

Meeting the challenges of the 21st century – A scientist's view*

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WHEN I took a faculty position as an Assistant Professor at the University of Chicago in 1968, the end of the 20th century was some 32 years away. I always liked to imagine at that time just how much progress in science and technology (S&T) could be made by such a distant future time. Would nuclear fusion really start to provide infinite amounts of energy for human society? Would supercomputers allow us to predict many natural phenomena entirely based on first principles and the law of mechanics? Could we spend Christmas holidays on a trip to the Moon? Would the war disappear completely from the human society? Well, without knowing it, all those 32 years have managed to slip away, and we are in the fourth year of the 21st century already!

The events of 11 September 2001, measures for counter terrorism, the war on Iraq, and the spread of Severe Acute Respiratory Syndrome (SARS) last year made us keenly aware of the fact that the 21st century is going to be very different from the previous one, and could be difficult for mankind. It is certainly very important to ask the question: 'What then will be the destiny and challenges of mankind for the 21st century?'

If we look back at the history of mankind, the beginning of agriculture in many parts of the world around 10,000 years ago, was an important landmark. In the following years, however, although there was a noticeable population increase on earth, things did not change very rapidly. It was not until 250 years ago, when the Industrial Revolution started with the invention of the steam engine by James Watt, that development of human society really accelerated – accelerated to such a level that changes during the last century have, in some areas, been more substantial than those that occurred during the entire preceding millennium.

What happened during the last 250 years is simply remarkable. As we learned to transform energy from one form to another – from chemical and mechanical to electrical – and invented various machines that could perform work a thousand times more powerfully, more precisely, and more reliably than could be done with human and animal labour, productivity increased immensely, and an unprecedented improvement of living standards was achieved. Along with the rapid advancement of S&T and the improvement

of medicine and medicare, the population on earth increased drastically. Just during the last century alone, the population has increased by four times; and by 2025, it is expected that there will be somewhere around 8 billion people living on earth. The population is now predicted to reach a maximum of 9 billion people midway through this century, and then it might start to decline.

Before we glorify the tremendously rapid development of human society brought about by the Industrial Revolution, let us pay some attention to two important facts. First, as our consumption of energy has increased, we have come to depend more and more on fossil fuels that took millions of years to accumulate on earth. The depletion of this resource in just a couple of centuries is simply irresponsible, not to mention the problems caused by emission of greenhouse gases, acid rain, and particulate matter that are intimately related to excessive wasteful usage of fossil fuels. It is interesting to note that the total human energy consumption of the entire world, although it is mammoth, is only equivalent to the energy transmitted to the surface of the earth by solar radiation within the time-span of 55 min. If we were clever enough, and making good use of solar energy, we would not need to burn fossil fuel reserves to anywhere near the extent we do.

Secondly, the impact of the Industrial Revolution turned out to be very uneven and very different for peoples in different countries. It is not easy to convince people in Third World countries that the Industrial Revolution brought them immediate benefit, although it certainly did some good for the European people up to this point. Depending on whether a country caught up with the moving tide of the Industrial Revolution or fell behind, the fate of her people could be entirely different. Most European countries did catch up with the tide of the Industrial Revolution, and they became powerful and expanded their circles of influence substantially. Most countries in Asia, South America and Africa, however, did not fare so well. They ended up as the colonies of Western powers. Japan is the exception – it did go through a successful Meiji reform and fared somewhat better.

It is interesting to note that 1000 years ago, China, in the early stage of the Sung Dynasty, was still leading the world in S&T. Large overseas trading ships had sailed to Korea, Japan, and also through various parts of Southeast Asia and the Arabian region. The compass was used for navigation. Explosives, printing and papermaking were used quite extensively, and there had been noticeable progress

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in textiles, manufacturing and metallurgy. But, if we were to examine the China of 100 years ago, not only would we fail to find any of the glory of 1000 years ago, but we would also see that, after failing to catch up with the Industrial Revolution and being repeatedly defeated by Western powers and Japan, China seemed to have declined to the status of a semi-colony.

At the beginning of the 20th century, some people in Asia realized that in order to catch up with the Western world, 'science' and 'democracy' needed to be pushed forward. But, since the most acute problems under colonial occupation or foreign invasion were the oppression or unequal treatment perpetrated by foreigners, it is not surprising that it was nationalism rather than the democratic movement that transformed Asian countries during the last century. In China, even after the socialist revolution, what unites and mobilizes the people most effectively is often nationalism, rather than idealistic socialist thought, which now seems to be fading away rapidly. At the end of the Second World War, most Asian, African and Latin American countries had become independent, and had started to march forward in various directions. Taiwan has certainly moved a big step forward, especially during the last twenty years, from the governance of a repressive regime toward a democratic society.

As we look back on various changes that have taken place in the 20th century, we find nothing more striking than the rapid advancement of S&T and its profound influence on the social life of mankind. During the last several decades, among the dazzling changes that have taken place, some noticeable trends have appeared. The first trend is that of continuing Industrial Revolution – this time, not related to energy, but based on microelectronics and information technology. If the first Industrial Revolution enabled mankind to overcome limitations imposed by muscle power, the second Industrial Revolution will surely allow us to go beyond the limits of our brainpower. By using various tools and machines, man has certainly become more capable and more powerful, but the next generation of tools will make us more powerful in an altogether new way. It is very likely, in this next century, that we will witness a profound influence on human society from rapidly developing biotechnology, especially when it is successfully applied to agriculture and medicine. Problems of starvation in many parts of the world might be solved with the advancement of agricultural biotechnology; and people might live healthier and longer lives with the advancement of medical biotechnologies, such as genomic medicine and high-throughput drug discovery. We have to be mindful, however, that this time we are tinkering with both our natural lives and the basic evolutionary processes of biological systems, rather than simply inventing tools to enhance our abilities.

It is interesting to observe that in spite of many important changes that have taken place in the world, the rules of the 'game' governing competition among nations and regions seem to be substantially unchanged. Although com-

petition based on military might has been replaced by high-tech-based economic competition, the latter is no less fierce than the former. Again those countries capable of catching up with this second Industrial Revolution will become rich and powerful, while those that fall behind will again be poor and miserable. There is no doubt that some Third World countries will catch up this time, but many of them might not be so fortunate.

The second major trend is the globalization of the entire world. As a result of highly developed transportation and communication technologies, our globe has shrunk in relative terms, while the influence and mutual interdependence of the peoples of various countries has increased sharply. Especially during the past fifteen years, thanks to globalization of information and the world economy, the concept of a 'global village' is slowly being realized, and we are moving closer and closer to a borderless society. At the same time, however, one cannot fail to notice a number of serious problems confronting mankind – the menace of constant population increase, the aggravation of differences in wealth between rich and poor and between developing and industrialized nations, and the damage done to the world's ecosystem and environment. These are all serious global problems we will have to face together.

In recent years, depletion by man-made chlorofluorocarbons of the stratospheric ozone layer that protects us from UV radiation has caused significant alarm. Three decades ago, the observation of a huge ozone hole in the Antarctic stratosphere was completely unexpected. The Montreal protocol signed by most industrialized nations more than a dozen years ago to deal with ozone-depleting substances has started to take effect, although continuing efforts will be needed for the next several decades. In contrast to the stratospheric ozone situation, however, tropospheric ozone near the surface of the earth is quite harmful to both human health and plant life. Recent measurements around the world have indicated that tropospheric ozone, which increases in summer, has already formed an extensive belt in the industrialized northern hemisphere.

The other major problem, which has become increasingly important, is the trend to global warming and climate change. Taiwan is again facing a dilemma, just like many other developing countries. We have not quite caught up with the highly developed nations. Yet, from the point of view of CO₂ emissions from combustion of fossil fuels, and the ability of our forests and coral reef to absorb those emissions, we belong to a growing group of 'over-developed' countries. This is certainly a trans-national problem that everybody on earth must deal with together.

If we examine the world in its entirety, we find that it is in fact in many ways overdeveloped, especially in terms of the excessive consumption of natural resources and the damage done to our living environment. From the point of view of CO₂ production and absorption, and the consequent worsening of global-warming trend, the common practice of categorizing countries as 'developed', 'developing,' and

'underdeveloped' has become increasingly unrealistic, and the so-called developed and even developing countries should all be categorized as overdeveloped. Unfortunately, every developing country has been attempting to follow closely in the footsteps of the so-called developed countries, obsessed with improving its national competitiveness, especially in terms of increasing per capita income. They are adopting the so-called developed countries' patterns of growth, which require excessive or often wasteful consumption of natural resources. These obviously are not the ideal models for not yet overdeveloped countries to emulate. We need to find a new, sustainable way of development for human society, paying special attention to harmonizing the relationship between humankind and nature. It is in a sense very ironic that the global warming trend, a problem so serious that it may lead to the termination of humanity from the surface of the earth, might completely disappear when fossil fuels, which took millions of years to accumulate, are depleted. However, the likely onset of the energy crisis will undoubtedly present a formidable challenge for humankind. We should also recognize the fact that modern civilization, especially as associated with the prosperity and modern conveniences achieved in the twentieth century, depends on the energy provided by the combustion of petroleum and the development of the petroleum industry.

Global reserves of various types of energy, unfortunately, remain limited. It is estimated that the time to depletion is 40 to 60 years for crude oil, 80 to 100 for natural gas. However, production will probably peak much earlier, perhaps within the next 20 to 40 years for crude oil and natural gas. This means that before we are halfway through this century, it is very likely that the gap between energy demand and supply will have greatly widened, and the energy crisis will be here to stay.

In fact, the arrival of the energy crisis will also signal the arrival of food shortage, as modern agriculture depends greatly on chemical fertilizers, which require a fair amount of energy to synthesize. Without abundant and inexpensive energy, we will not have enough fertilizer to maintain such high efficiency in food production.

Another important consequence of the globalization of human activities is the spread of diseases around the world. With a vast fleet of airplanes flying across oceans, between continents, loaded with people and goods, disease-causing bacteria, viruses and other microbes certainly will not be confined to certain localities. The recent spread of SARS is a good example – from Canton to Hong Kong, then across the Pacific, all the way to Toronto and Singapore in just a matter of weeks. In addition to the spreading of diseases, we also have to be aware that our species, *Homo sapiens*, is in constant evolutionary competition with the bacteria, viruses and other microbes that affect us, as forewarned by Joshua Lederberg, a Nobel laureate in medicine. With our relatively long life cycle, the evolution of *H. sapiens* is a lot slower than the evolution of bacteria or viruses – whose life cycles can often be only hours or days. Exposure

of these agents to radiation and chemicals could easily enhance the rate at which they can evolve to new forms.

It seems obvious that the future of humanity depends upon a global system of politics, economics, culture and ecosystems, which calls for interdependence among all countries and regions of the world. And, no matter where we are, no matter whether we are paying enough attention or not, we will soon realize that the world in which we live is in fact the whole earth – a global village in which the destinies of all peoples are irrevocably linked.

Certainly we cannot go on as we have been doing. Things have to change and we are the ones who must make it happen. We have to face the problems resulting from energy usage and the closely related impacts on our environment. If we are to achieve sustainable development for the entire world, we must all increase energy efficiency, reduce dependence on fossil fuels, develop renewable energies, maintain biodiversity, make a more careful examination of population policies, and reduce the consequences of all human activities on our living environment and ecosystems. But, perhaps most important of all, it is time for those who live in developed countries and consume excessive amounts of natural resources to ask themselves the question, 'If everyone on earth were to live like us, could the earth carry the burden?'

In the past decade, interactions among the scientists and technological personnel of Third World countries have become more frequent. Seemingly, they have become aware that they share problems that are of little interest to those in developed countries. They also understand that in order to catch up, it is necessary to commit a certain percentage of GDP to education and research. The question still remains, however, that if development of the 'North' is not sustainable, does it make any sense at all for the people of the 'South' to try so hard to catch up? The American way of life, typified by automobiles and large houses, has been the admiration of people around the world. But we have also come to realize that, in the United States, 5% of the world's population has been consuming nearly 30% of the earth's natural resources. After India gained independence, in answering questions about the future of the Indian nation, Gandhi rightfully asked how many earths would India need, if the Indian people were to live like the people of England. Perhaps, we should encourage countries of the 'South' to begin their own efforts to find a new way of life that the 'North' might follow. Considering that we all live in the same global village, we have to learn to think and act together with global interest in mind. We should all recognize the fact that the increasingly interconnected world cannot be a safe place if a large portion of its population still suffers from poverty, diseases, illiteracy, unemployment, and other barriers to survival.

For centuries, the scientific knowledge accumulated by mankind has been shared quite freely. Scientists generally still believe firmly that the knowledge accumulated through their efforts should be shared by all – as advocated by Francis Bacon a long time ago. Early last century, when Madame

Curie was asked why she did not apply for patents on her discoveries (after all, if she had done so, she would have been as wealthy as Thomas Edison at that time), her reply was quite simple. She did not want to take advantage because she believed that scientific knowledge should belong to all mankind. In a modern society, however, when scientific knowledge is further developed, transformed into technology and put to use in society, it becomes the basis for economic competition. Protection of patents and intellectual property rights (IPR) has become a very important issue, and the sharing of knowledge now stops at basic scientific knowledge and so-called 'pre-competitive' technology. Competitive technology is not freely shared. However, the gap, or time lag between scientific discovery and technology in the marketplace has become shorter and shorter. The lag was 100 years for automobiles, five years for computers, and only 18 months for microprocessors. Now, in certain areas of scientific investigation, it is no longer possible to distinguish between basic research and associated competitive technology.

As the relationship between S&T become closer, the dilemma of 'to share or not to share' has become an important issue – not only for application of technologies, but also for the basic scientific discoveries themselves. It certainly does not seem fair if some countries produce most of the public scientific knowledge, while others mainly dedicate themselves to protected, mission-oriented technological development to gain economic competitiveness. Certainly, in a market-driven economy, free and open economic competition and adequate protection of IPR are necessary for development. Yet, we must ask seriously whether, in a highly globalized world, we can find a new and better way to allow both creation and sharing of knowledge as well as technology to be carried out in a more orderly fashion to promote sustainable development for the entire world.

Many of the problems we face today are problems that cannot be solved with current scientific knowledge and technologies – they await the accumulation of new knowledge and the development of new technologies. That is why it is so important to continue our efforts for the advancement of S&T, and for the education of a new generation of creative scientists. In the mid-30s, many scientists gathered together to forecast what they believed would be the major new discoveries in S&T over the next 50 years. Many predictions were made but they were, of course, only extensions of the knowledge of that time. None of the important discoveries that have since shaken the world – discoveries such as semiconductors, computers, communication technologies, genetic engineering, and exploration of the outer space – were on the list. This is why we often say that scientific discoveries cannot be planned. Nevertheless, the establishment of fertile fields of science for new ideas to grow, and the empowerment of young creative scientists to carry out research driven by curiosity will certainly bring good results.

S&T, however, cannot solve all the problems we face. On the contrary, the rapid development of human activities,

especially the fast-moving global economy propelled by the advancement of S&T, could create further new problems as contact among peoples becomes more intimate.

In spite of the fact that globalization of the world economy is driving us toward a borderless society, it will not reduce the differences among peoples in various regions overnight. Establishment of a new common global culture, together with more effective ways of communicating among all the peoples, will certainly take time. The differences among cultural heritages, languages and religions that make this world so rich and colourful will not, and should not, be made to disappear. As the world shrinks in relative terms, and contact between peoples becomes more frequent, whether or not differences in civilization are likely to cause an inevitable crash (as suggested by the well-known scholar Huntington), would seem to be entirely dependent on how well peoples around the world learn to communicate and to understand, appreciate, and respect cultural heritage. To become good citizens of the global village, we need to learn quickly, and also to teach our young people, to take a global view and to respect, appreciate and understand the different cultures of different peoples.

To meet the challenges of the 21st century, proper education of our younger generation is of utmost importance. Indeed, many countries around the world are now engaged in educational reform. Educational systems in many countries, it seems, have not caught up with the changing world. It is quite clear that young people need to do better in reading, communication, and science in order to be competitive in the globalized world. But, it also seems clear that education should, in the future, go far beyond the goal of achieving competitiveness. It is important for us to educate all people on earth to be good citizens of the global village, to ensure a combination of life skills and global viewpoint – the personal tools for a productive living in this changing world.

We should also be aware that, in the rapidly changing world of today and tomorrow, many of yesterday's accepted and traditional 'good' practices for bringing up our young might not work anymore. They may no longer be effective in a highly industrialized society in which social structures have changed substantially. It has often been said that even the best school education can never replace the important role played by family education. But, as the family becomes simpler and family ties weaken in industrialized societies, the family unit is often not the same old ideal environment for children to grow up in. This situation is especially true in urban environments. And the problem cannot be solved by simply stressing the importance of family values – as some social leaders have tended to do. I agree entirely with what Hillary Clinton once said: 'It takes a village to bring up children properly'. We should be considering communities, not simple families, as the basic building blocks of society. It is only within a strong and healthy community that neglected children and children from broken families will find the chances they need to grow and develop properly.

I hope that I have convinced you that the 21st century will be the critical turning point for mankind. I am quite certain that globalization of the world economy will ultimately reduce the risk of military confrontations being used to settle international disputes. If what replaces military confrontation, however, is simply high-tech-based economic competition, then the tensions between advancement of science and sharing of technology, between economic rationality and the political passions of nation states, will not be resolved, and the advancement of S&T will continue to be used as a tool of domination by some, rather than liberation for all. If, however, we learn to solve problems together, learn to share knowledge, new technological options and the limited resources available, and learn to respect and understand different cultural heritages, then it will be possible to realize the establishment of a genuine global village that enables sustainable development for all.

These are the challenges of the 21st century. I am confident that with adequate preparation, firm commitment and determination, we will meet these challenges and take them in our stride. We cannot change the past, but we are the ones who must write the history of mankind for the 21st century. This is the first time in human history that all human beings on earth have been faced with learning to work together and live together as one family in a global village – the time for finally realizing that the planet Earth on which we live is only finite in space, capacity and natural resources. This is a necessary awakening – vital for the survival and sustainable development of mankind. I believe that if we make the correct choice at this crossroad, then the 21st century is likely to be marked as the great turning point, or great transition – the beginning of a new era in the history of mankind.
