Keynote Speech

Day 2: Wednesday, 24 Nov. 2010

Venue: Sicily Hall

Keynote Speech 2:

Engineering Education: A Path for Wealth Creation and Its Challenges

Prof. Weng Cho Chew, IEEE Fellow, OSA Fellow and IOP Fellow
The University of Hong Kong, Hong Kong SAR, China

Prof. Leslie George Tham, FHKIE, MASCE
The University of Hong Kong, Hong Kong SAR, China

10:10 ~ 11:05

In a world driven by knowledge economy, education lifts people out of poverty. In a globalized world economy, the manufacturing of technologies is not localized in one part of the world. Hence, when a populace is highly educated, they can benefit by participating in the technology and manufacturing sector of the world. Engineers make products. The more high value-added are the products, the more wealth they can bring to a society. Hence, technology like wireless communication and the internet actually helps the flow of wealth to previously unreachable parts of the world.

Engineering education can enhance the technological sophistication of the populace, and allows them to shift from an agrarian economy to a technology-based economy. This paradigm shift has lifted over 260 million people out of poverty in China, who produces over 700,000 engineers a year. Hence, engineering education can create wealth for a nation that is previously impoverished.

Engineering Education: A Path for Wealth Creation and Its Challenges

W.C. Chew and L.G. Tham
Faculty of Engineering
The University of Hong Kong
Hong Kong

Introduction

Education is important in transforming society. A notable historical example is Scotland. Once known as the most backward part of Britain, a Calvinist priest by the name of John Knox (1505-1572) [1] promulgated the idea that everyone in Scotland including women should be educated so that the Bible was accessible to everyone. As a result, literacy rate in Scotland rose over the years, and later produced a large number of intellectuals for Britain, such as Sir Walter Scott (1771-1832), David Hume (1711-1776), Alexander Bell (1847-1922), James Watt (1736-1819), and James Clerk Maxwell (1831-1879) to name a few.

The source of wealth in many modern economies is science and technology. When one looks at the industrialized nations, the high standard of living is indicative of how man has harnessed the forces of nature using science and technology to create wealth and hence improve the quality of life.

The power of science and technology to create wealth has been known for a long time. In ancient China, the use of technical knowledge to harness the force of nature to alter the lives of the people has been demonstrated in many remarkable projects. One of the more famous ones is in Dujiangyan in Sichuan, China. It was a water work of irrigation canals and flood control technology developed by LI Bing over 2200 years ago. The technology brought great wealth to the Chengdu plain. Then, the Sichuan basin was dubbed the Heavenly State, and henceforth, has been supporting a large population even to this day [2].

Even though technology has been used to create wealth in the East for centuries [3], such as the invention of paper, printing, food-processing, sericulture etc, nothing compares to the science and technology development in Europe in recent centuries that create a culture that enjoys a high standard of living. The power and productivity of Western science and technology create wealth in unprecedented scale. In an old agrarian society where ninety percent of the population farm to feed everyone, in a modern society such as North America, one to two percent of the people farm to feed the whole population. (It is to be noted that in 1870, about 50% of the people in USA lived on a farm [4,5].) Technology allows the mass production and transportation of raw materials such as bricks and mortars, lumber on an unprecedented scale. The US automobile industry employs about half a million workers creating four or five million related jobs that provide most of the transportation need of a population of over 260 million people [6,7].

Science and technology allows the basic necessities of people to be met by a small fraction of the population. The rest of the population can focus in other activities such as creation of knowledge, education, health care, high-technology research and development, defense, service, entertainment, and so forth. While the West went through the pain of the industrial revolution to reach the present state of affluence, many countries around the world are now thrown into convulsion by their own brand of “industrial revolution”.

Globalization of the World Economy

Modern technology brings about new opportunities that never existed in the pre-modern era. Globalization initially meant the marketing of goods by a company to the whole world. In the modern era, globalization means the participation of the whole world in the production of goods. The rapid development in transportation and communication technologies and the Internet make the world a smaller place than it previously was. While an airplane or a car may be made in one place in the world in the past, the rapid transportation and communication technologies globalize the production of an airplane; namely, different pieces of an airplane are made in different parts of the world, depending on the cost of raw material transportation, human resource availability, etc. Many multinational corporations can exploit the talent pool worldwide instead of relying on just local talents to produce goods and services [8].

The communication technology also means the rapid sharing of knowledge and technology knowhow across the globe. The developing world population can now be trained to do some of the works that have primarily been done in the developed world in the past. Talented human capital is a resource to be tapped around the world.

Technology as a Source of Wealth

It is clear that technology is the source of wealth in the developed world. If one looks at the largest companies in the developed world, they are invariably related to technologies. In the US, we have General Motors, Exxon-Mobil, General Electric, Intel, Microsoft. In Japan, we have Toyota, NTT, Sony, Tokyo Denki.

The Nordic countries in Europe, Denmark, Norway, Sweden, and Finland, are prime examples of the importance of science and technology in reshaping their economies. These countries are scarce in natural resource. Historically, periodic famines decimated their populations--despite their vast landmass, these countries typically have about five to seven million people. When famine struck in the past, the population organized themselves into Viking marauders, who were notorious for raiding southern European for resource.

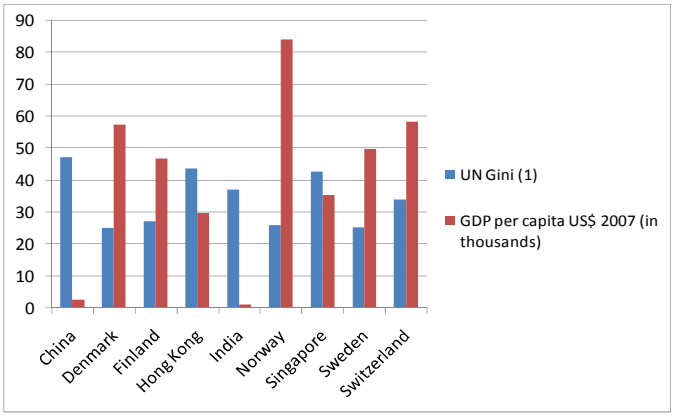

Figure 1. Different per capita GDP and Gini coefficeints of different countries compared to the Nordic countries.

However, a technology based economy has helped transform these Nordic countries. They are into automobile, aircraft, wireless communication industries, in addition to the paper pulp industry. These

technologies bring about wealth that these countries can be used to trade for food, and famines are the things of the bygone era. The per capita incomes of these countries are also among the highest in the world [9], with relatively low Gini coefficients[1] [11] (see Figure 1). In fact, the educational standards are also relatively high compared to the rest of the world: even high school teachers acquire a master's degree.

The pockets of wealth in the developing world are also the result of the developing world population participating in the global economy through technology: examples are the manufacturing industry in China, and the software industry in India, where low-end technologies are used to create jobs and to attract foreign direct investments into these countries. The "industrial revolution" in China has enriched about 250 million people and lifted 500 million people out of poverty [8,9]. Many countries in Asia are attractive to foreign direct investment due to their potential for human resource and low wages.

Engineering Education to Address the Needs

Engineering is a profession whereby scientific ideas are converted into practice through ingenuity. It hence is a profession which requires creativity: sky is the limit as to how engineers can be creative. Engineering education can also be viewed as the training of human resource and human capital for nation. The wide availability of skilled labor or engineering labor is attractive to foreign direct investment [17,18,19].

Given the development of the Internet, there is no reason why engineers in a developing country cannot learn the same knowledge as engineers in the developed country. It is well known that many students in the developing world excel when they study in the developed world. But they lack opportunities when they remain in the developing world. When in the developed world, they are given access to the best knowledge and tradition that have been established in the developed world institutions. Many of them continue to become successful academics and researchers, participating in the education and creation of new knowledge when they remain in the developed world. Being in the developed world, they are close to the community of scholars who dabble in the same field as they do. Scientific and engineering research and development is not a hermit art, but an endeavor that needs the synergism among a group of people sharing the same interest.

It is interesting to note that science and technology research in North America was not as advanced as Europe in the 1700s. Benjamin Franklin (1706-1790) was however, an American scientist and inventor of note [12]. He confirmed the relationship between lightning and electricity, and invented the lightning rod for instance. He was also a member of the "Lunaticks" Club in Britain and frequently travelled to Europe to attend their meetings. Members were so called because they chose a night of a full moon to meet until midnight, and relied on moonlight to navigate their way home. Notable members of the Lunatick Club included Erasmus Darwin[2] and James Watt [13,14]. Even though Albert Einstein (1879-1955) was a patent examiner in a Swiss patent office in Berne, he frequently travelled to attend the Solvay conference to mingle with other theoretical physicists of his time. Hence, in science and technology, we cannot work in a vacuum, but require the support of and synergism with a community of scholars.

[1] Lower Gini coefficient indicates a more even wealth distribution.
[2] The father of Charles Darwin.

Therefore, it is important to align our engineering education with the best in the world. The availability of global communication means that engineers can work without borders. Engineers should not be trained just as high-class technicians, but rather as thinkers, leaders, and creators of knowledge and technology. In a knowledge-based economy, the creation of knowledge also implies the creation of wealth.

Engineering education should be broad based, with emphasis on learning the fundamentals. Fundamentals are knowledge that will last a lifetime. In addition, they improve the problem solving and reasoning ability of an engineer. Engineering students usually learn elective courses that help them delve deeper into a certain specialization. Due to the rapid change in technology, the knowledge learned from elective courses may have a shorter lifetime. Hence, engineers have to acquire the habit of lifelong learning [16]. A typical four-year curriculum is shown in Table 1.

Engineers' major role is to translate scientific concepts into practical applications; they should know the science and mathematics well. It has been said that "Once a mind is stretched, it does not regain its original dimension." Knowledge grows like a tree, where a field of knowledge develops into many branches (see Figure 2). Students should be taught the big boughs in the knowledge tree, and they can fill in the leafy branches when needed throughout their career.

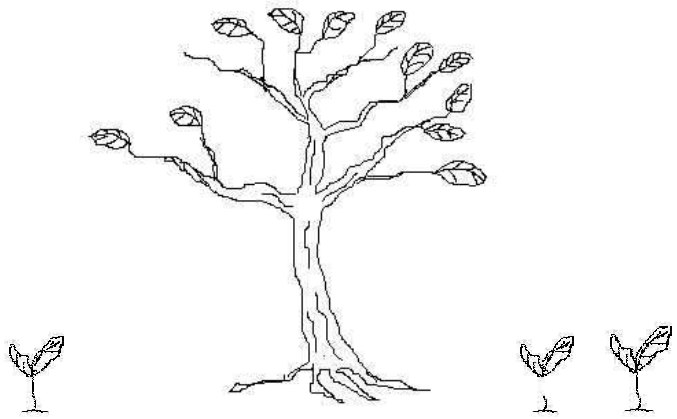

Figure 2. Knowledge grows like tree. It is important that we teach the important boughs in school, while the leafy branches can be filled in through life-long learning.

Year 1	**Fundamental science courses such as intro mathematics and physics; Intro to faculty requirements**	**Language requirements**	**Liberal studies**
Year 2	Faculty wide requirements; advanced mathematics and physics; computer programming	Intro to department requirements	Liberal studies
Year 3	Department requirements on fundamental courses	Intro to elective courses	Liberal studies
Year 4	Elective Courses for Specialization	Free Electives	Liberal studies

Table 1. A typical broad based four-year engineering curriculum.

If one looks at the surprise technologies that have change our lives, such as airplane, transistors, lasers, concrete technology, computers, and automobile, they invariably depend on multidisciplinary knowledge. A student who knows more than just their specialty can work better in a team. A student who knows more also has a larger space to work with in terms of creativity. Increasingly, it is important to expose engineering students to multidisciplinary programs.

The massification of engineering education also opens hope for a larger fraction of the population. China produces about 600,000 engineers a year, while India produces about the same number. The availability of a large pool of skilled labor has been very attractive to foreign direct investments. It provides the stimulus for economic growth, which in turn creates jobs in the developing world. In some industry, for example, the tourist industry, the wealth is created by a small fraction of the population, while the wealth will trickle to the rest of the population by the service economy. However, the technology-sector of the world's economy is huge, especially in the developed world. The integration of the developing world economy with the developed world economy can stimulate the flow of capital to the developing world [17,18] from the developed world. One way is for the developing world to be engaged with the developed world in the technology sector. The creation of the technology sector will also spawn jobs needed to support the sector, providing its basic service needs. The globalization of manufacturing and software industries is a way where wealth starts to grow in the developing world.

Engineers can also help to add diversity to an economy. A technology-sector of the economy improves the diversity of jobs compared to one based on finance, service, banking, or tourism. A diverse economy engages a larger portion of the population in productive activities, and hence, even out the distribution of wealth. It can help reshape the economy: technology-based economies such as those of the Nordic countries have a higher per capita income, a lower Gini coefficient [15], and a higher median income.

Future Challenges

The world has seen the globalization of low end technology such as manufacturing, and software industry. The future trend will be the globalization of research and development (R&D) industry. Table 2 shows the R&D expenditure as percentage of GDP for different countries. Intelligent people are found worldwide, and they can participate in global R&D activities. The challenge is to train people to work at the frontier of R&D in the field. This requires international engagement of engineers and scientists from around the world. Hence, it requires a mindset change in how we should educate our engineers, so that they could contribute to a technology-sector of the economy, and participate in global knowledge (technology) creation.

As technology creates wealth, there are also tremendous challenges, one being the ability to create wealth without the destruction of environment. The high standard of living in the developed world is achieved at the expense of machines replacing humans in many tasks. Machines run on energy and consume inordinate amount of energy. A mismanagement of technology development and a technology economy can result in the pollution of the environment. A vast amount of energy will be consumed if the whole world is to share a high standard of living as the developed world using existing technologies.

Hence, we are confronted with an important chapter in human history: a world economy that requires an unprecedented amount of energy to run. It is not possible to just rely on existing technologies for energy

production: new means of clean energy creation and harnessing are badly needed to sustain the growth and development of the developing world economy.

Nation	Total R&D / GDP Ratio	Gov't R&D / GDP Ratio	Industry R&D / GDP Ratio
Sweden	3.95%	0.93%	2.56%
Finland	3.51%	0.92%	2.43%
Japan	3.13%	0.57%	2.34%
South Korea	2.85%	0.66%	2.14%
United States	**2.68%**	**0.83%**	**1.70%**
Taiwan	2.56%	0.60%	1.64%
Germany	2.49%	0.76%	1.67%
Singapore	2.25%	0.24%	1.43%
France	2.16%	0.85%	1.11%
Canada	1.99%	0.67%	0.95%
United Kingdom	1.88%	0.59%	0.83%
European Union	**1.81%**	**0.63%**	**0.97%**
China	1.23% (1.52 in '08)	0.28%	0.82%
Italy	1.11%	N/A	N/A
Spain	1.07%	0.44%	0.51%

Table 2. Total R&D as Percent of Gross Domestic Product (GDP), 2004 (selected nations). Source OECD

Moreover, the byproduct of economic activities is the pollution of the environment. To achieve sustainable growth, new technologies to manage our environment are badly needed. The whole world can participate in this knowledge creation rather than relying on the developed world. As more talented people work on these problems, we have a better chance of solving them.

Conclusions

Engineering education is very important for the developing countries. It can be a source of wealth for the developing world, and changes the way man lives with nature. The true source of wealth is energy in this world. If one learns how to harness this wealth, one can enjoy a higher standard of living, by developing technology economies worldwide. Massification of engineering education, and the training of talented human resource and capital can help reshape the economies of the world [17,18,19]. It is important that we develop an enriched global economy without polluting our environment. Hence, new knowledge is urgently needed in environment management and control, and well as new means of energy creation and harnessing. This can be the effort of the talented people of the whole world rather than just the responsibility of the

developed world.

References

1. H. Cowen, *John Knox: the Hero of Scottish Reformation*, AMS Press Inc., New York, 1970.
2. K. Gillet, H. Mowbray, *Dujiangyan: In Harmony with Nature*, Metric International Pub. House, 2008.
3. J. Needham, Editor, *Science and Civilisation in China Series*, Cambridge University Press, 1954-.
4. Environmental Protection Agency, http://www.epa.gov/oecaagct/ag101/demographics.html
5. The American Experience http://www.pbs.org/wgbh/amex/trouble/timeline/index.html
6. S. Cooney and B.D. Yacobucci, "US automotive industry: policy overview and recent history," Congress Research Service Report for Congress, Library of Congress, April 2005.
7. S. P. McAlinden and K. Hill, "Economic contribution of the automotive industry to the US economy—an update," Center for Automotive Research, 2003.
8. J. Bhagwati, *In defense of Globalization*, Oxford U Press, Oxford, 2004.
9. S.H. Chen and M. Ravillion, "China is poorer than we thought, but no less successful in the fight against poverty," Policy Research Working Paper WPS 4621, World Bank, May 2008.
10. Source: International Monetary Fund—Report for Selected Countries and Subjects.
11. A value of 0 represents absolute equality, and a value of 100, absolute inequality. In Inequality in income or expenditure/Gini index, Human Development Report 2007/08, UNDP, accessed on February 3, 2008.
12. E. S. Morgan, *Benjamin Franklin*, Yale University Press, New Haven, 2002.
13. A. Hart-Davis, "James Watt and the Lunaticks of Birmingham," Science, vol. 292, no. 5514, pp. 55-56, April 2001.
14. Darwin Exhibition, Chicago Field Museum, June 15, 2007 to January 1, 2008.
15. http://en.wikipedia.org/wiki/Gini_coefficient
16. D.E. Hastings, "Curriculum reform and engineering education in USA," Engineering Faculty Seminar, The U of Hong Kong, June 30, 2010.
17. R. E. Lucas, "Why Doesn't Capital Flow from Rich to Poor Countries?" *American Economic Review* 80, pp. 92-96, 1990.
18. L. Alfaro, S. Kalemli-Ozcan, and V. Volosovych, "Why doesn't capital flow from rich to poor countries? An empirical investigation," The Review of Economics and Statistics, vol. 90, no. 2, pp. 347-368, May 2008.
19. R. E. Hall and C. I. Jones, "Why do some countries produce so much more output per worker than others?" *Quarterly Journal of Economics*, vol. 114, pp. 83-116, February 1999.