

Science and Technology in China

Personal recommendations for the advancement of Chinese technology

BY SHING-TUNG YAU

The prosperity of China is inextricably linked with technological progress. In the past ten years, China has shown significant leaps forward—in economics, politics, and other arenas—undergoing a complete make-over from the past two hundred years. The world pays close attention to China's developments, not only because China is the biggest market for their products, but also because China's accomplishments in technology are gradually maturing—advantageous to them on the one hand for opportunities in collaboration, and on the other hand, a potential competitor who might warrant counter strategies. Speaking from the perspective of today's Chinese, we are proud of prospects for the future, but also worry that excessive confidence might overshadow the many problems we face, which need to be looked at squarely.

Technology is all about basic and applied science—science and technology are intimately related. Without sufficient science as a foundation, technology would find it impossible to meaningfully advance. Vice versa, technology can catalyze scientific advances, and promote progress in industries. Technology in China has been advanced before the Tang and Song dynasties, but since the Ming and the Qing dynasties, it gradually fell behind other nations. The European Enlightenment happened during this same period, triggering a flowering of technology, and later touched off the Industrial Revolution. The advancements in land, sea, and air transportation in recent history significantly spurred the great volume of exchange between the cultures of the West, catalyzing technological and cultural progress.

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On average, only when a nation's economic foundation is secure does it expend excess energy to build culture. Guanzi, the ancient philosopher, said, "Pride comes after food and shelter." So, if there is no conception of shame, there cannot be law and order or serious academics. Therefore, satisfactory treatment is necessary to technological progress.

Culture can endow a person with restraint and self-discipline. In modern society this is especially important: pirating and forging have become a serious cause behind economic downturns. In science and technology, pirating the fruits of others work is everywhere. Those whose research papers show serious errors but still shrug off correcting them are not novelties. Some well-known young scientists have even acquired great personal success while practicing this sloppiness! In this kind of environment, science and technology naturally cannot achieve great progress. Since opening up to the world, China's technology has seen considerable development, however, the flaws of some young Chinese scholars lie in hoping to follow the fastest route to achieve the goal of fame and success. This is linked with a lack of training in ethics. Under the sole influence of material achievement, group and personal discipline have no ground upon which to stand.

In Western countries, many outstanding secondary and primary schools instill at a very young age the concepts and understanding of law and ethical behavior. Often, lawyers or judges utilize free time to rehearse potential legal problems with secondary school students, inculcating a spirit of fundamental respect for the law. Understanding the law and the importance of teamwork is of extreme importance to a good scientist and engineer.

Science builds upon the cultural foundation of an entire race, while new technology builds upon the foundation of science and previous technology. It is

no coincidence that the Industrial Revolution of Europe took place after its cultural enlightenment and scientific revolution. Up to modern times, every progress in industry has been directly linked to progress in science and technology.

Two months ago, the inventor of laser, Professor Charles Townes, upon meeting vice prime minister Li Fengqing, pointed out that fundamental science was the force behind his invention of the laser, which later spawned countless new industries and businesses. Without the idealism to uncover the mysteries of the natural world, there would hardly be any advanced technological inventions. The United States' investment in fundamental science and technology through all these years has reaped enough profits from the invention of laser alone.

Besides research into the laser, research in material science has been an extremely important project for the past forty years. A great number of discoveries share intimate connection with fundamental research into the seemingly rarified world of quantum mechanics. Most recently, some fruits in fundamental research have found practical applications after only one or two years. For instance, the science behind atomic cooling and trapping can be used to construct extremely accurate atomic clocks, which enable advanced communications technologies.

Computer research and modern information technology require large amounts of research results from material science. In software there is great application of ideas from applied mathematics. Although hardware is powerful, it cannot act entirely alone. Many problems, such as finding the shortest route to go through all websites in a large network, must utilize mathematics in their solutions. Whether in organizing networks or handling imaging, all kinds of problems have direct and surprising connections to mathematics.

Mathematicians, through their understanding of theoretical mathematics, are gradually unearthing the potentials of applied mathematics, applying it widely in information technology, engineering design, and computer security—fields unrelated to theoretical mathematics. Surprisingly, mathematics in these situations all touch very advanced ideas, such as results in number theory which are widely used in software engineering. Not only in these physical sciences, but profound mathematical theories are already

widely applied to economics, investment, social management, and other areas that directly impact society.

Here, we can see an important fact. A nation's investment in science and technology can be short-term and long-term. In short-term, it's doubtlessly taking advantage of mature technology to achieve massive production to realize economic prosperity. But if the emphasis is only on this kind of investment, economics can only prosper short-term. Afterwards, there would be inevitable reliance on overseas science and technology, at most maintaining only a bourgeoisie situation. Long-term investment is closely related to the entire social and cultural milieu of a society. Progress of society and culture not only can aid technology progress, in fact it is the most important element in technological and scientific innovation. That important technological and scientific discoveries occur in places of culture is not a coincidence. The culture of a society not only catalyzes the congregation of first-class scientists and engineers, but also allows for the maturation of their ideas. Of course, taken the other way, wondrous growths in science and technology also promote the development of culture.

The place to nurture culture takes on different approaches in a country, such as fine arts museums, science and technology museums, opera houses, exhibitions, good journals and magazines to let the general public express its opinion, and so forth. But the most important is the building of first-class universities and institutes. This should be a place of academic nurture where quality and not only quantity is emphasized; an institution led by accomplished scholars with vision and foresight; a place of integrity, dedication, and excellence; a place to train academic or social leaders; a place to discuss national issues; a place where teachers and students wholeheartedly cooperate and collaborate in technological progress.

Universities are the wellspring of technological and scientific progress for an entire nation. The United States has the most copyright and patents in the world, and over three-quarters comes from university research. Progress in industry, commerce or the military, is inextricably entwined with research in universities and institutes, especially long-term investments in research, which are undertaken by a collaboration among universities, corporations, and the government.

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"Study science and prepare to serve the motherland" . . . or perhaps study science for it's own sake?

In corporate-sponsored research labs such as the famed Bell Labs, or IBM's T.J. Watson Research Center, many research discoveries have been awarded with a Nobel Prize. These discoveries often do not have any direct connections to commercial products. For instance, in the 1960s the engineers at Bell Labs obtained data on the Big Bang through efforts to improve information technology. In a place of scientific freedom, the most important feats in the theory of universe can be conceived.



Materials science is basic science, but leads naturally to technology

The United States' investment in biotechnology in the last twenty years has already surpassed hundreds of billions of dollars. Up to this point there have been no real profits, but schools and government are actively participating—never giving up—because this is a quest with huge potential future for both science and technology. The entire society is also excited by this new research. Because of cooperation among pharmaceutical giants, the government, and research institutes, many important drugs have already been manufactured, and have saved human lives.

To encourage collaboration in research between schools and the private sector, the United States has a variety of organizations to provide research funds, including the National Science Foundation, the National Institute of Health, the Defense Advanced Projects Research Agency, the Office of Naval Research, among many other sources of government funding, as well as significant private foundations, such as the Ford, Rockefeller, and MacArthur foundations, which all subsidize a large part of research. The advantage of the depth and breadth of funds is that nobody can control funds for

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a whole field. In comparison, the situation in China is vastly different. In technical fields, there is only but a single Natural Science Foundation. The evaluation process is not sufficiently transparent—only a small number of people make decisions on funding, and to a researcher not being funded in this way means that it would be nearly impossible to conduct their proposed research.

In technologically and scientifically advanced countries, besides the availability and diversity of funding, the evaluation

process of research results is relatively objective and flexible. In China, the distribution of funds and promotion of teachers and researchers are all held in the hands of a few. But these few do not necessarily know the opinions of contemporary experts. Even if they seek the opinion of overseas scholars, they usually end up being those who concur with the opinions of this decisive minority, not the experts in the field.

While domestic science and technology research still lags far behind other countries, a domestic bureaucracy has already formed in our nation's intellectual circle. Because fellows of institutes do not have to retire, the turnover rate in this stratum often takes a very long time. Some young and accomplished scholars seek the only route they can: going overseas. Those modestly able young scholars, if they can acquire the patronage of the intellectual aristocracy, can receive large material rewards, the amount of which can reach over several millions plus

frequent publicity in newspapers. But given that their actual accomplishments are only modest, once they reach some level of fame no impetus for true academic pursuit remains at all.

China's universities are mostly public universities, administrated by the Department of Education. Over the past decade the Department of Education has loosened the rein considerably, but funding is still controlled by the Department of Education or via subsidies from provinces and cities. Private donations and foundations are still rare. Brand name universities like Beijing University and Qinghua University, because of their publicity, naturally receive relatively more funding. The increase in funding in recent years, though undoubtedly a good thing, has resulted in much waste from inefficient administration. Some universities hire short-term overseas scholars and international students. Many international students go to several universities to collect compensation but stay there for an extremely short time. In the end, not only are funds wasted, but also this results in a harmful influence. There are also some international students, whose academics are only average, but demand various special treatments, usually surpassing the costs of native young scholars by more than ten fold. This kind of inequity in academics is equivalent to encouraging the brain drain of the young and able.

Many of the well-known professors at well-known universities spend half a year visiting overseas, and upon their return spend more time on administration than research, impeding the growth of their graduate students. This situation is absolutely discouraged at well-known universities overseas. A celebrity like Kissinger, upon retirement from being US Secretary of State, was refused by Harvard University a faculty position because he refused to teach courses. Most of the world-class universities treat the education of students and research as paramount objectives, and so professors must accomplish this objective to gain respect.

Still, when economic conditions are satisfied and the evaluation processes are standardized, how does one encourage young people to innovate? This is the biggest problem that China's science and technology circles face today. Since ancient times China's engineering and technology has been extremely accomplished, but every time technological progress reached a certain level advancement slowed, as if people were content. But Western societies can overstep this malady, because of the spirit of integrity and beauty brought through the Greco-Roman tra-

dition. Chinese civilization indisputably has outstanding traditions, but in sustaining long-term progress in science and technology, it has not yet achieved greatness. The Chinese believe that science and technology serve the people's daily lives. Thus Shunzi said, "It is the divine mandate to make in order to use." Because of this there was not that spirit of undiluted curiosity and investigation as evidenced by the Greeks and post-Enlightenment scientists. Without seeking out the source of technology, there naturally cannot be progress.

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China treats the family as the primary unit, and treats human relationships as the primary moral fiber, which directly impact scientific and technological progress. Because of filial piety, there must be respect for the elders, and by logical deduction, the actions and words of the elders

of a clan and the elders of a society overshadow the law and the truth. Cooperating with filial piety has shown the Chinese's reverence for the old, not the new, and thus, "the first emperors are the supreme limits on human accomplishment." The extremes of filial piety hamper creativity—"Three years after the father's death and not changing his ways is filial piety." When this philosophy is too extensively applied, in laboratories students must pursue the research directions of their mentors. In factories apprentices must pursue the ways of the master, not daring to explore new paths. As time passes, the influence of clans and schools overshadows everything else. In China, a successful scholar often is supported by a group—by clans and elders in villages and by a professor in school. Therefore, one has the responsibility to give back in return for the support, and at the same time, the impetus to support the growth of disciples under one's own school in the future.

The outlook that extends from the clan to society and a nation takes deep hold of the hearts of the Chinese intelligentsia. Intellectual development is circumscribed by bigotries of schools. During the Three Kingdoms, the Yuan Shao clan's achievement of "four generations with three high officials and disciples and students all over" has been admired even to this day. To secure one's status, a considerable number of intellectual aristocrats promote scholars on the basis of marriage and blood relations. Even if the relative's academics are poor, there are plenty who still can rise to as high as fellows and institute direc-



Science is a cultural phenomenon, and is the foundation upon which all technology must stand

tors. What the intelligentsia scramble for is the interest of a faction, “rich but outside of one’s homeland is like wearing luxuries in the dark.” Learning is no more than showing off in front of one’s fellow countrymen, while the spirit of integrity and beauty does not receive encouragement.

The fact that children do not receive societal encouragements to satiate their curiosity and pursue integrity and beauty is undeniably a weakness of the cultures of the East. Overly advocating “learning for applications,” or “study in order to receive a position,” distracts scholars away from devoting themselves to the studies of the world’s essential questions.

In contrast, the universities of other countries are relatively more open and encouraging of exchange. After students finish their studies, mentors often insist that they go to other places for employment or research to expand their points of view.

Originality needs an environment of academic freedom—the paramount example of this occurred during the before the Qin Dynasty in China, when

many schools flourished. After the Qin and Han dynasties, conditions became more institutionalized. The scholarly atmosphere was satisfactory during the Song Dynasty, but became more confined during the Ming and Qing Dynasties. There had been a direct

correlation between technological advancement and the government’s respect for the intelligentsia throughout the dynasties. The technological progress of today depends on promoting a lively and free academic atmosphere, and also shattering the baneful trend of age-based systems.

Any academic evaluation needs to be just, by a standard of quality instead of quantity, and must promote young scholars by the actual content of their work. Schools should base their pride on nurturing truly excellent research and outstanding students.

So, professors in academic or research institutions should be appointed by just evaluation methods, funds should be distributed according to ability and results, and not by age and or by connections. Any researcher or professor should have regular sab-

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baticals, and only during those sabbatical should they take up positions in other research institutes, and research personnel should not have to spend too much time participating in politics. Academic accomplishments should not be “rewarded” by increasing administrative burdens—the society should reward academic activities that have a direct positive impact on the economy, technology, and most importantly in fundamental science that might have long-term impact.

A technologically advanced country must explore all the ways possible to provide outstanding scientists and engineers with a satisfactory work environment. Give them satisfactory compensation to allow them to wholeheartedly create, transforming their ideas into scientific results or industrial products.

In the past, our country measured industrial progress by the quantity of steel produced. Today, if schools only measure their prestige by the *quantity* of papers, fellows, and scholars, I’m afraid this method of “surpassing England and catching up with the United States” will be hard pressed to bear fruit. Developing curiosity and promoting scholars justly—based on quality and originality—are the most important links in scientific innovation, while equal competition is the most important link in technological innovation.

Technology today can quickly find applications in production, but while many domestic scholars are able to create new technology overseas, they encounter difficulties domestically, and one of the causes is the lack of protection for intellectual property. From creating new technology to producing software, hardware, production; and to marketing, they all need a comprehensive plan, and also need investment. In nascent industries, entrepreneurs hardly possess the inventive spirit and the capital, while inventors don’t have this kind of stamina, so plans must be government-sponsored and comprehensively planned.

Regardless of new technological developments, nurturing and commercialization require a great deal of expertise. In technologically advanced countries, not only do universities cooperate by cultivating talent and the government establishing research institutions to cooperate, they also attract large amounts of expertise and capital investment from all over the world.

Since opening-up, China has attracted considerable number of experts, but most of them are graduate students, and most of those are short-term visiting scholars or engineers. They have indeed contributed significantly, but we still need to have our hearts in China, with scholars and engineers who voluntarily stay for long-terms, and we should also attract some scholars and engineers of non-Chinese descent. From the Han Dynasty to the Yuan Dynasty, China had always invited outsiders to China to be officials. Through this interaction, technology experienced great developments.

The increasing isolation of the Ming and Qing dynasties impacted Chinese scholars in that they did not have contact with the scholars after the European Enlightenment. Although missionaries did import some technology, they did not represent the leading edge of innovative science.

China also did not send young people to follow the scientific giants of Europe, and domestic scholars intractably resisted Western studies. The scholars of mid-Qing overemphasized studying ancient mathematical texts and lacked creativity, thus causing technology to lag far behind. Since Truth and technology do not distinguish between the East and the West, when looking for the able, one should not be limited to the few schools or institutes in China, and furthermore should not be limited to Chinese, or scholars of Chinese descent.

The Meiji emperor of Japan began his reign in 1868 with the *Meiji Restoration*. With effective central command, he vowed to the whole nation to improve domestic education and to pursue knowledge from the whole world. He sent many visiting scholars overseas who later returned to Japan to work, and foreign scientists and engineers were welcomed. In an astonishing short amount of time, Japan’s accomplishments in industry and technology had become comparable to the West, and to this day Japan has, on its own soil, cultivated seven Nobel Laureates and three Fields Medal winners.

Today’s China—in economics, politics, and in the educational level of the population—surpasses many times the situation during Japan’s Meiji Restoration. After China has appropriately handled issues relating to scientific and technological development, in a short time China will become a giant in science and technology.

The most important is the building of first-class universities and institutes . . . universities are the wellspring of technological and scientific progress for an entire nation.
