatic envoys and experts from different countries were brought under the same roof to share their opinions on how Shanghai Cooperation Organization (SCO) member countries can further deepen practical cooperation in fields such as interconnection, trade and investment, green development, and people-to-people exchanges.



The photo shows the opening ceremony of this event. (PHOTO: XINHUA)