

GLOBALIZING ENGINEERING EDUCATION: PUBLIC POLICY IMPACTS

J. Thomas Ratchford
Distinguished Visiting Professor
National Center for Technology & Law
George Mason University School of Law
Arlington, VA

ABSTRACT

Technology and the science underlying it are widely accepted as the major driving force of the modern global economy. This attitude is reflected in actions of the governments, industrial companies and equity markets of the capitalist economies. In China Chairman Deng Xiaoping has stated, “science and technology is the primary productive force,” and technological advances have set the pace for economic growth.

In recent years, dramatic changes have occurred in best practices for obtaining and utilizing knowledge. These changes have affected the roles of governments in supporting and encouraging R&D, the strategies and style of industry technology expenditures, perceptions of the value of research, and evolution of new “rules of the road” for international cooperation in research and in technology development. Changes are also occurring in best practices for transmitting knowledge, especially at the graduate level, and the policy impacts of these changes in the years ahead are almost certainly to be large.

This paper looks at the globalization of graduate engineering education and its policy relationships. This is done in the context of other major trends in technology and science worldwide. These trends include R&D investments, governmental policies, legal and regulatory environments, pressures for more efficient technology development in industry, and increasing convergence between nations in technology, education and economic growth. Related policy impacts are identified for further examination. These include the broader policy consequences of policies related to engineering education, the impacts of changes in those policies on national and global policy environments, and in turn the influences of these broader policies on education, including engineering education.

INTRODUCTION

It is a great personal pleasure for me to participate in this precedent setting bilateral “Seminar on Engineering Education for the Global Economy.” The seminar Co-chairs, Professor Weng Shilie of Shanghai Jiaotong University, President Shen Shituan of Beijing University of Aeronautics and Astronautics, and President Edward Parrish of Worcester Polytechnic Institute deserve the credit for developing the intellectual content of the seminar and recruiting the impressive array of participants and speakers. We on the U.S. side also want to congratulate Professor Zhang Yantong of the Beijing

University of Aeronautics and Astronautics and Dr. Chen Huai of the National Natural Science Foundation of China, among others, for their skill and expertise in coordinating both the Shanghai and Beijing portions of this event.

I have counted the engineers and scientists of China as my very good friends for many years. Since my first visit to this great country more than twenty years ago Chinese science and engineering have grown rapidly in both quality and quantity. Successes in China's engineering and science education have been striking, and the U.S. has been a major beneficiary of this success. Our best graduate engineering and science programs at the leading U.S. universities are populated with students trained in China. The result is a growing interdependence among our research and educational systems, and the individuals who constitute them, that is certain to grow and flourish in the years ahead. It is our responsibility, as teachers, students and policy makers, to see that this interdependence evolves in ways that strengthen the technological capabilities of both countries, and in turn contributes to international stability and the continued growth of the global economy.

Policies affecting engineering education are important. They flow in both directions: there are educational policies that affect broader social and economic policies, and there are broader policies that affect engineering education. There is a feedback phenomenon that can be positive or negative (in both the electrical engineering and policy senses of the phrase). We as engineers and scientists must do our best to make sure that we get the policies for engineering education right. We need to work constructively within our respective national political systems to make sure that the broader policy environment is supportive, or at least benign, in its impact on engineering education.

IMPORTANCE OF TECHNOLOGY

Technology, and the engineering and science that underlie it, are very important in the modern world. Advances in technology have changed our social interactions and lifestyles. The economic impacts of technological change are profound.

Recent generations have seen dramatic changes in the ways technology and science affect our daily lives. Communications technologies - voice, data, video and the Internet - are instantaneous and inexpensive. Transportation technologies give us fresh fruits and vegetables, flowers, and vacations in faraway places, all at reasonable costs. Biotechnology is making our plants and animals more productive than we ever imagined. And health care technologies are so good we find that citizens of all nations want more than they can afford.

These advances in technology have not occurred by accident. The people of the world have invested in science and technology, and the level of investment is large and increasing. A supportive policy environment, including protections for intellectual property and public financing of engineering and science education, have encouraged these investments.

Scientists are beginning to understand the origin of the universe, using strikingly different tools from high energy physics and space astronomy. Studies of biological systems, including the human and rice genomes, are providing so much information that we face ethical and environmental dilemmas about prudent application. Advances in condensed matter physics and in various fields of chemistry are giving us a deep understanding of the properties of electrons in many very different materials, providing the basis for engineered materials that are strong or have desirable electronic or other desirable characteristics.

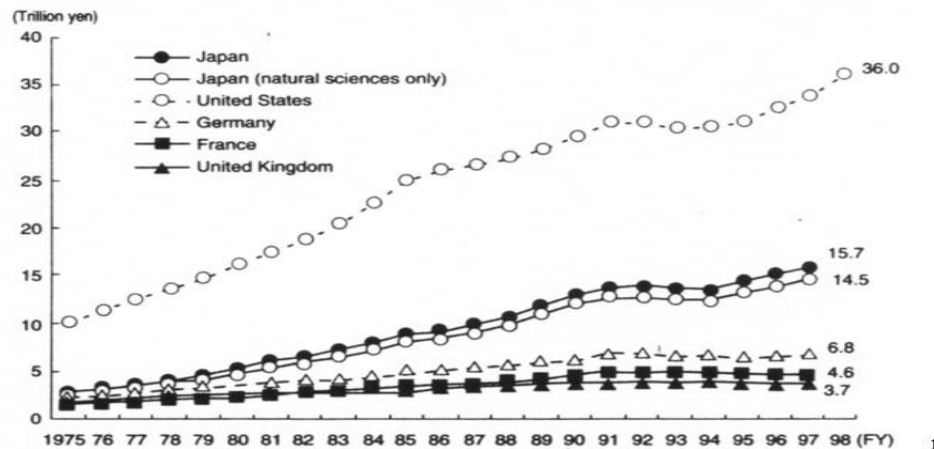
Science is a powerful method that ultimately results in technological knowledge. This knowledge can be used for any purposes, good or bad. The scientific method provides no “user’s manual” on how the resulting knowledge should be applied. From antiquity, the desire for new and better weapons probably has been the strongest force driving R&D. Military budgets propelled development of aeronautical and space technologies, and nuclear weapons appeared before nuclear electric power. Even well intentioned civilian technologies can cause both physical and social damage. Automobiles kill more people than many diseases, and television affects our society and its children in ways that are both evil and good. We are constantly involved in the calculus of assessing benefits and costs.

Producing technology is only a part of the equation. Transmitting engineering knowledge, both explicit and tacit, to younger generations of engineering students is just as important. I was struck by an interview with Leslie Robertson, the lead structural engineer responsible for the construction of the two World Trade Center towers. He was 34 years old when the project began. They incorporated a number of engineering innovations that have received widespread praise at the time and that have also received careful examination during the last year. Robertson noted that if he had been much older these innovations would not have occurred, because more experienced engineers tend to replicate their earlier methods with which they are comfortable. The important point I would like to make is not whether these specific innovations were right or wrong in hindsight, but that there is a need to have in place an engineering education system that both preserves best practices from the past and encourages innovation in the future.

A. Investments in Technology (Inputs)

SLIDE 1

Trends in R&D expenditures of selected countries – OECD purchasing power parity

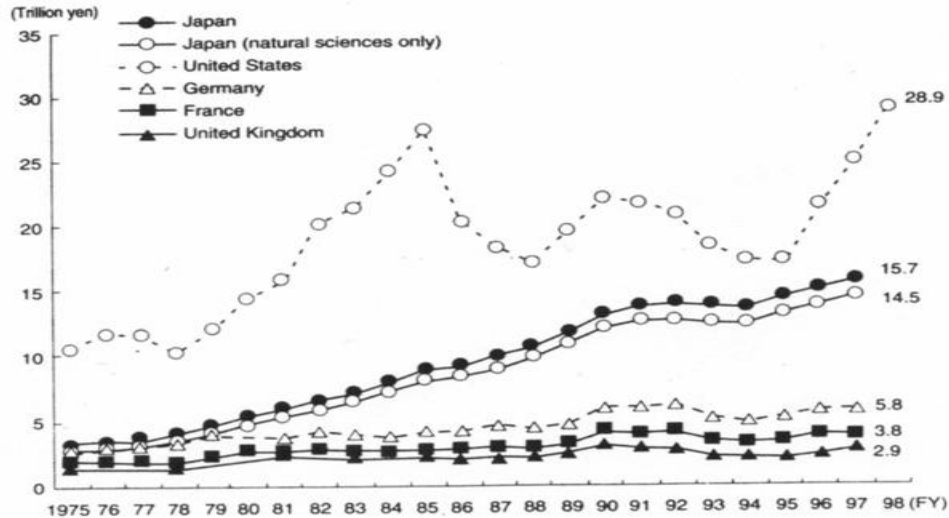


I shall first look at inputs to technology. Most nations are increasing their investments in technology, specifically research and development (R&D). SLIDE 1 shows R&D expenditures for the five OECD nations that spend the most. Note that the expenditures are in trillions of yen. The slide shows that these countries spend a lot of money on R&D and that the trend in these expenditures has

been steadily upward over the last 20 years. The OECD Purchasing Power Parity (PPP) methodology is used in making these comparisons.

SLIDE2

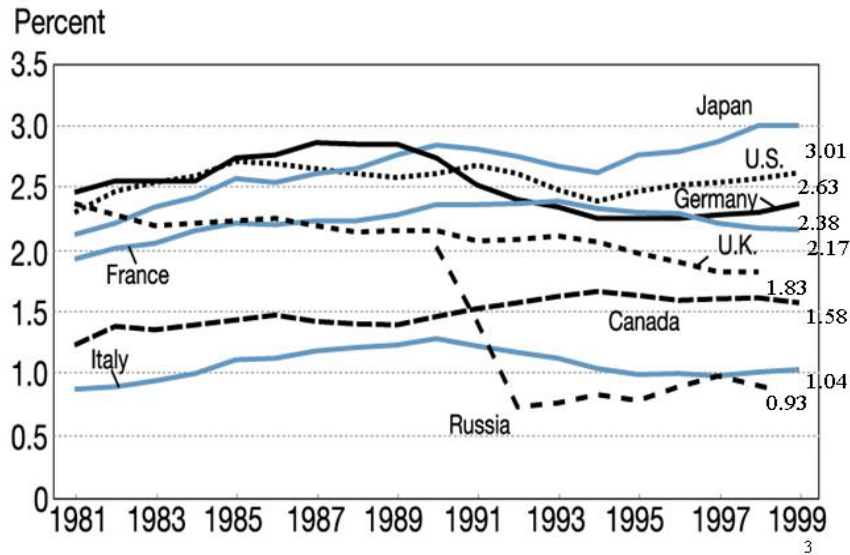
Trends in R&D expenditures of selected countries – IMF exchange rate conversion



It is important for us to understand early on the difficulty in making accurate international comparisons of R&D, or almost anything else, for that matter. This is apparent when you compare Slide 1 with Slide 2. The latter uses exactly the same data as Slide 1, except that IMF exchange rates are used for comparison between nations instead of OECD PPP relationships. It is changes in the yen-dollar exchange rate that makes SLIDE 2 so misleading.

SLIDE 3

Total R&D as a percentage of GDP



Source: Science & Engineering Indicators – 2002

Another way to compare national inputs to technology development is to examine **R&D as a percent of GDP**. The R&D/GDP ratio is shown for these same large countries plus a few others in SLIDE 3. If one examines all the OECD countries and the larger developing countries, one finds that generally, but with exceptions, countries fall into three categories:

Large, rich countries generally spend between 2% and 3% of GDP on R&D.

Small, rich countries spend less, on the order of 1.5% of GDP on R&D.

Developing countries spend much less, on the order of 0.5%, but with substantial variation. China, for example, in recent years has spent around 0.6% or 0.7% of its GDP on R&D. The fact that this percentage has remained constant is a remarkable achievement given the rapid growth in the Chinese economy.

Small, rich countries that spend a higher fraction of GDP on R&D than their peers include Korea, Switzerland, Finland, and Sweden.

B. Value of Technology (Outputs)

What is the value of technology? That is, regardless of the inputs for technology development such as those noted above, what are the outputs? The results of research and technology are valuable to nations and companies for a variety of different reasons. I shall discuss some that are relevant to our interests today.

National Security

Governments support research and development for a variety of reasons. First and historically foremost has been national security. In weaponry technological superiority is of great importance. This is obvious in the case of nuclear weapons, but it is also true in the aggregate for a wide variety of other technologies, both offensive and defensive. The end of the Cold War resulted in a reduction in the level of support for defense technology but the expenditures remain large for many countries, including both China and the U.S.

National “Missions”

Governments of most countries also support research and technology development because they are essential to the accomplishment of defined national missions. These usually include health, energy, standards, transportation, and environmental protection, as well as national security. In some countries government supports research and technology related to industrial development and trade as part of a broader industrial policy. Measuring the output of these investments by “mission agencies” may be difficult analytically, but the political process in most countries does this quite nicely.

Basic Research

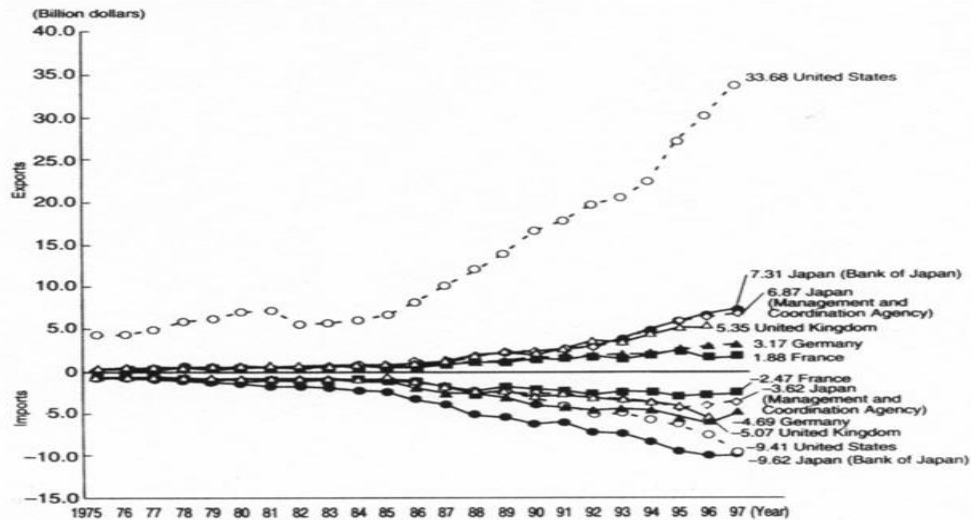
The rationale for government support of basic research is well known. The private sector has difficulty justifying the support of much basic research because (1) the difficulties of capturing the results through the intellectual property system (“someone else may gain the commercial advantage from our discovery”), (2) the risk of technical failure (“the failures in basic research may cost our company more than we get from the successes”), and (3) the long time required for translating basic research results into commercial technologies (“the interest rate will kill us”). But basic research is integrally related to higher education, and the results of basic research are crucial to the technologies supported by mission agencies. Also academic studies have shown the rate of return on basic research to society as a whole is very high. As for direct measurement of output, counting research publications is a common if not very satisfactory method.

Economic Outputs

Measuring the commercial success of investments in technology aggregated at the national level is difficult. Trade in high-technology products and services is sometimes used as a measure, but the velocity of technology transfer around the world is so high that high-tech manufacturing can take place in locations with little enduring scientific and engineering excellence. As just noted, macro-economic measures of the rate of return on some types of research investments vary from zero to over 100%. National patenting activity is sometimes used as another measure, but it is also not very satisfying because of differing national habits with respect to patenting.

SLIDE 4

Trends in technology trade of selected countries



4

The next slide compares the major nations of the world with regard to how well their companies are doing in developing and exporting technology. It also provides a rough indication of the rate of technology transfer, which has increased greatly over the last decade. Note that “trade in technology” is not the same as trade in high technology products and services. Rather it measures payments for intellectual property such as royalties and licenses. The U.S. consistently runs a large trade surplus in technology. For example, in 1997 the U.S. exported around \$34 billion of technology and imported only \$9 billion. I should also point out that much of this trade in technology is between related companies, not all intellectual property is “technology,” and that in general the activities of multinationals complicate national comparisons. However the concept of exports of technology as a measure of technology output is useful.

Effects on Stock Values

For decades, expectations of stock price increases have been tied to the quality of a company’s technology development program. The explanation for this, commonly accepted by investment services like Standard and Poor’s in the U.S. for many decades, is that the productiveness of a company’s technology development program (its R&D budget) is a key determinant of the company’s rate of earnings growth, which in turn leads to higher future prices for its stock. On balance, investors have felt there is a correlation between R&D expenditures and price to earnings ratios.

“R&D capital” (which represents intellectual property and know-how) is an accepted investment expenditure just like “tangible capital” (representing plant and equipment). The amount of R&D capital necessary for a company to compete successfully varies greatly by industry group, as will be demonstrated later on. One characteristic of R&D capital as compared to tangible capital is its volatility. Advantages in technology and intellectual property can be gained and lost rapidly, whereas it takes longer times for buildings and vehicles to depreciate. This volatility in R&D capital no doubt is a major contributing factor in the volatility of stock prices, including the appearance and bursting of bubbles, on the major exchanges of the world.

OTHER IMPORTANT GLOBAL TRENDS

My objective here today is to address the policy impacts of globalizing engineering education. In order to do so, however, it is important to identify important boundary conditions that affect engineering and engineering education. Some were discussed in the sections above. Others are considered below.

A. Economic Convergence

SLIDE 5

Real gross domestic product per capita, for selected countries: 1960–96
(1996 U.S. dollars)

	United States	Canada	Japan	South Korea	Austria	Belgium	Denmark	France	Germany*	Italy	Netherlands	Norway	Sweden	United Kingdom
1960	13,797	9,738	4,508	1,458	7,890	8,568	9,690	8,380	9,928	7,128	8,839	8,356	9,508	9,791
1961	13,882	9,846	5,119	1,498	8,263	8,964	10,190	8,749	10,251	7,684	8,975	8,794	9,995	9,960
1962	14,500	10,348	5,429	1,487	8,410	9,393	10,671	9,167	10,604	8,094	9,231	8,958	10,363	10,000
1963	14,901	10,684	5,942	1,579	8,697	9,729	10,836	9,485	10,797	8,484	9,405	9,228	10,854	10,331
1964	15,553	11,183	6,658	1,687	9,160	10,309	11,498	10,000	11,401	8,634	10,078	9,617	11,508	10,819
1965	16,339	11,707	6,924	1,739	9,361	10,579	11,956	10,389	11,879	8,846	10,468	10,047	11,836	11,020
1966	17,206	12,271	7,588	1,902	9,820	10,840	12,136	10,841	12,101	9,305	10,621	10,342	11,969	11,168
1967	17,452	12,406	8,316	1,968	10,040	11,198	12,442	11,261	12,036	9,888	11,058	10,896	12,277	11,358
1968	18,084	12,870	9,271	2,141	10,435	11,622	12,862	11,654	12,646	10,459	11,679	11,046	12,650	11,766
1969	18,449	13,366	10,281	2,382	11,052	12,359	13,602	12,369	13,461	11,026	12,331	11,447	13,191	11,956
1970	18,258	13,523	11,137	2,535	11,798	13,139	13,777	12,961	14,003	11,524	12,880	11,596	13,917	12,191
1971	18,626	13,846	11,512	2,697	12,346	13,590	14,047	13,454	14,283	11,665	13,289	12,048	13,952	12,367
1972	19,438	14,470	12,312	2,774	13,036	14,254	14,702	13,928	14,796	11,922	13,561	12,574	14,229	12,762
1973	20,366	15,395	12,998	3,074	13,598	15,050	15,145	14,568	15,425	12,611	14,131	12,999	14,768	13,670
1974	20,050	15,852	12,664	3,266	14,110	15,619	14,936	14,923	15,436	13,080	14,590	13,590	15,195	13,435
1975	19,768	16,030	12,896	3,425	14,096	15,344	14,793	14,814	15,298	12,711	14,487	14,078	15,522	13,340
1976	20,634	16,794	13,260	3,767	14,767	16,173	15,710	15,382	16,190	13,462	15,053	14,967	15,630	13,713
1977	21,381	17,197	13,707	4,091	15,432	16,232	15,918	15,806	16,687	13,802	15,312	15,437	15,326	14,044
1978	22,292	17,804	14,299	4,408	15,454	16,662	16,102	16,265	17,207	14,270	15,579	16,077	15,549	14,532
1979	22,672	18,310	14,959	4,851	16,214	17,006	16,631	16,720	17,825	15,037	15,818	16,715	16,111	14,922
1980	22,335	18,343	15,259	4,466	16,687	17,721	16,538	16,905	18,040	15,553	15,880	17,487	16,347	14,576
1981	22,620	18,782	15,629	4,860	16,597	17,487	16,394	17,009	18,024	15,594	15,890	17,594	16,325	14,383
1982	21,928	17,961	15,998	4,936	16,758	17,731	16,899	17,342	17,867	15,603	15,437	17,560	16,479	14,640
1983	22,593	18,344	16,258	5,423	17,112	17,734	17,341	17,374	18,245	15,728	15,640	18,122	16,760	15,163
1984	23,964	19,314	16,788	5,822	17,337	18,174	18,110	17,521	18,834	16,099	16,092	19,132	17,423	15,479
1985	24,600	20,048	17,422	6,142	17,746	18,348	18,879	17,767	19,264	16,506	16,513	20,070	17,730	16,010
1986	25,129	20,506	17,817	6,784	17,933	18,613	19,540	18,128	19,702	16,951	16,876	20,715	18,094	16,647
1987	25,640	21,082	18,467	7,491	18,205	19,039	19,575	18,444	19,990	17,449	17,002	21,037	18,601	17,400
1988	26,378	21,847	19,527	8,255	18,901	19,833	19,791	19,173	20,609	18,093	17,333	20,900	18,933	18,223
1989	27,007	21,886	20,386	8,695	19,514	20,512	19,892	19,880	21,144	18,590	18,039	21,006	19,254	18,556
1990	27,057	21,609	21,350	9,428	20,157	21,073	20,144	20,267	21,930	18,959	18,653	21,346	19,366	18,564
1991	26,517	20,874	22,092	10,188	20,508	21,326	20,361	20,310	22,741	19,115	18,924	21,907	19,020	18,122
1992	26,943	20,823	22,249	10,594	20,659	21,559	20,340	20,433	22,860	19,199	19,162	22,493	18,640	17,964
1993	27,278	20,987	22,253	11,089	20,533	21,153	20,585	20,063	22,164	19,239	19,172	22,971	18,120	18,280
1994	27,947	21,611	22,346	11,920	21,264	21,575	21,410	20,220	22,788	19,815	19,757	23,006	18,472	18,601
1995	28,233	21,844	22,542	12,856	21,206	21,558	21,945	20,362	22,865	20,125	20,304	23,262	19,118	18,341
1996	28,752	21,905	23,289	13,635	21,375	21,829	22,401	20,583	23,059	20,227	20,881	24,364	19,293	18,715

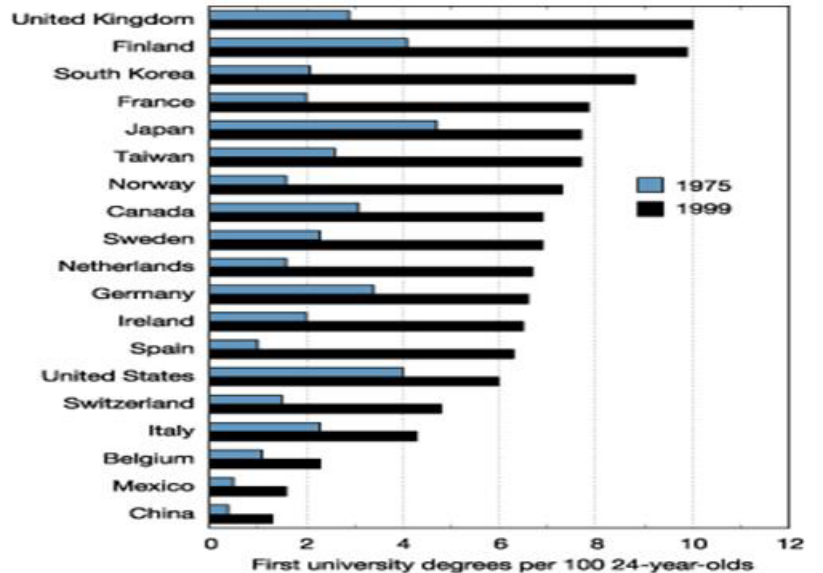
Source: Science & Engineering Indicators - 2000

Education is expensive, especially engineering education at advanced levels. Although the rich nations have had a substantial advantage in the past, this is changing as economies converge. Economic convergence among nations can be measured by comparing Gross Domestic Product (GDP) per capita over a long period of time. SLIDE 5 compares the per capita GDP of 14 Organization for Economic Cooperation and Development (OECD) countries for the period 1960-1996. Although the U.S. is the leader during this period, the GDPs of every one of these countries increased as a percentage of the U.S. GDP. Generally speaking, the smaller the GDP as a percentage of the U.S. GDP, the greater the relative increase has been. In other words, those back in the pack are running faster than the leaders.

B. Educational Convergence

SLIDE 6

Ratio of natural sciences and engineering first university degrees to 24-year-old population



NOTES: Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, agricultural, as well as mathematics and computer sciences. The ratio is the number of natural science and engineering degrees to the 24-year-old population. China's data are for 1985 and 1999. Other countries' data are for 1975 and 1998 or 1999.

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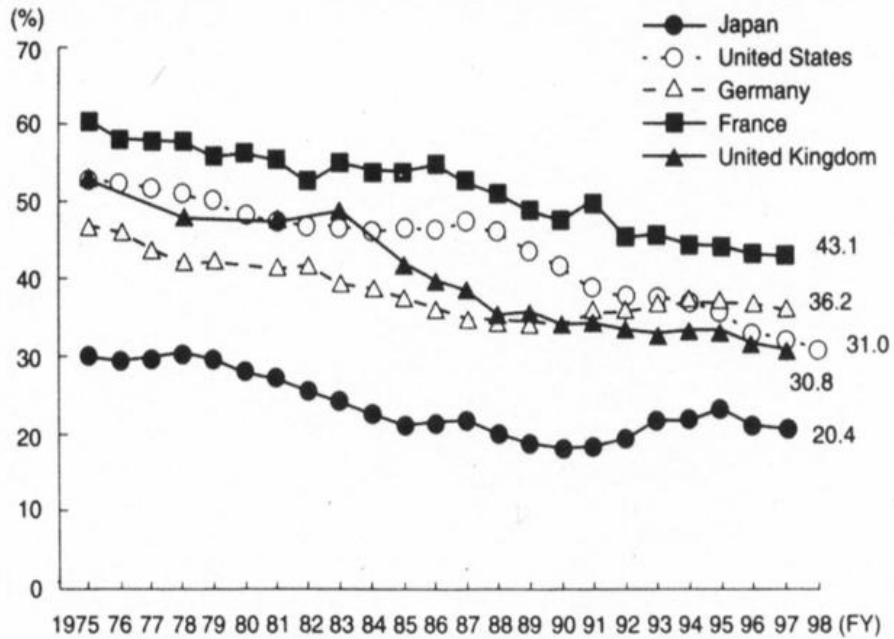
Source: Science & Engineering Indicators – 2002

Since the Second World War most countries have made more progress in education, including science and engineering education, than has the United States. SLIDE 6 shows the ratio of natural sciences and engineering first university degrees to the 24-year-old population for 19 mostly OECD countries. Note that between 1975 and 1999 all these countries increased this ratio faster than did the U.S. The increase for the U.S. was about 50%, while China approximately tripled, for example. Convergence in quality during this period is likely as well since the percentage of doctorates in science and engineering awarded to foreign students by the most prestigious U.S. universities increased substantially.

C. Decreasing Role of Governments in Technology Development

SLIDE 7

Trends in government-financed R&D expenditures

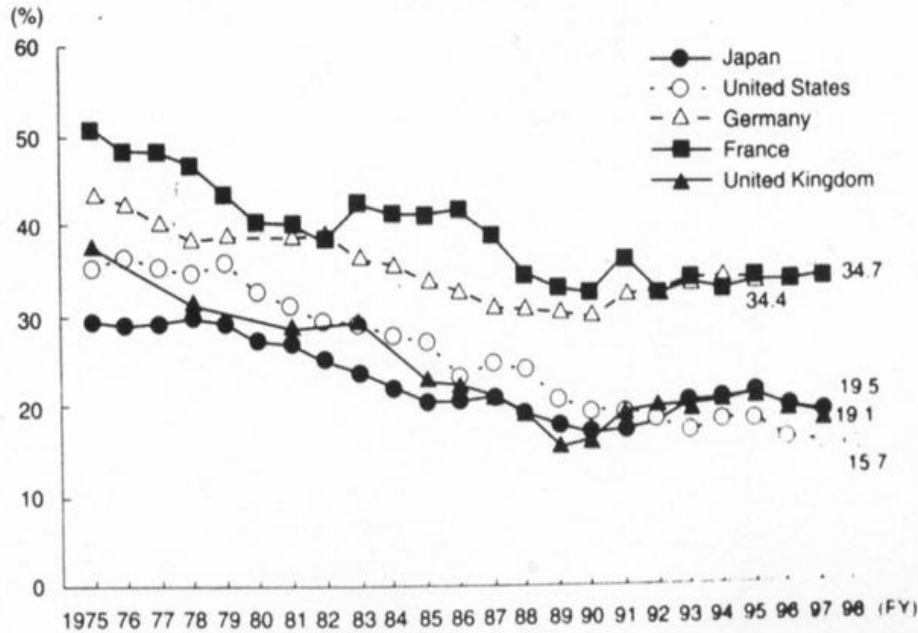


Share of R&D expenditures financed by government ⁷

The role of governments in financing research and technology development is decreasing everywhere. The trend is shown in SLIDE 7. Government support of R&D over the last 20 years relative to that of the private sector is down for all industrialized countries, although large differences still remain between nations. This is true whether or not defense R&D is included, as shown in SLIDE 8.

SLIDE 8

Trends in government-financed R&D expenditures



Share of R&D expenditures financed by government exclusive of defense-related R&D expenditures

The next slide (SLIDE 9) clearly demonstrates this for the U.S. Between 1960 and 2000 there was a forty-fold increase in company support for R&D. During the same period federal support of R&D in industry a little over three-fold. Although it is not shown in this table, overall federal support of R&D increased by about 50% in real terms during this period.

SLIDE 9

R&D performed by industry in the U.S. 1955-2000

Billions of U.S. dollars

Year	55	60	65	70	75	80	85	90	91	92	93	94	95	96	97	98	99	00
Federal	2.1	5.6	7.4	7.3	7.9	13	25	26	24	22	21	20	21	21	22	22	20	19
Company	2.4	4.4	6.4	10	15	30	57	81	90	94	94	97	109	121	133	145	160	178
Total	4.5	10	13	17	23	43	82	107	114	116	115	117	130	142	155	167	180	197

Source: NSF Science & Engineering Indicators 2002

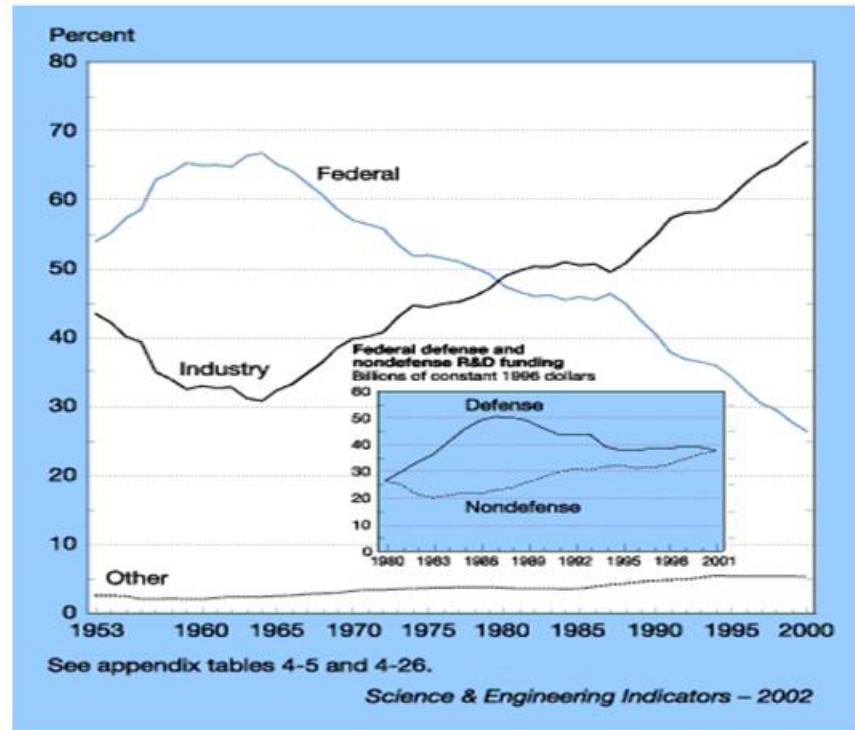
9

These trends can be demonstrated another way as shown in SLIDE 10. Note that in the mid-60s the federal government in the U.S. funded two thirds of all R&D. Around 1980 the federal and private

sector curves crossed, for the first time since before the Second World War. Now the private sector's margin is not only large, it is growing rapidly.

SLIDE 10

National R&D Expenditures, by source of funds



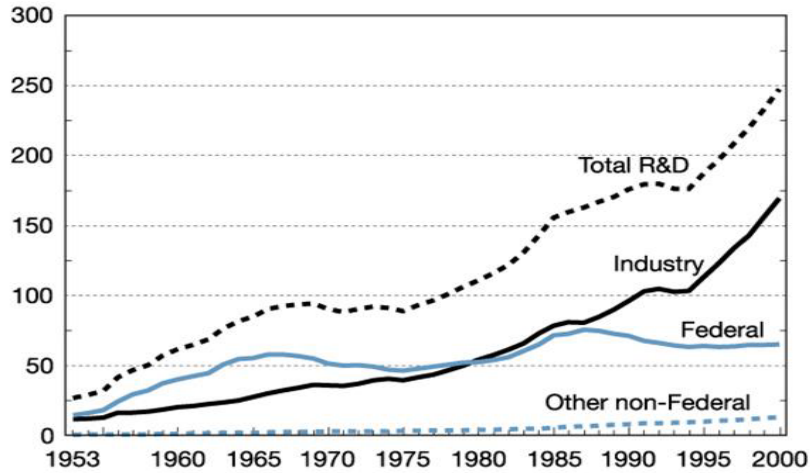
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SLIDE 11 shows the same phenomenon in constant dollars rather than percentages.

SLIDE 11

U.S. R&D funding, by source

Billions of constant 1996 dollars



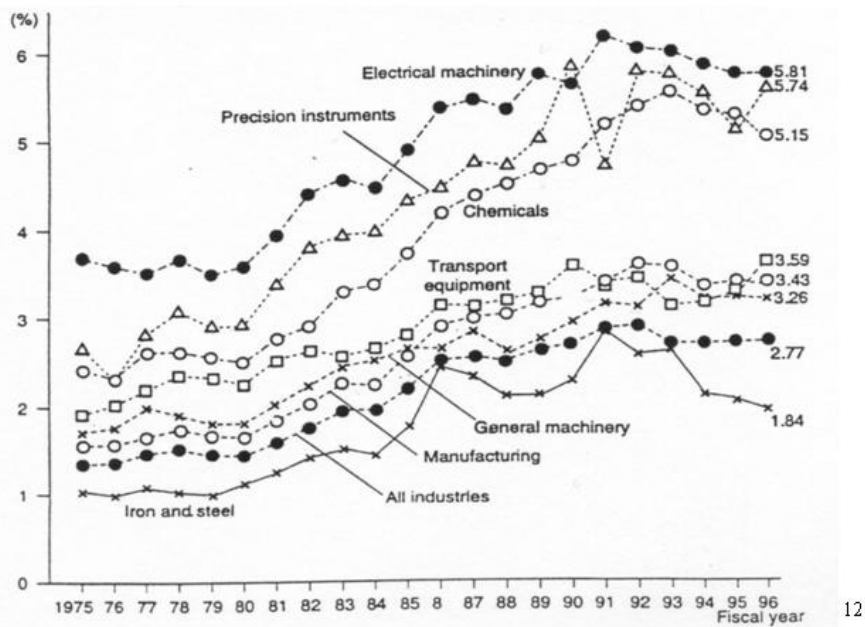
Source: Science & Engineering Indicators – 2002

11

D. A More Technology Intensive Economy

SLIDE 12

Ratio of R&D expenditures to sales figures in selected industries in Japan



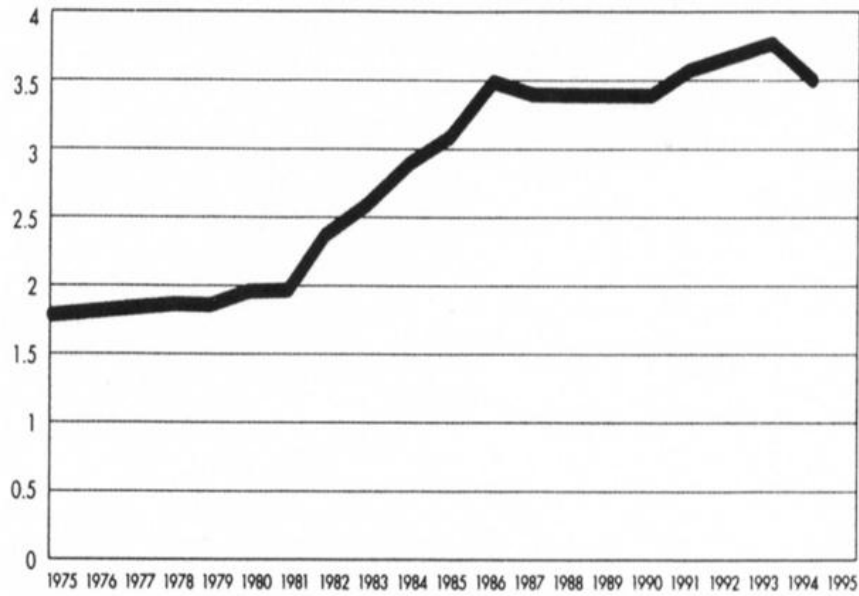
12

Companies have to spend more to keep their technology up to global norms. R&D expenditures as a percentage of sales have roughly doubled over the last generation. SLIDE 12 shows the ratio of these expenditures to sales for several industry groups in Japan. Note the wide variation between

industrial sectors in R&D intensity. This is not surprising, given the very different dependencies upon and interactions with technology found in various industrial sectors. Over the past generation R&D as a percentage of sales has roughly doubled for major industry sectors in Japan.

SLIDE 13

U.S.A. R&D: as a percentage of sales

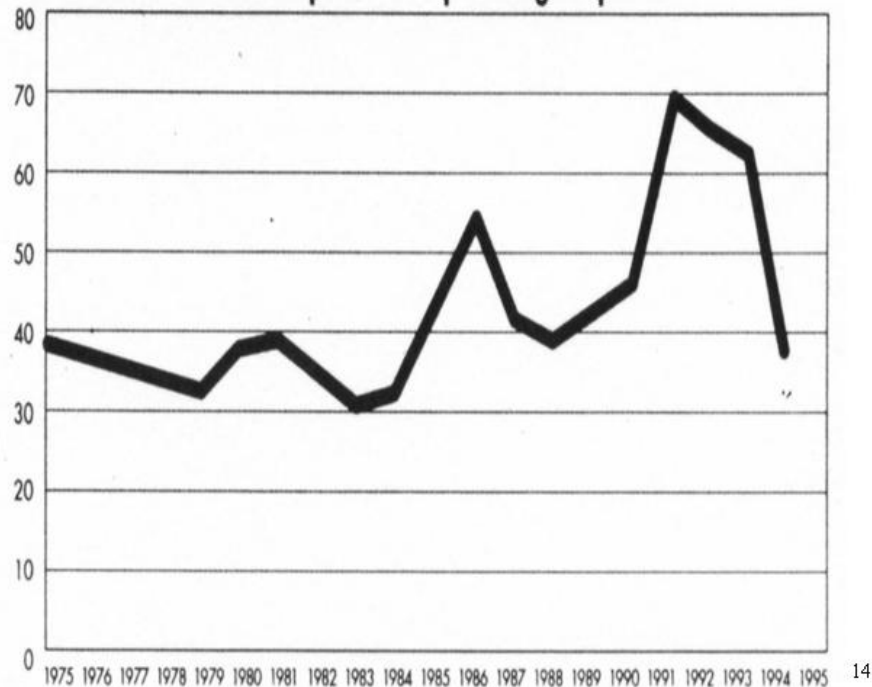


13

Altho
ugh I have not analyzed similar data for the U.S. by industry group, SLIDE 13 shows the overall change in the R&D/Sales ratio from 1975 to 1994. This percentage also approximately doubled, from 1.8% in 1975 to 3.5% in 1994.

SLIDE 14

U.S.A. R&D: as a percentage of profits



Companies are naturally very interested in maximizing profits. In the short term, reductions in R&D expenditures flow directly to the bottom line. Currently, R&D costs run at about 50% of profits in the U.S., as shown in slide 14.

BEST PRACTICES FOR OBTAINING AND UTILIZING KNOWLEDGE

Over the past century “best practices” for obtaining and utilizing knowledge have constantly evolved. Governments have instituted reform after reform in their strategies for support of basic research. Systems for the procurement of technology for defense and other “mission” agencies constantly change. Industrial companies search for more cost-effective ways to obtain knowledge for commercial innovation. And universities routinely reform their curricula for propagating these best practices.

Basic Research

Basic Research is in some ways the easiest type of research to support and in other ways the hardest. Its funding is mostly a function of government. In the past decades peer review procedures were developed to help assure that decisions were merit based. In most countries this is still an ideal not yet entirely reduced to practice. For example, in the U.S. Congress it is common to “earmark” research funds for particular projects at specific institutions regardless of scientific merit. This is known as “pork barrel” funding and it tends to degrade the overall effectiveness of support for academic research.

Another characteristic of a sound system for the support of basic research is the coupling of research and education. This approach has been very successful in the U.S. and is now the norm in an increasing number of countries.

Globalization of Ordinary Science. Substantial changes have occurred in best practices related to international cooperation in technology and science. Average bench scientists doing basic research in university, government, and other laboratories in almost any part of the world are collaborating more and more with colleagues in other countries. This is happening because the process of solving common problems benefits from a broader base of talents and different perspectives on common problems. Increased collaboration is also made possible by the ease and low costs of air travel, and the instantaneous and inexpensive communications available because of new information technologies. The Internet generation includes everyone in today's research laboratories. The end of the Cold War has also resulted in much less red tape for researchers interested in international cooperation. Most international cooperation needs no special government support or interest; it happens naturally.

This increased collaboration is reflected in the scientific literature. According to the NSF's 2002 Science and Engineering Indicators, one in five scientific papers coauthored by U.S. scientists had at least one non-U.S. author in 1999, compared to 1 article in 10 in 1988. Engineering was at about the norm, one in five. U.S. collaboration with Chinese scientists, as measured by cooperative publication, is substantial. 30 per cent of China's internationally coauthored papers have at least one U.S. coauthor. This reflects a striking increase in the globalization of research.

Megascience. Although most research collaboration needs no governmental involvement at all, megascience projects are very different. By megascience projects I mean very large, predominantly basic scientific research projects. Some involve very expensive central facilities, such as particle accelerators or neutron sources. There are also distributed megascience projects associated with many geographic locations, such as the several Global Change Research Programs

Megascience projects generally are too expensive for any one country. They need more involvement of governments and the institutions of organized science (including better coordinated funding and management) to prevent foolish things from happening. Megascience projects are one area of concern deserving increased attention in the evolving bilateral China-U.S. relationship.

Industrial Technology Development

As just noted, R&D as a percentage of sales has roughly doubled over the last generation. Technology-driven market changes have also had dramatic effects on company support of R&D. Thus companies have to deal with the need for more technology in a more volatile market place with quickly changing capital valuations. These pressures have led companies to seek increased efficiencies in the management and development of technology. The result has been a revolution in industrial R&D.

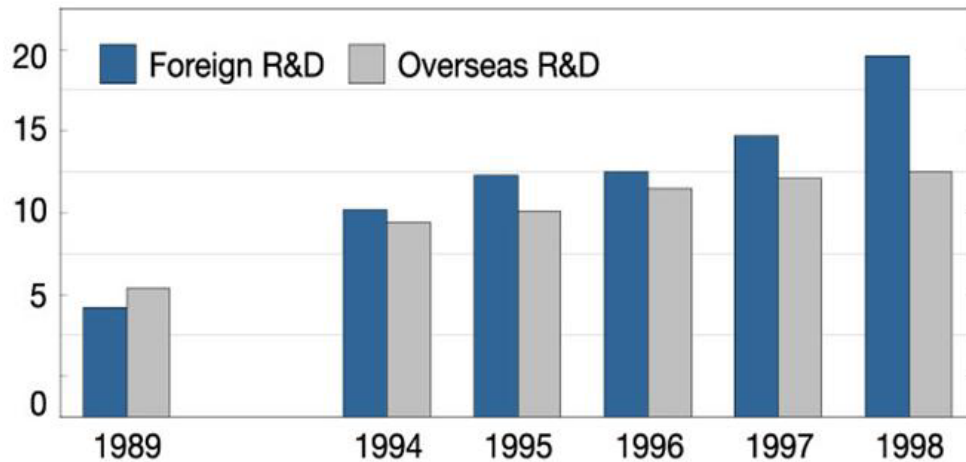
A common characteristic of these changes is a focus on short-term goals of individual business units and a massive shift in influence and resources away from central research laboratories. Sharing risks and expense in the development of technology is another trend. This involves support of R&D outside the companies' own laboratories, and across national boundaries. SLIDE 15 shows the

magnitude of R&D investment flows today between foreign and U.S. companies and their overseas affiliates.

SLIDE 15

Globalization of U.S. industrial R&D

Billions of current dollars



NOTES: Foreign R&D refers to R&D performed in the United States by U.S. affiliates of foreign parent companies. Overseas R&D refers to R&D performed abroad by foreign affiliates of U.S. parent companies.

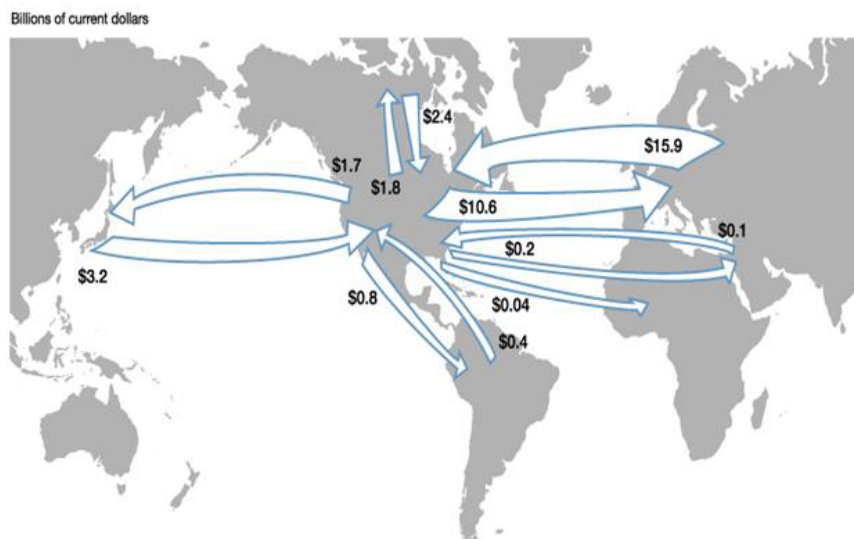
15

Source: Science & Engineering Indicators – 2002

These R&D flows generally are two way. Unlike trade flows, R&D funding tends to seek excellence, even if it is in a high cost location. SLIDE 16 shows these flows between the major regions of the world using 1998 data.

SLIDE 16

Industrial R&D spending flows of U.S. & foreign affiliates, by world region: 1998



Source: Science & Engineering Indicators - 2002

16

As you might suspect, this two-way flow is driven by alliances in which companies seek to reduce the costs of acquiring the technologies they need.

Using sophisticated information technology, non-technical managers of companies are able to shape and monitor technology strategy as never before. With flatter organizational structures, mid-level R&D managers see their authority eroded above and below simultaneously. As engineers and scientists involved in company R&D evolve from researchers to “knowledge providers” and spend more of their efforts searching for knowledge outside the firm, long-standing industrial research traditions are disappearing. These include the loss of informal tenure for researchers, resulting in increased anxiety among R&D managers and staff.

Outsourcing and collaboration are effective tools in improving efficiency in obtaining knowledge, especially the so-called *strategic necessities*. These are capabilities that all companies need to meet minimum competitive standards in a particular line of business. Alliances, consortia, joint ventures, and purchase of technology sometimes offer cheaper alternatives to in-house R&D. As industrial technologists shift from full-time research to a combination of research and searching for relevant technology outside the corporation, the “search to research” ratio is increasing.

Strategic differentiators are another matter. These are corporate attributes, especially technological attributes, which provide distinctive competitive advantages. There is great reluctance to cooperate or share in this kind of technology development, at least in the same market area.

Outsourcing of staff for certain R&D tasks is also growing. “Research temps” are now being hired to carry out intermittent research activities or to avoid the high overhead associated with in-house staff. Internationally the outsourcing of support functions (routine testing, for example, or transcription services) by research professionals in low wage countries is used to reduce costs.

EVOLUTION OF BEST PRACTICES FOR TRANSMITTING KNOWLEDGE

Finding, developing and applying new knowledge is at the heart of engineers' responsibility today. The resultant "best practices" are constantly evolving and the challenge for engineering educators is to propagate these best practices effectively.

The policy environment – national and global – is very important to the creation and sustenance of effective educational systems. This policy environment is a two-way street: national policies and international agreements provide important boundary conditions for these systems. At the same time advances in knowledge and in educational technology affect the policy environment. We need good policies for engineering education: "policies for education." But we must also recognize the contribution of engineering education to the process of shaping the broader policy environment and the impacts of those policies on education: "policies affecting education." Some important issues populate both policy regimes simultaneously.

Policies for Education

What are the policies directed toward engineering education that are consistent with desirable outputs and effective utilization of resources? Some, of course – perhaps the vast majority – are common to the broader education community, not just to engineering education. I cannot state with certainty what the correct policies should be in most cases. Also, policies that were correct last year or ten years ago may not be correct today. But since this seminar is directed toward seeking answers to policy questions facing China and the U.S., I have confidence in posing these questions to help identify important issues for this distinguished group of experts to address. I leave it to you to provide the best answers.

Below are some of the policy issues and questions facing us today. Although presented in non-traditional groupings, I hope they will challenge you to respond.

1. Balancing Tradition and Education

There are traditional ways of doing things and regulating professional practices that we in the West have inherited from our forebears in the medieval guilds. I am sure China has a similar tradition among its historic and highly regarded civil service. The challenge to the engineering community is how best to balance respect for tradition with constant need for change and innovation. Leslie Robertson faced this issue when designing the World Trade Center towers.

What are some of the issues where this balance must be re-struck today? Some are:

- Curriculum content and presentation
 - Accreditation procedures and content
 - Professional regulation
 - Technology
 - Research and its relationship to education
2. Financing Engineering Education
- a. Sources of funding
 - b. Methods of allocation, both education and research funds
 - c. Cost control/efficiency
 - d. Technology
3. Globalization

- International education
 - Distance learning, telework
 - Immigration and related issues
4. Human resources
- How many engineers?
 - How good should they be?
 - How much mobility is desirable?

Policies Affecting Education

In addition to policies intentionally crafted for Engineering Education, the field is often affected (inadvertently or not) by broader national policies and international agreements. The engineering community is often involved in the development of these broader policies. In turn, these broader policies are affected by educational and research advances. This is a two way street.

1. International Agreements and Treaties
 - Competition/anti-trust policies
 - Reciprocity in licensing and regulation (free trade/WTO issues)
 - Accreditation and other educational credentialing issues
 - IPR and educational technology/distance learning
 - Immigration and related issues
 - Professional services procurement overseas
2. R&D environment
 - Support of graduate research and education
 - Job market/corporate R&D funding
 - Balance among R&D fields
3. Multinational Corporations
 - Support of education
 - Location of R&D facilities
4. Technology/industrial policies

A Few Examples

We would be here all day if I were to discuss many of these issues. And we would be here even longer if this short, incomplete list were expanded to a larger, more realistic one. Therefore I shall attempt to begin our discussion by expanding briefly on a couple of the issues noted, more by way of example than pretending to present a comprehensive analysis.

Let's take financing of engineering education. We know that sources of funds include students, governments, companies, charitable foundations and individual contributors. They have mixed motives for their financial support. What we do not hear discussed often, especially in the academic community, is the vast and continuing escalation in the costs of higher education. In the U.S., this escalation has continued at least twice the rate of inflation for decades. Clearly this is not sustainable, no more than the recent stock market "bubble."

In most industries, costs are contained through application of new, more efficient technologies. We have new educational technologies, but they appear to increase costs, not contain them. Cost efficiencies in education, including engineering education, may be our greatest challenge.

Another challenge is that of human resources. How many engineers do we need and how well trained should they be? It appears that companies are becoming more efficient in their use of engineers. At the same time our global economy is becoming more technology intensive, as shown above. What is the correct balance? And what role should immigration play in the balancing of supply and demand worldwide?

As for policies affecting education, the World Trade Organization and other international agreements have great potential for affecting national professional education and accreditation/regulation systems. Reciprocity in treatment of nationals is a cornerstone of free trade agreements. How does this principle affect credentialing, including professional regulation? Has the need for such credentialing diminished with the rise of large Multinational companies? Is the issue academic excellence or protection of the public health and safety? How are the two related?

Conclusion

Engineering Education is central to making our world of tomorrow a better one. China and the U.S., two of the world's great powers with a history of friendship and cooperation, have a special responsibility to address the questions of how we can adapt our educational systems to meet the challenges of the future. This future is certain to be dominated by technology, and our global economy will be more interdependent than ever. It is our responsibility to address the issues we all face ahead and develop appropriate policies for dealing with them. I hope this seminar, and the proceedings and other publications resulting from it, will make a positive contribution to this process.

REFORM IN ENGINEERING EDUCATION AND ENHANCING INDUSTRIAL COMPETITION

Wang Sunyu

Institute of Education Research

Tsinghua University Beijing China

After 18th century, due to the completion of the first Industrial Revolution in Europe with the steam engine as its representative, the interrelation between the growth of a nation's economic power and its international competition has become increasingly explicit and prominent. The imperial powers ran amuck overseas with their powerful guns and strong warships. At the same time, the awareness that the backward was forced to take a beating was aroused among the underdeveloped countries, which paved the way for the determination to build up their national industry. The Chinese industrialization can be traced back to over 100 years ago, and over the past 50 years, especially in the last 20 years since China's open and reform policy, the industry in China has achieved a dramatic development. The appearance and development of China's industrialization has helped to inject a fresh element into the international competition. China and other developing countries are no longer the passive followers to the international competition, but have become positive participants, which has opened up a new prospect in the international competition.

With the development of economic globalization, China's industrial competition has drawn more and more attention from the people all over the world. Naturally, people would associate this severe competition with the conflict of qualified personnel. The main purpose of engineering education is to train a large number of high-level talents for China's industrialization, who have well received engineering training and acquired the quality of fine adaptation. Therefore, the issue on the structure of engineering education, i.e the issue of structure of personnel training, has caused a concern from the fields of education, engineering, enterprises, etc. Due to the fast development of the market economy in particular, the research on the interrelation between the engineering education and the industrial competition has become an important issue for strategy studies on education development.

Confronted with the severe international competition, higher education of engineering in China has to speed up its pace in the reform so as to make the professional structure of engineering education fit in well with the industrial structure of the national economy, and its layered structure with the technological structure of the industrial economy, and its formulated structure with the university-enterprise horizontal structure.

1. Professional Structure of Engineering Education and Industrial Structure of National Economy

Professional structure refers to the proportional relation among the specialized fields, which determines the types of high-level personnel who have received the training of engineering education. Thus, it is important to make the professional structure of engineering education fit in well with the industrial structure of the national economy,

Since the open and reform policy, the industrial structure has undergone a great change. The traditional agricultural economy is beginning to turn to the direction for the modernization, industrialization and commercialization. The proportional relation between heavy industry and light industry was unbalanced for a long period, which has also been changed fundamentally. It is estimated that transportation, energy, electronics, light industry, foodstuff and other newly-booming industries in China will witness a fairly greater development in the days to come. The tertiary industry, especially information, financing, commerce, consultation service, etc. will develop into an important industrial sector. Compared with the developed countries, the industrial structure in China has a long way to go. This gap can be reflected in the following: industrialization is not very satisfactory, the productivity is comparatively backward, the industrial structure is of not highly standard, and energy, materials, transportation, communication and other basic industries and facilities are still the weak sectors in the national economy. In comparison, it can be found out that there is a severe competition between the main-leading industries in China and those in the developed countries. And there is a rather big gap between China and other countries in transportation facilities, metal and mineral products, printing and publication, food processing, non-electrical machinery, electrical machinery, etc. which indicates that China's industry has to follow the developed countries. At the same time, it can also be found that China is in lead in the fields such as iron and steel production, textile, tobacco manufacturing, industrial chemistry, etc. However, these industries are no longer the main-leading industries in the developed countries. It is necessary to conduct research on the development on these industries in China.

The adjustment and development of industries will affect the adjustment and development of engineering education. Like the adjustment of industries, the great waste of resources will occur if the adjustment and development of the engineering education would go against the main-stream, which will lead to the loss of the international competition in the future. Therefore, we should attach our great attention to it. So the reform and optimization of the professional structure of engineering education has become an urgent issue now. We should renew and reform old disciplines, and develop the new ones which the society needs a great deal through the adjustment of the professional structure of the engineering education so as to meet the demand for the personnel market. The adjustment of the engineering education should adapt to the structural changes in these industrial sectors. Although the engineering education has its own inertia, and it can't change itself in accordance with the change in industry, it should show its concern about the transformation in industrial structure and the causes for the transformation so as to readjust its special causes and syllabus timely. In particular, an analysis on the dramatic rise and drop in the structural changes should be made in order to prepare well for the special demand for the training of qualified personnel.

2. Layered Structure of Engineering Education and Technological Structure of industrial Economy

At present, the layered structure of engineering education in China can be shown mainly as follows: graduate level, undergraduate level, and vocational level. This layered structure has been determined, on the whole, by the technological structure of industrial economy. With the development of our economy from an extensive pattern to an intensive one, the level of the whole technological structure of industrial economy has been gradually raised, which has led to various requirements for a large number of highly-trained engineering and technological personnel at various levels.

From the viewpoint of the industrial development in China, the technological structure of industrial economy looks like an olive. In the whole country, there are a very few high-leveled industrial structures, which are highly automatic, and the majority are medium-leveled and semi-automatic. The low-leveled and poorly-equipped industries still compose a certain proportion in China. Under such circumstances, on one hand China needs high-quality and high-leveled engineering and technological personnel to develop new products, and explore the new areas. On the other hand, she needs a large number of the medium and primary-leveled technological personnel for hundreds and thousands of enterprises. Even though China's economy has developed in the future, this kind of practical personnel will be needed and will account for a certain proportion of the whole staff in the enterprises. On the basis of complete outfit of personnel, the reasonable ratio of college-educated personnel and vocational-trained personnel should be about one to three. However, China overemphasized the undergraduate education and graduate education for a period of time in the past, and overlooked the development of the vocational education, which has brought about the unbalanced layered structure. Recently, many industries and large enterprises reject vocational-trained students. As a result, the ratio between the engineers and technicians is irrational, and a number of college-educated people have to take the jobs which are intended for medium-leveled or even primary-leveled personnel.

Whether the level structure is rational is an important yardstick to examine whether the engineering education conforms to the need of economical and social development. But is hard to say what the rational level structure should be like. One thing is certain, though, that is, the demand for lower-level talents is usually higher than that of higher-level talents. As a result, the rational level structure for the engineering education roughly takes the shape of an upside down pyramid. This structure should keep abreast of our present situations and its center of gravity should not be put too high.

1) Postgraduate education, the topmost level of the pyramid, cultivates advanced and specialized talents for various engineering subject fields. As the requirement for postgraduates is no longer the unitary "scholar type", the engineering education must further extend its adjustability, and provide the much-needed talents of scientific type, technique type and management type, so as to meet the process of industrialization.

2) Taking our country's engineering education as a whole, undergraduate education is still the focal point. In line with the requirement of our construction cause for talents, we should do a solid job in both fundamental and vocational education, and in the meantime strengthen the practice of field work and the development of practical working abilities. Compound talents should be encouraged in order to facilitate the development of subject fields and technology. Double major, as cross-department, cross-specialty compound talents, have greater adjustability and therefore are welcomed by society.

3) It is necessary to put more emphasis on professional schooling. For a long period, China's engineering education had been focused on the training of under/postgraduates. The status of professional schooling has long been unsteady, undergoing ups and downs. The objectives, standards and content of professional schooling have blindly followed those of undergraduate, resulting in a blurred bounds between professional schooling and undergraduate education.

The developed countries boast of relatively perfected professional schooling, as the secondary education has been made universal in those countries. In addition, tens of thousands of graduates join the working force every year, thus the technicians' cultural quality is greatly enhanced. While in China, though the enterprises are dotted with some graduates from colleges, the number is far from satisfactory. Without enhanced cultural quality, the high-tech is difficult to master and the highly intellectual working force will not be formed, the situation of which greatly restrains the gradation of industrial structure.

In the report of international competitiveness published by Switzerland in recent years, China ranks in the rear in terms of the index "Is technical worker easily accessible?" This indicates that there is still a distance between the level of elementary and intermediate technicians, and this distance seriously restricts the development of manufacturing technology, especially the application and development of high-tech. Thus, straightening out level structure and making rational adjustment are top priority task for improving industrial competitiveness.

3. Formulated Structure of Engineering Education and University-enterprise Horizontal Structure

With the rapid development of science, technology, and social economy, the subject fields and vocational types have been constantly increasing, and people have ever increasing need for higher education. As a result, the unitary traditional full-time schooling can no longer meet the need of present situations. The concepts of "learning to learn" and "never too old to learn" have been gradually accepted. It has been a problem of common concern to establish and develop other forms of education so that people of different ages can receive diversified forms of education and training.

After the foundation of new China, alongside with traditional full-time higher education, there appears various forms of adult higher education, such as radio and television university, administrators' college, correspondence university; there appears various part-time schools, classes for advanced studies and training classes; there appears adult higher education testing system. All these have broken through our traditional model of higher education. So is true for the engineering education. In order to keep abreast of the need of industrial enterprises, the engineering education has the tendency of diversity in terms of educational objects, training standards, educational and learning methods, and schooling system.

The major problem presently existed in the technological activities of large and intermediate scale enterprises is the problem of talents. The number of enterprises who can give full play to their technical works and can fully carry out research and development (R & D) is too small, less than half of the total. The proportion of R & D institutions is low, too; the personnel are not centralized, and the institutions do not work well. The most central problem, however, lies in the technicians' lack of abilities of independent development and innovation.

In order to establish the large and intermediate scale enterprises as the center of scientific innovation, it is necessary to carry out the engineering education so as to promote the enterprises' competitiveness.

It is important for enterprises to devote major efforts to develop continuation and vocational education. Continuation education not only help trainees expand and renew knowledge, but also promote their technique. Its purposes are to extend and expand workers' knowledge and ability; to improve their knowledge structure; to enhance their vocational level and strengthen innovation. In this sense, continuation education is an extension of regular schooling. The gradation of industrial structure requires that workers constantly replace their knowledge and enhance their techniques. Continuation education, therefore, is their best choice. On one hand, it is necessary for higher institutions to get involved in continuation and vocational education. On the other hand, enterprises should encourage their workers to receive training, and through horizontal correlation with universities, promote the gradation of industrial structure.

From now on, continuation engineering education and advanced vocational training will become another focal point. Proceeding from China's present situations, it is possible that modern distance education will be treated as a more widespread educational form, using modern network technology so as to satisfy the extensive need for continuation and vocational education. With the development and application of modern educational technology, it is believed that distance education will become a new and important feature of next century's education; it will serve as an important bond between college and enterprise education; it will become an important way to promote technical workers quality and to enhance the competitiveness of industry.

All in all, we can see that the reform of engineering education and the promotion of industry's competitiveness are closely related. In face of intense international competition, higher engineering education must quicken its pace of reforms. Presently industrial enterprises have shifted their requirement for engineering education from quantity to quality. The central problem of talent structure is to meet the need of economical construction and social development for various specialized talents. Considering the demand for talents, enterprises expect that engineering graduates can not only conduct research, but also can solve practical problems; not only master specialized technique, but also understand management — this is the overall quality for requirement for engineering graduates. Of course it is not practical to require that every graduate is multi-talented, especially for engineering education — it is difficult to complete the basic training for an engineer at schools. What the colleges produce is only “blank of engineers”. Colleges only accomplish limited goals. But we must also see that the total number of college enrollment is over 3,000,000, over one third of which are engineering students. That is to say, each year about 1,000,000 engineering graduates or blanks of engineers will go to work. But their task is not simply to work, but more importantly to start an undertaking and create more working opportunities for society. Then our engineering education should be prepared to adjust its educational structure according to the market need and help those “blanks” to become talents who can prosper our country, start an undertaking and do scholarly research. Thus laying a solid foundation for rapid development of industrialization and the promotion of industrial competitiveness.

MULTINATIONAL PROJECT-BASED APPROACHES TO THE INTEGRATION OF ENGINEERING EDUCATION AND RESEARCH

Gretchen Kalonji
Kyocera Professor of Materials Science
University of Washington

Introduction

While the structure of higher education varies significantly from country to country, several challenges are recognized universally as significant to the future of research universities. These challenges include: doing a better job in integrating education and research; providing more multidisciplinary, creative opportunities for our students; linking our research more effectively to the needs of the local communities we serve; internationalizing our work more effectively; and, learning how to do a better job on evaluation and assessment of all our activities. At the University of Washington, in recent years we have been exploring some new models for simultaneously addressing several of these challenges, in collaboration with a number of partner institutions around the world, through a new initiative that we call *UW Worldwide*. In this initiative, we bring together multinational teams of students and faculty to work together on common, pressing, practical problems, and to integrate this collaborative research into the curriculum in a variety of disciplines.

In this paper, we describe some pilot efforts in our new multinational project-based approach. We outline our progress to date, elaborate on some lessons learned, and lay out some of our plans for the future. We focus most of our attention on a collaboration with Sichuan University, in Chengdu, entitled “Scientific, Engineering and Social Challenges to the Environment in the US Pacific Northwest and Southwest China”.

Design Features of our Multinational Project-Based Approach

Before going into the details of some of our projects, we offer a brief description of our basic strategy. It is clear that most of the big, multi-disciplinary research challenges are shared across national boundaries. Examples of such challenges include environmental quality, public health, access to technology, and the quality of education itself. It is also clear, as mentioned above, that all of us are struggling with change within our own institutions. The key strategic question, then is, can we couple collaborative work on common practical problems to mutually supportive work on the reform of higher education itself?

Our approach to this coupling is through the creation of ongoing teams of faculty and students, working at a set of partner institutions, which engage in common collaborative, multi-disciplinary projects. The projects are chosen such that they:

- are embedded in genuine faculty research interests on all sides;
- can take place within curricular structures which have the potential to affect *large* numbers of students on all sides, rather than a select few;
- contribute to the solution of practical regional problems, and;
- invoke deep partnerships with other allies, including industry, state and local government, NGO's, etc.

Of course it is nothing new for faculty members, particularly in science and engineering, to collaborate across national boundaries in their research. What distinguishes our approach is our commitment to involving undergraduate students (starting as early as their freshman year) in multinational research teams, and to finding ways in which to re-structure the curriculum, at UW and at partner institutions, such that participation in such teams can become the core of the undergraduate experience. There are indeed other notable international engineering programs we can learn from, such as the Global Perspectives Program at Worcester Polytechnic Institute (1), which has the most extensive track record in providing international project opportunities for undergraduates, and the International Engineering Program at the University of Rhode Island, which offers a five year program combining engineering, language study, and an international internship in a corporate setting (2). Our *UW Worldwide* model, while much younger than either of those programs, differs from them primarily in the degree in which it is embedded in multi-university research collaborations, and in the disciplinary breadth of the activities.

It is interesting to note that the type of research-based and internationalized undergraduate education we are exploring has the potential to create communities that have many of the features that have been identified as effective in the intellectual and professional development of our students. These communities are intrinsically interdisciplinary; they emphasize practical problems; they provide complex layers of mentoring; they develop students' communication abilities, and they provide experience in cross-cultural collaboration. Fortuitously, these same communities also offer an excellent platform for addressing important research questions. Thus, if structured thoughtfully, and carefully assessed, the basic approach may be useful in a quite fundamental re-formulation of how we undertake university "research" and "education".

UW-Tohoku University Collaboration on First-Year Engineering Design

Our first pilot project in integrating collaborative international research and undergraduate education was a program with Tohoku University, in Sendai, Japan, on first-year engineering design. This project builds on much of the experience with creating freshmen design programs gleaned from the US National Science Foundation's Engineering Education Coalitions program (3), as well as with several projects linking Japanese and US engineering education reform efforts (4, 5).

In this collaboration, teams of UW and Tohoku University students and faculty work together on common engineering design projects, sharing data, designs, ideas, etc, electronically. The undergraduate students are recruited to the program in their freshman years. Their initial research experience is integrated into their core curriculum as an engineering design course. Each year, five to

eight research projects are identified, based on common interests of UW and Tohoku faculty members. Each research team is binational consisting, typically, of 3 – 5 freshmen on each side, at least one professor on each side, and some graduate students, and/or advanced undergraduate students to act as “senior peers” for the freshmen. This collaboration began in 1999, and is ongoing. Each year approximately 25 students on each side join the program. Research topics have included tsunami research, piezoelectric materials, bio-MEMS, robotics, and computer simulation of defects in materials. While the required duration of the formal collaboration is only one academic quarter (during which the joint course is offered), many of the freshmen continue in their research teams throughout their freshmen year and beyond. On the UW side, the curriculum also includes a seminar in Japanese Culture, Science and Technology. There is no required language study, nor any required time to be spent at the partner university.

Evaluation of the UW-Tohoku program has taken place through a variety of methods, both qualitative and quantitative (6). In general, the program has been found to have a variety of benefits for participating communities. For the freshmen students themselves, the primary benefits have included: significant professional development in engineering; increased awareness of/desire for international experiences; development of multinational teamwork skills; and enhanced confidence in their ability to contribute to science and engineering. For faculty and graduate students, benefits have included an increased respect for the ability of novices to contribute to research, and the formation of new research ties with a powerful partner university. For the two partner universities, the collaboration has proven effective in providing mutual assistance in engineering curricular reform.

Based on our experience with the UW-Tohoku program, we catalyzed a number of other *UW Worldwide* pilot projects utilizing similar joint course approaches. Some of the partner universities and topics of collaboration are listed below:

- UW-University of Tokyo (international contract law)
- UW-University of Port Elizabeth, South Africa (marine affairs)
- UW-Tsinghua University, Beijing (art and graphic design)
- UW-University of Asmara, Eritrea (the Biography Project, social work)
- UW-San Andrés University, Argentina (the Global Citizen Project)
- UW-Chiba University, Japan (landscape architecture and urban design)
- UW-University of Auckland, New Zealand (geography, political economy)

Many of the projects above were catalyzed through a generous grant from the Hewlett Foundation. Most of them are ongoing, and it has been extremely interesting to see how the basic approach plays out in a variety of different disciplines. In parallel to continuing to explore the model employed with Tohoku, in which the formal duration of the collaboration is limited to a number of joint courses, we decided to pilot a more dramatic and extensive cooperation, which incorporates joint research, language study, extended stay at the partner university, and a full four-year collaborative undergraduate curriculum. Our partner university for the first version of the four-year model is Sichuan University.

UW-Sichuan University Collaboration on Challenges to the Environment

Building on some of the lessons learned from our collaboration with Tohoku University, we designed a four-year model, which:

- allows deeper research experiences for students;
- promotes stronger institutional partnerships;
- opens up a richer domain of project topics;
- allows time for language instruction, and for humanities and social sciences, and;
- includes a year at the partner university.

The over-arching research theme for our collaboration is “Scientific, Engineering and Social Challenges to the Environment in the US Pacific Northwest and Southwest China”. Within this broad theme, we have several research groups, working on five topics: 1) water resource management and waste water treatment; 2) “eco-materials”, i.e. reducing the environmental impact of materials processing and use; 3) forest ecology; 4) biodiversity; and 5) anthropology/archeology, focusing on the effects of humans on the environment (and vice versa) in our two regions. UW and Sichuan University (SU) faculty chose these research topics together, based on common interests and based on our assessment of topics that are of particular importance both to Washington State and to Sichuan Province.

Basic Program Structure

The curricular structure of our program is the following. Each year, we admit 25 first-year undergraduate students on each side, clustered into five teams to focus on the five project topics. Each team is binational, consisting, in addition to the first-year students, of at least one faculty member on each side, and at least one graduate student or senior undergraduate. For the first two years of their curriculum, the binational student teams work on their projects in their home countries, sharing ideas, data and designs with their counterpart teams electronically. In parallel, the students in Washington undertake intensive Chinese language study (typically 2 years, or 30 credits) and a year-long seminar on Chinese Society, Science and Culture. In their third year, the UW students travel to Chengdu, and the Sichuan University students come to Seattle, staggering the travel such that they can work together in Sichuan during the first summer and together in Washington State during the second summer of their junior year. This differs from more traditional “junior-year abroad” programs in that the focus is on continuation of their research, in collaboration with academic, industrial and local government partners. In the fourth year, the students return to their home countries to complete a senior thesis/design project, based on the collaborative research. The status of our program with Sichuan University is the following. We admitted our first group of students in the fall of 2000. The 2002-2003 academic year is the first year that the undergraduate student exchange is taking place. 31 UW students are currently undertaking coursework and research in China, and 28 Sichuan University students are here with us at the UW. Please note that in steady-state we hope to have 100 students enrolled in the program on each campus at any given time: 50 freshmen and sophomores preparing for their year abroad, 25 juniors from the partner university, and 25 seniors, returned from their experience abroad and completing a senior thesis on their work.

Project Participants

The undergraduate students in the program have a wide variety of academic majors and career aspirations. Undergraduate majors include: civil and environmental engineering, materials science, mechanical engineering, industrial engineering, computer science and engineering, bioengineering,

botany, biochemistry, sustainable resource sciences, forestry, conservation of wildland resources, anthropology, international studies, Chinese language, business and art. What unites the students is a strong commitment to working on environmental issues and a deep interest in international experience. Faculty members are also drawn from many departments, and 12 – 15 professors are actively participating on each side at any given time. In addition to the faculty members, graduate students on both sides are active and invaluable members of each of the five research teams.

In addition to the university participants, we have created some deep partnerships with the local government, trade, non-profit, and industrial sectors, which greatly expand the scope of projects we can undertake. On the Washington side, the primary partners outside the university are: the Washington State Office of Trade and Economic Development (OTED): a cabinet-level state agency created in 1994 to assist companies to export their products, and promote the expansion of Washington's businesses internationally; the Washington State China Relations Council (WSCRC): a non-profit trade association dedicated to promoting stronger commercial, educational and cultural relations between the state of Washington and the People's Republic of China; the Northwest Environmental Business Council (NEBC): the trade association representing the environmental industry of the state of Washington, a sector which comprises over 600 mostly small firms (2 – 25 employees); EarthTech, a large environmental technology firm; and the Washington State – Sichuan Province Friendship Association, a non-profit organization dedicated to strengthening educational, artistic and commercial ties between the two regions, which have been linked through a formal sister state-province relationship since 1982. Support from the National Science Foundation's Partnerships for Innovation program has been of great assistance in strengthening these natural alliances. All of these partners mentioned above are heavily involved in the planning and implementation of the program, and on the Sichuan side there is a similar set of partnerships in place. These partnerships are particularly important in maximizing the probability that the research of the student-faculty teams will actually be implemented in real products and services that can benefit our regions.

Overview of Projects

What follows is a brief description of some of the research directions of the students in our program. This is very much a work in progress; for continuing developments please consult the project website (7). It is interesting to note that while the faculty on both sides designed some initial research directions, many of the projects that have evolved are now student-designed and led. By taking the program in new and unexpected directions, the students themselves have, in turn, brought new faculty into the program. In addition to research that takes place in Seattle and Chengdu, a lot of fieldwork takes place in remote areas. In China, a cluster of projects in the fields of anthropology, forestry and biodiversity are located in a site in a Chinese minority area – Yangjuan Village, in the Liangshan Autonomous Prefecture. Organized by research theme, here are some brief descriptions.

Anthropology/Archeology: understanding the complex interactions between humans and the environment in our two regions. Chinese students at UW are currently working on Northwest Native American culture and art, in conjunction with an exhibit at the UW Burke Museum. They are collaborating with UW freshmen to produce a video in Chinese, to introduce this topic to academic and general audiences in China. UW students in China are working on a variety of projects, including: a study of the apple industry in Sichuan Province, investigating the reasons for market collapse and possible solutions, emphasizing finding new markets, and; a nutritional and health survey of the rural Nuosu minority group in Yangjuan, focusing on nutritional deficiencies in children and women.

Biodiversity: understanding biodiversity in our two regions, and the relationships between speciation and geography. UW and SU students have focused on: biogeography and the evolutionary relationships of plants in the Pacific Northwest and Southwestern China; compiling a complete herbarium collection of the flora surrounding Yangjuan Village; an ethnobotany study of the traditional uses of plants by local Nuosu minority people; using DNA analysis to determine the phylogeny among species of various genera including rhododendron and passiflora; a survey of botanical biodiversity in Wang Long Nature Reserve, and; techniques for the statistical estimation of giant panda populations.

Eco-Materials: reducing the environmental cost of materials processing and use. UW and SU students are working together on the design of industrial ecology models for the effect of the materials processing industry on the environment in the Sichuan Basin and the Puget Sound. They are also working on the processing of environmentally friendly ceramic materials, for solid oxide fuel cells and for lead-free piezoelectrics. Support for this portion of our effort comes from the NSF's new MUSES initiative (Materials Uses: Science, Engineering and Society), and from the Natural Science Foundation of China.

Forest Ecology: understanding the dynamics of forest ecosystems and the balance between environment and development needs. UW and SU students are focusing on: the natural history of the Olympic Peninsula, and the relation between vegetation and soil erosion; in Yangjuan Village, constructing the natural history of forest stands; assessing the currently existing ecosystem; researching human uses of and impacts on forest resources, including surveys of fuelwood use; and, developing recommendations for future ecosystem management.

Water: understanding river systems in Sichuan and Washington, and investigating waste water treatment strategies. UW and SU student projects include: Using low-cost and effective biofluidized bed reactors to treat domestic waste water in Luzhou City, Sichuan (partners include Luzhou municipal government and local companies); mathematical modeling of waste water treatment processes; research on the White River and the effects of water quality on endangered salmon populations; and working with the partners on the NSF Partnerships for Innovation grant to help environmental companies in Washington identify opportunities in the area of waste water treatment in Sichuan.

Program Support

Both universities have committed local resources to the project, on the UW side through a grant from our Tools for Transformation program to launch the *UW Worldwide* program. On the US side, we also receive support through the Fund for Improvement of Post-Secondary Education (FIPSE) of the US Department of Education, and a number of NSF grants, as mentioned above. Analogously, Sichuan University receives support for the project as a whole through the Chinese Ministry of Education; two of the research teams (water and eco-materials) also receive support from the Natural Science Foundation of China.

Lessons Learned in the UW-Sichuan Program

The evaluation component of our program is led by the UW's Office of Educational Assessment (OEA), under the guidance of Dr. Laurie Collins. A full-time doctoral student in education, Ms. Chia-lin Huang, who is fluent in Chinese and English, also works on the project. The OEA people are assisted by an external evaluator, Dr. Susan Millar, of the Learning through Evaluation, Assessment and Dissemination (LEAD) Center, at the University of Wisconsin, Madison (8). The evaluation is both formative and summative, including a variety of methods for triangulation purposes. Methods employed include: surveys, peer assessment, performance-based tasks, monitoring of research accomplishments, interviews, observations, focus groups, and longitudinal tracking of students. While the evaluation process is led at UW, to the greatest degree possible we try to implement similar activities on both sides.

While the project is still in its early stages (the first group of students to be exchanged has yet to return home), we have learned a great deal about the benefits and challenges of the approaches we have undertaken. The research and professional development of the students is quite extraordinary, and exceeds the expectations of most faculty involved. The program does serve as a motivation for continued international experience; many of the US the students are already planning to continue to their careers in China; others are anxious to explore other international opportunities in graduate school. The program has also proved to be a powerful platform for faculty and graduate student professional development. For the faculty, it provides increased international dimensions to their work, as well as greater experience in working with multidisciplinary, cross-cultural teams of students. For the graduate students, new opportunities for international research and collaboration are opened up, and they get valuable experience in management of research teams.

A key challenge for our integrated approach is to get the faculty on both sides to collaborate beforehand on a coherent, yet flexible, four-year plan. We have found face-to-face meetings to be indispensable in this matter, though costly. Another challenge is the effective incorporation of the industrial, governmental and non-profit sectors in our work. It is vitally important, but many faculty have little experience in that regard, and all of us are stressed for time. On the US side, a very challenging matter is recruiting students who will agree to spend the time needed on Chinese language studies and on study abroad. Particularly for engineering students, who have no language requirement in their curriculum, we have to expend a great deal of energy to help them understand how valuable such a commitment might prove for their professional futures. On the financial side, the biggest problem is raising the money to support the room and board for the Chinese students during their year in Seattle. Because the two universities have a home tuition exchange agreement, the tuition is not a burden, but the differential cost of living is a challenge. We have managed so far with a combination

of loans and grants, but need to continue to involve additional partners to make sure the approach can be sustainable in the long run. Another serious challenge to overcome has been the cultural differences between disciplines. In our program, we have botanists working closely with engineers, anthropologists, forestry professors, etc., and the cultures of the ways we do research and teach our students are very different – at least as challenging as understanding the cultural differences in the higher education communities in our two countries, which are certainly significant.

The biggest challenge to overcome on both sides has proven to be curricular constraints. One thing that unites professors across national boundaries is the deep underlying assumption that education for students is synonymous with the completion of a set of courses in which all the required materials are “covered”. With our model’s heavy emphasis on research, and with the very extensive time needed for language and other studies, it is extremely difficult to continue to fit in all the required courses for all the majors in the program, themselves extremely diverse, without unreasonably extending the duration of the undergraduate program. It is an ongoing challenge on both sides to determine what can be cut out, what among truly essential sets of knowledge and skills can be acquired and assessed through alternate routes, and what really has to remain as formal coursework requirements. And, of course, all this has to be negotiated within a complex set of institutional frameworks on both sides. Nevertheless, the progress in addressing these curricular constraints has a very large potential pay-off; if we can come to grips with some of these fundamental issues we can free up the energies of faculty and students for many other creative pursuits in the future.

Future Directions for the *UW Worldwide* Program

We are currently pursuing several parallel directions with the *UW Worldwide* program. We are deeply committed to continuing to strengthen the collaboration with Sichuan, and to making it a sustainable one that has a significant role in building ties between our universities and regions. As for the UW-Tohoku program, both sides would like to move the program to one that has several of the features of the UW-Sichuan program, with some modifications. Specifically, we would like to build on the existing joint program on freshmen engineering design to create a program in which at least some of the students on both sides can incorporate continued research, language study, and physical exchange into their undergraduate degree program. In addition, we are continuing to launch new pilot projects on the undergraduate level, with a number of new partner institutions and on new topical areas. Some support for expanding the basic approach comes from the NSF’s Distinguished Teaching Scholar Award. The last major direction we are pursuing is to greatly enhance our focus on internationalizing graduate education. As mentioned above, graduate students have vitally important roles to play in this multinational project-based approach, and the graduate students, in turn, have a great deal to gain in their academic and professional development through participating in these novel integrative communities. Together with a small set of partner institutions around the world, we are designing a plan for collaborative graduate education in the broad area of environmental research. Lastly, we will continue to work on mechanisms to more effectively involve the broader community, with the goal of making these challenging approaches to education sustainable in the long run.

Conclusions

We have initiated an ambitious set of projects with partner institutions around the world, projects that share the common distinguishing feature of integrating collaborative multinational research into

undergraduate curricula. Though the results are promising to date, a great deal more information needs to be gathered to enable a scholarly assessment of the benefits and drawbacks of the approaches we have piloted. We are committed to scholarly assessment of the results of our work, and to reporting the insights we have gained to the broader educational community. We welcome questions from other universities or potential collaborators in the private sector that would be interested in joining us in some of these activities.

Acknowledgements

The author would like to acknowledge the vital contributions to this work of faculty leaders at some of the partner institutions, primarily Prof. Tetsuo Shoji, at Tohoku University, and Profs. Yan Shijing, Zhao Shiping, Xiao Dingquan and Jiang Wenju, at Sichuan University, as well as all of the participating faculty at UW too numerous to mention. In addition, we are grateful for financial support from the Dorr Foundation, the Hewlett Foundation, the FIPSE Program at the US Department of Education, the National Science Foundation, the Natural Science Foundation of China, and the Japanese Ministry of Science, Education, Sports and Culture (Monbusho).

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HOW TO EDUCATE STUDENTS WITH THE ABILITY OF INNOVATION AND CREATION

Xie, You-Bai

**Internet-Based Collaborative Research Center on Modern Design and Manufacturing of Ministry of Education of China, Xi'an Jiaotong University
Industrial Innovation Center, Shanghai Jiaotong University**

Abstract

The situation of engineering education on the ability of innovation and creation is discussed from the results of an Innovation Cup Contest organized by the Industrial Innovation Center, Shanghai Jiaotong University. During a face-to-face examination and evaluation most of the candidates coming from universities cannot answer or answer clearly what's new in their innovation and cannot make a comparison between the technique they used and what in existed products or design. The insufficient points in engineering education in these aspects are discussed and suggestions are given.

Key words: Engineering Education, Innovation, Creation, Knowledge

Due to competition, which controls the progress of almost every thing in the world, innovation and creation has become the key to the existence and development of any company, any team or any individual person. Can we teach the young people in universities, the future engineers or scientists or train them with the ability of innovation and creation? Is the situation of engineering education in universities today good enough for such teaching and training? How can we do the teaching and training better?

For the first question there are lots of arguments. Some think that the ability is defined by the inherent quality of each student and there is no general way of education. Others argue that education should do some things for the purpose even though we cannot expect that the process will be completed in universities. They argue also that the situation is not so good today.

Recently there was an Innovation Cup Contest organized by the Industrial Innovation Center (IIC) in Shanghai Jiaotong University. About 20 items selected from more than 80 proposals were examined and evaluated later by a committee face-to-face, the members of the committee come from many large companies such as ABB, GM (Shanghai), Toshiba (China), UTC, Hair, Shanghai Electric Corp, Yaskawa, Fujitec, SAIC and so on. Most unanswerable questions for the candidates are: Can you give a comparison on the advanced level of technique between what you used in your innovation and in existed products or designs? Is the technique you used an innovation? It implies that they do not know or do not know clearly the situation in the outside world and deal with their "innovation" subjectively and cannot answer what is new in the innovation.

Considering that the candidates came from most important universities in the mainland of China the second question mentioned in the first paragraph arises.

1. How can we do better in universities for the ability of innovation and creation of students?

At least two points should be thought.

Firstly, due to the closed situation in China for a long time, a popular accepted goal in engineering circles is to fill in the gaps in the fields of science and technology [1]. People do not care what existed outside the country boundary since they cannot get them. They have to solve each problem themselves. Such a point effects deeply the education (also the research) in universities. The situation is now absolutely changed. You can get almost every thing in the world and have to compare the benefit between that you do it yourself and you request the service when you need since you are under a competitive condition. If you make every thing without innovation and creation you will definitely lose your power in competition and be defeated. Innovation and creation is the key to existence and development. Have we changed the goal of engineering education in universities thoroughly?

Secondly, innovation and creation are not a mystery. They have their own pattern and law. Five steps in engineering innovation must be taken:

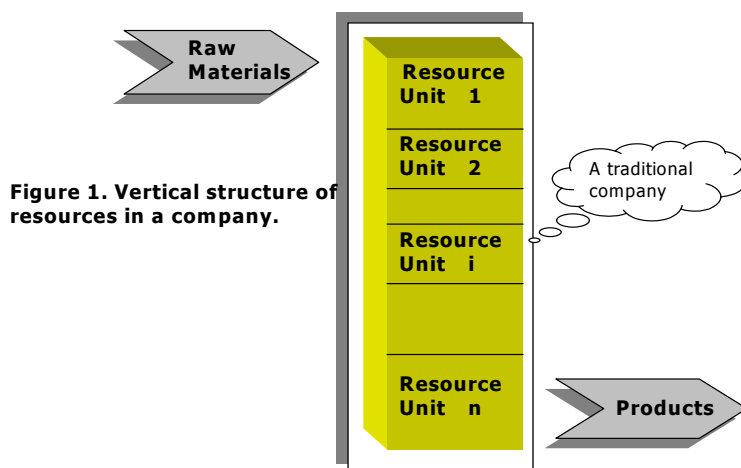
1. Know the new requirements.
2. Know the situation of existed techniques and the gap between the techniques and the new requirements.
3. Develop new concepts to meet the gap through association based on the existed knowledge in a very wide scope.
4. Assess the new concepts, select the best and do detailed design.
5. Realize the prototype of the design and check if its performance meets the requirements.

The fifth step implies that the ability of innovation and creation for an engineer includes not only the power of thinking but also the power of realizing practically his idea.

Is there any course in the standard curriculum in universities dealing with such topics? Most courses in universities are for transferring knowledge in a special scope, for example mathematics, physics, chemistry or computer science. Other courses dealing with design are limited in components or special equipment and mainly

for transferring knowledge concerning with the components or the special equipment. Teaching and training students to learn from such topics are not only for any special product design. Design can be designing products, designing processes, designing organizations and designing any thing need to do [2].

Therefore the author suggests setting up a new course in universities named “Modern



Design”[3]. It involves knowledge acquirement, knowledge integrating, knowledge utilization, and the modern viewpoints in design. The goal of the course is teaching and training students how to design their own activities and focus on the ability of innovation and creation.

2. Knowledge service in web-based design and engineering education.

Any individual person, any team and any company cannot have all of the knowledge, which they need in innovation and creation, not only for new knowledge but also for existed knowledge. According to the definitions given in [1] new knowledge acquired for an innovative design will become existed knowledge (experience) in the next innovative design. Therefore knowledge needed in design is a dynamic integration.

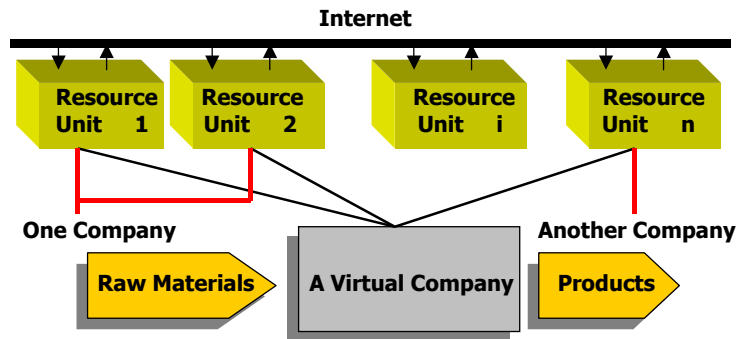


Figure 2. Horizontal structure of resources.

It is regret that many people do not accept the viewpoint deep in their mind. They prefer transferring as much as possible existed knowledge in universities to students and do not like to take a bit of time on teaching and training the power of knowledge acquirement, knowledge integration and knowledge utilization. Power of knowledge acquirement is the key between them. Since the knowledge integration is in rapidly renewing much existed knowledge taught in universities will be no use in innovative design and engineers must find other ways to have the necessary knowledge support. Reference [4] reported, analysts have estimate that manufacturing companies now outsource from 40% to 70% of their product development activities to external suppliers, contract manufacturers, and contract design service companies.

Meanwhile the traditional vertical knowledge resource structure (figure 1) in many companies is changing into a horizontal structure (figure 2) distributed in the world. The author believes that knowledge rapidly renewing is the main reason of using distributed resources rather than for a continuous-24 hours designing process.

A kind of collaborative work mode named knowledge service via Internet [5] is suggested as shown in figure 3. The structure of design entity, which is the service requesting side, is shown in figure 4. Its characters can be described as follows:

1. It has a design target.

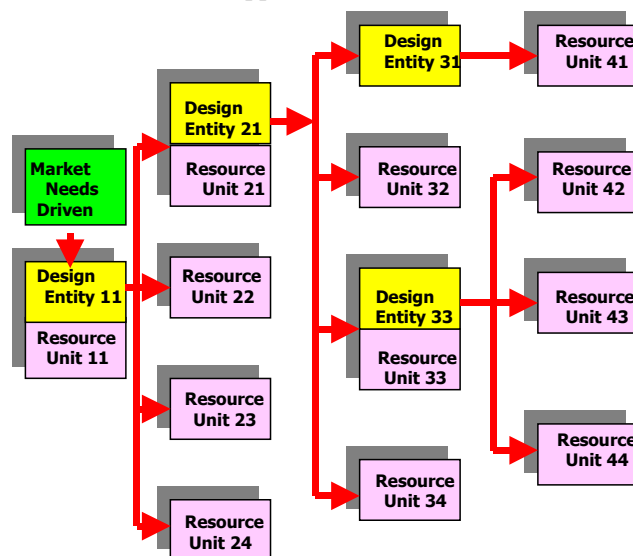


Figure 3. A suggested mode of collaborative work via internet.

2. It does the design or part of the design.

3. It is responsible for the completion of the target and the success or failure of the design and then the product in later competition.

A resource unit can be defined as a smallest unit, which can live individually and provides service with its knowledge resource or knowledge acquirement resources at least in a knowledge area. It is the service providing side in the design chain and the structure is shown in figure 5. The four living conditions for resource units under competition are concluded as follows:

1. The resource units should keep themselves as the most advanced in the world. Therefore they must renew themselves frequently.

2. The resource units should keep themselves operating on the highest service quality and efficiency. Therefore they must serve for any user in the world instead of a company.

3. The owners and the operators of the resource units must have higher income to keep themselves with a highest initiative and activity on having point 1 and point 2.

4. There must be enough service requesters on the Internet.

Either in the structure of design entities or resource units educated and organized human,

not computers, is on the top position of the structure since the collaboration is a very complex socio-technical activity. It is completed via negotiation to find a compromise between stakeholders with different perspectives rather than via computation in computers [6].

Under the condition discussed before the engineering education in universities should focus its attention on the power of knowledge acquirement, knowledge integration and knowledge utilization rather than simply knowledge transferring, even though in the fundamental disciplines. The course “Modern Design” is with the goal of teaching and training students to understand that what are innovation and creation, how to innovate and create and to have the power on knowledge acquirement, knowledge integration and knowledge utilization. The demonstrations of distributed design knowledge and knowledge acquirement resources organized by the Internet-based Collaborative Research Center on Modern Design and Manufacturing of the Ministry of Education of China (ICRCMD) can be found in [3]. It will be also useful for the “Modern Design” course in engineering education. A team coming from Shanghai Jiaotong University and Xi’an Jiaotong University awarded the Innovation Cup of IIC in the Context they used the knowledge and knowledge acquirement resources of ICRCMD via Internet.

Conclusions

1. Under the global competitive condition in engineering education the courses should be organized to ask students thinking what’s new and what new requirements it will satisfy at first in their



Figure 4. The elements in a design entity.

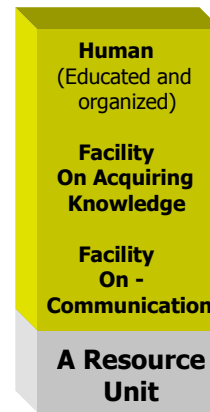


Figure 5. The elements in a resource unit.

innovation and creation activities.

2. Teaching and training students with the power to realize their innovation and creation practically are important as well.

3. Due to the rapidly renewing knowledge integration engineering education in universities should focus its attention on the power of knowledge acquirement, knowledge integration and knowledge utilization rather than simply knowledge transfer.

4. A course named “Modern Design” is suggested in the engineering education in universities, which deals with the goals mentioned from point 1 to point 3.

Acknowledgements

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ACHIEVING A GLOBAL ACADEMIC INDUSTRIAL NETWORK FOR STUDENTS AND FACULTY

**James L. Melsa, Dean
College of Engineering
Iowa State University
Ames, Iowa 50014**

Abstract

It is clear that the engineer of the 21st century will be required to spend an appreciable portion of his or her career in an environment rich with a variety of global connections. Colleges of engineering must develop ways to prepare their students for this world. Students, of course, will only fully understand global concepts through the role models that their colleges provide.

The Global Academic Industrial Network (GAIN) is an attempt to create multi-organizational, international partnerships of academic and industrial organizations that emphasize collaborative educational programs and research that meets the global needs of faculty, students, and industry.

Introduction

The need for a global perspective in engineering education is, perhaps, best understood from a quote by Peter Drucker¹, “In the new mental geography created by the railroad, humanity mastered distance. In the mental geography of e-commerce, distance has been eliminated. There is only one economy and only one market.” For example, when using the Internet to purchase an item, a consumer has no idea of the locations of the server on which the transaction is taking place or the warehouse from which the product will be shipped. In fact, little or no attention is given to location when one transacts business on the Internet.

We in engineering education must begin to understand the reality of one economy and one market. We must learn to think globally but act locally; that is, we must understand the importance of a global perspective for our students and take action to ensure that our local environment satisfies this need and that our efforts at globalization fit the local culture.

If educational programs are to have a real impact on global perspective, then the vast majority of students and faculty must be exposed to international engineering educational and work experiences. To date, colleges of engineering have made little progress because the approaches used by most programs are fragmented and individual. At the same time, most universities have not involved industrial organizations in helping them to achieve their international goals. It is clear that a different approach is needed if meaningful improvement is to be made in the global skills of engineering students and hence early career practitioners.

¹ *Managing in the Next Society*, Peter Drucker, 2002

In forming an international experience for students, it is important to not get too involved with defining the concept. After all, any experience is better than none. It is equally important not to get bogged down in a search for the ideal or perfect experience; six weeks in a structured summer program is a beginning. There are many forms of international experience, and no single experience will be best for all situations. It is important to start early to create interest and facilitate continuing opportunities at later points in the students' educational career.

This paper presents the results of a recent Global Academic Industrial Network (GAIN) Workshop in Mannheim, Germany. This workshop brought together engineering educators from universities in the United States, Mexico, South America, and Europe along with representatives from several multinational industrial corporations. The goal of the workshop was to develop an action agenda that would improve the global perspectives and experiences of students through academic and industrial partnerships. The action agenda was to be built on extensions of existing successful models of international collaboration.

For purposes of simplifying discussions, examples of successful collaboration were divided into academic models where the primary collaborators were two or more universities and industrial models, which involved one or more universities and one or more industrial organizations. Of course, it is possible to have many combinations and variations on these models. Each of these models has been successfully deployed in one or more cases as reported at the 2002 GAIN Workshop.

General Issues

All of the following models for providing international experiences share several common needs and issues. First, it is important to match experiences to students' future job requirements. This will make the international experience more meaningful for students and will help engage their interest. It is helpful if one can show that obtaining an international experience will provide an advantage in future job opportunities.

Faculty members are critical and essential elements of all international exchange programs. Institutions must work on ways to engage their faculty members in international experiences, including extended stays at a foreign institution. Programs built around a single faculty member and his or her international connection are very fragile and will likely fail if the faculty member changes jobs or loses interest. The best and most sustainable programs will be based on a wide variety of research and educational relationships.

Funding is certainly an issue for any of these programs. However, international programs will not happen if we let funding become too limiting of an issue. While many programs can be started with ad hoc funding, sustainability depends on creating a systematic funding model. Sustainability is also enhanced if the exchanges are multi-dimensional and involve several faculty members from each institution. Since it is often necessary to innovate and stretch the rules to make these programs work, institutional support at the highest levels is essential.

Students who are involved with international programs will be asked to study and learn under challenging conditions, which might include a foreign language and many distractions. In addition, students will generally encounter a living and learning environment that differs greatly from their previous experiences. As a result, students selected for international programs must be of high quality and possess a great deal of flexibility.

There is significant paperwork associated with international travel, including passports, visas, entrance requirements, and perhaps work permits. Much of this is unavoidable. However, it is wise to

work on ways to streamline and systematize paperwork. Timely communication in both directions is critical to ensure that all necessary paperwork is completed at the appropriate time and that students are comfortable with their situations.

The different academic calendars of the host and home institutions can cause problems. This is especially true when two universities are in different hemispheres, such as an exchange between the United States and Australia.

Housing is an issue to be addressed in every exchange. Student dormitories, if available, can provide an excellent solution since the visiting students are placed into a good social environment. In many institutions, however, students live at home during their university education. In these cases, the cost of room and board can be a significant new expense for the exchange student.

An additional issue arises for students involved in international work experiences: Pay scales vary widely among different countries. The problem can be acute when students from the United States work in foreign countries where the pay scale for junior practicing engineers may be less than that of a student intern in the United States. Early discussion of this issue and clear understandings by all parties offer the only possible solution.

In general, few students are involved in international experiences. If we truly believe that the majority of students need this experience we must address the problem differently. The “classical” profile of engineers and their rigid educational format with its need to arrive at a single, correct answer may be counter to the flexibility and openness that is required to successfully engage more students in international experiences.

It is important that all international programs attempt to include opportunities for students to establish appropriate social contacts and obtain cultural knowledge of the host country. It is clear that language is a critical part of the culture because people think in the ways in which they communicate. As a result, students involved in international programs should have opportunities to become familiar with the language of the host country.

The lack of foreign language skills by U.S. students is a complicating factor in almost all international programs. The solution to this problem will be long-term and will be effectively addressed only by looking at earlier language education. Compared to their European counterparts, U.S. students also have little or no opportunity for international experience. European students can get an international experience by crossing borders within their own continent; U.S. students must travel more extensively.

Academic Models

Academic models deal with international experiences between two or more universities located in different countries and their associated faculty and students.

Standard international exchanges

This is probably the most widely used form of international experience for students. It involves a student of one university (the home university) matriculating at a university (the host university) in another country. In this model, the assumption is that the student is not seeking a degree from the host university but simply wishes to take certain courses or to have a language and cultural experience there. The transferring of credit from one institution or another is the biggest challenge of this form of

exchange; it often necessitates a careful evaluation of courses and the grading systems used by the universities.

In the simplest form, the student applies for admission to a host university. Upon acceptance, the student studies at the host university for a period of one or two semesters, paying tuition as appropriate to the host university as well as any needed travel and living expenses. In this case, the student is responsible for making arrangements at his or her home university to receive credit for the courses taken at the host university.

This type of exchange can also be facilitated through a formal agreement between the host and home institutions. In such cases, the goal is an approximately equal number of students moving in each direction. The host university agrees not to charge tuition to the home university's student/students. However, the host university does facilitate appropriate paperwork and housing. The students pay tuition, as appropriate, to their home university since they will eventually receive credit for their programs there. One or more faculty members from each university are involved and can help with evaluating the equivalency of course content and grading systems. Maintaining the balance of student flow can become a challenge.

International learning communities

A learning community is a team of students enrolled in a common set of courses. The community has an academic thread because the students study together, teach each other, and learn from one another. It also has a social thread because the students have fun together and develop a commitment to the success of the community. An upper division student provides mentorship, leadership, and team building to the learning community. Students in an international learning community come from two or more countries.

The version of this model that has been implemented by Iowa State University and Monterrey Technical Institute (Mexico) involves a group of six to eight students from Monterrey Tech who study for a semester at Iowa State with a group of six to eight Iowa State students. The entire group then moves to Monterrey Tech for the second semester.

The experience to date has shown that students in leaning communities have an easier acclimation to a foreign culture. Peer acknowledgement, support, and respect generally lead to improved academic performance as well.

Bi-national, dual-degree programs

In this model, exchange students follow a formally designed model of course work at two universities. The exchange portion of the program usually begins after the second or third year of study. Upon completion of the program, the student receives degrees from both institutions. These programs can also involve awarding a bachelor's degree from one institution and a master's from the other. Dr. Director discussed an excellent example of this type of program in the first keynote talk. The Fachhochschule Mannheim and the Tongji University in Shanghai have developed this type of program.

The establishment of dual-degree programs can take considerable time since the faculties at both institutions must approve of the curriculum and possible substitute courses.

International summer programs

In their generic form, international summer programs involve a group of students traveling from one country to another for a period of four to eight weeks. The programs can be focused on a laboratory experience, one or more lecture courses, or a combination of lab and lecture. To date these programs have largely focused on taking students from the United States to other countries. Students from outside of the United States seem to have less need for such an introductory international experience. This may be because they are more likely to go abroad or to other countries for a year; this is especially true for European students who do not have to go far from home to have an international experience. Summer programs are a good way to introduce a large number of students to an international experience. While students naturally have some fear of the unknown, they become more confident when they are with a group of friends with familiar backgrounds. Their comfort levels are also enhanced by the fact that a faculty member from their home university normally accompanies them. The short duration of a summer program appears less risky. Generally, the cost of a summer program is low compared to longer programs; however the cost per week of international exposure is higher.

(Is this right? Two N.A. universities?) At least two North American universities should be involved (but they should have compatible students). The program need not be located in an English-speaking country if the host faculty member speaks English well. It is desirable that the faculty member from the host institution teaches most of the material. There should be an adequate number of computers for report writing and e-mail; inadequate availability of computers can become a real frustration for the students.

These programs will not be cost effective if both the host and home universities charge normal fees. Creativity will be required to overcome this problem. It may be possible to combine the program with other international exchanges or perhaps the home institution will underwrite some of the expenses on the basis of addressing an important student need.

If possible, visiting faculty should be housed near—but not with—their students. It is important to note that the visiting faculty will probably have a greater role in the students' lives than they would have when the students are resident at their home institution. The visiting faculty may also be called on to play a greater disciplinary role than at home.

It is important to leave time for cultural experiences or to specifically schedule them into the program. Plant visits in the host country should be an integral part of summer programs. They are an excellent way to introduce the students to work processes in other countries.

International project experiences

In this model, students are sent to another country to conduct project work under the supervision of faculty members at the host university. The Fachhochschule Mannheim and the University of Maryland, College Park, have engaged in a program of this nature since 1990. The Mannheim students go to the University of Maryland for a six-month diploma theses, master theses, or practical semester. Because the students are working on funded projects, they are paid a stipend; housing is provided in apartments or homes. The German students work on degrees in areas such as process, mechanical, electrical, and communication engineering, as well as computer science. They participate in projects at the research centers in the Mechanical Engineering Department on topics such as environmental energy engineering, electronic packaging, smart materials, energetic concepts, smart small systems, automotive systems, micro-engineering. The students expect that they will be involved

in engineering-related work on a level that fits the demands of their profession, and that they will have social contacts with people from the United States.

International design projects

This model involves a team of students drawn from two or more universities who are assigned a collaborative design project. The projects normally run for one semester. The team members communicate using tools such as video conferencing, websites, email, chat rooms, and Internet-based meetings. Each institution provides one or more faculty members to serve as mentors to the students. Faculty members from the home institution assess the work.

In most cases, the students never have a face-to-face meeting. For this reason, this approach is sometimes referred to as a virtual collaboration. In other instances, the program may include face-to-face meetings at the beginning and end of the project. While such face-to-face meetings are advantageous with regard to several internationalization objectives, they do significantly increase the complexity of running such a program as well as the costs.

These design projects help students understand how culture can affect what would otherwise appear to be standard engineering problems. For example, Bruno Ramond of Universite de Technologie de Compiègne in France, who reported on his experience with this model, showed dramatically different design results based on the culture (American or French) of the team leader. He also noted that although the students were using the same design tools, the methods of using them differed considerably.

The students involved with these projects learn several things. They gain an understanding and appreciation of engineering standards and common practices in other countries. They also develop the personal skills necessary to work on a common problem with a team of students from another country. The students also understand and master the difficulties of communicating clearly and concisely by electronic means.

In-country resident programs

To address international experience opportunities for their students, some universities have established resident programs in foreign countries. Instructors from the home university provide most or all of the instruction for these programs, and the courses follow the home university's syllabi. The students normally attend for one or two semesters. The calendar for the program can follow the calendar for the home institution.

This model provides an excellent chance for students to experience a foreign culture with minimal disruption in their academic progress. These programs require a great deal of work since the home university must schedule a steady supply of instructors willing to spend a lengthy period in a foreign country as well as a sufficient supply of students to make the program economically viable. In some cases, these programs are done in conjunction with a foreign university, which provides classroom space, housing for students, and some instructors.

Industrial Models

Many of the industrial models involve some of the elements of the academic models but extend them through some form of industrial experience.

Industry-sponsored academic and work experiences

These programs involve a three-way partnership between two universities and a global industrial partner of both universities. The students combine an education experience with the partner university and a work experience in another country with the industrial partner.

Ingolf Pruefer of John Deere, Mannheim Works reported on an exchange program sponsored by John Deere that has operated since the summer 2000. To date, 11 German students from the Fachhochschule Mannheim have attended classes at Iowa State University and made an internship with John Deere, Waterloo Works or PEC, and five U.S. students from Iowa State University have attended classes at the Fachhochschule Mannheim and made an internship with John Deere in Mannheim.

John Deere provides round-trip airfare for participants as well as the cost for accommodations and transportation within the U.S. The students receive a monthly stipend during both the study and work periods; the German students also receive a book allowance. Participants are guaranteed an internship at a John Deere facility. As a part of the agreement between the two universities, the host university charges no fees to the students although all fees at the home university remain unchanged.

The German students usually stay in the U.S. for approximately 12 months. They attend lectures for two semesters at Iowa State University and get practical training afterwards at John Deere or PEC, Waterloo. The U.S. students begin their experience with practical training at John Deere Mannheim followed by a semester of lectures at the Fachhochschule and a second practical training experience.

Industrial design projects

This approach shares most of the elements of the international design projects, which were previously discussed. However, in this case, there is an industrial sponsor for the activity who normally specifies the design project to be undertaken. Industrial sponsorship provides several advantages to the program, including more realistic design problems, support of practicing engineers from the company, and resources for communication, travel, and prototypes.

Barry Butler, dean of engineering at the University of Iowa, reported on his experiences with a program of this type that he has run since 1998. The program involves University of Iowa students (U.S.) and students from Universite de Provence (France). The industrial sponsor is the HON Company of Muscatine, Iowa.

This program now includes face-to-face meetings and a period of time during which the French students reside in Iowa and serve as interns at HON. When the program was initiated, however, it did not involve face-to-face meetings. According to Dean Butler, the face-to-face interaction has added appreciable value and improved subsequent electronic communication. The related team social activities also decreased student anxiety. Butler also noted that financial support from industry has been very valuable because these programs are highly labor intensive (of faculty time).

Industry-sponsored master's programs

In one form of this model, students travel to a host university to complete an industrially sponsored master's program. This program is similar in nature to the dual-degree program discussed above, except that it includes industrial sponsorship.

The University of Iowa and Iowa State University participate in a program of this nature with Rockwell Collins of Cedar Rapids, Iowa. Their home institutions under guidelines defined by Rockwell Collins nominate Chinese students from either Beijing University of Aeronautics and

Astronautics or the Northwest Polytechnic University of Xian. Students must satisfy the admissions requirements of the intended university and be approved by Rockwell Collins. They spend one academic year taking classes at one of the two universities and then move to Rockwell Collins, where they work on their thesis for six to nine months. Rockwell Collins provides funds for a stipend and other costs during their studies.

International faculty-industry collaborations

All of the aforementioned programs involve faculty members who support student exchanges. This model, however, involves a direct international experience for faculty, who take a leave at a foreign industrial organization to carry out one of a variety of engineering jobs.

Dr. Scott Chumbley of Iowa State University reported on his experiences at Perkins Engines in Peterborough, UK. During his six-month leave, Dr. Chumbley engaged in failure analysis, product development, and production support activities. The opportunity enhanced him personally and professionally. He experienced living in another country, received an industrial perspective of engineering activity, and gained a better understanding of personal ethics when challenged with the fact that his decisions might stop the line. The experience also helped him shape his research agenda to benefit industry. He suggested that six months is a minimum period for a visit of this nature.

Dr. Chumbley suggested companies planning such an exchange experience for faculty members arrange for housing, transportation, and an appropriate stipend. He also encouraged them to provide assistance and information regarding such topics as banking, the locale, culture, history, and so forth to the faculty member. The faculty member should also plan to share his or her background, expectations of the visit, and possible family needs with the host site. It is helpful if the faculty member can make a preliminary visit to the site before the longer visit begins.

Finally, Dr. Chumbley suggested that companies think proactively about bringing faculty members to their sites. Faculty can provide help for new product development, strengthen university relations, and help to develop students as future employees.

Proposed New Forms of Collaboration – Action Agenda

The participants in the GAIN Workshop were asked to define an action agenda for the next year focused on real, meaningful actions. The goal was to be able to demonstrate measurable success by the 2003 GAIN Workshop in Monterrey, Mexico. In selecting actions, the participants were asked to look carefully at the related benefits, barriers, and metrics for judging success. They were asked to assign actions to specific responsible parties and to set a timeline for achieving the desired results. The following action items were identified.

International co-operative education

The attendees agreed that it would be important to benchmark industrial co-operative education models in both the United States and other countries. This would help to identify the important aspects of successful programs so that others could replicate them as they implemented new programs.

A portfolio for international cooperative experiences will be developed, beginning with information from GAIN 2002. Once again this will be helpful in the institution of new activities.

Virtual collaborations

In order to facilitate virtual collaborations on design problem, it was suggest that academic-industry working groups be formed that can identify real-world, global projects. This will ensure that the problems being addressed by students are relevant and interdisciplinary. Investigation should also be undertaken regarding the use of new media-based tools to communicate.

An international team will be formed to develop new media content to assist in the instruction of mathematics and physics.

Summer programs

A multi-university, multi-cultural summer program of four to six weeks duration will be established between partner universities. The program will rotate among the members. A small number of students will be located at a partner institution for six weeks to complete a project under the direction of the host institution. German students will be placed on research teams in the U.S. for four months to complete their senior theses.

Research programs and technology transfer

International MS students will be recruited and funded to study abroad. The goal will be to obtain this funding from a single company. An industry mentor will be recruited to participate in a virtual, international design project or research program

Summary

Global perspective will be a critical skill for the engineer of the 21st century. College of Engineering must ensure that our educational environment offers a variety of challenging and rewarding international experiences.

It is important to remember that industrial partners have much to add to this dialog. They are not just potential sources of funding but also sources of ideas and solutions. They have faced many of the challenges now confronting the academic world as universities seek to embrace a global perspective.

E-LEARNING AND SOFTWARE ENGINEERING EDUCATION

Dr. Jin Huang

Ambow Corporation

5201 Great America Parkway

Santa Clara, CA 95054

1. Introduction

Education has seen quite a lot of changes in recent years and is faced with both challenges and opportunities due to rapid development in computer network, information technology and communication technology. The popularization of Internet has resulted in radical transformation in traditional education thinking, education methods, education content, education model and even education system. Including synchronous and asynchronous teaching/learning model and such technology as videoconferencing, Web-based training, satellite broadcasting, streaming media, E-learning is widely accepted around the world.

Engineering education will provide crucial human resources and intelligence power for boosting coordinated development in national economy and all round social advancement, ensuring essential transformation in economy increase, building up comprehensive national strength and international competitiveness and will become important drive for promoting new industries and new sources of economic growth. This can be represented as follows:

- ◆ Increasing demand for human resources due to integration with the global economy
- ◆ Economic globalization presents new requirements and challenge for content and educational model in engineering education
- ◆ Information, which increases explosively, requires new teaching methods and modes to meet needs of different levels

Without doubt, science technology has become a significant production factor. Human resources with the latest knowledge, innovative spirit and proficient skills are determinants in promoting productive forces. People, especially engineers hope to receive the best, the latest education to have sound qualities. However, lack of teachers and other teaching resources has become a bottleneck for the above hope to come true. Many people in underdeveloped areas can only wish that they could have the same resources and competitiveness as those in developed areas.

Today E-learning can enable their wish to come true. Excellent teachers and educational resources can be accessible everywhere in China, and even around the world. Competitive educational products in every subject with their own advantages will be developed. Therefore, the overall national educational level will be raised. We can also benefit from the globalization of education owing to optimum allocation of educational resources around the world.

Ambow Corporation has invested a lot in e-learning and software engineering education and has achieved good results and gained experiences. The open e-learning platform and Learning

Management System developed by Ambow are one of the most advanced e-learning support platforms and reach international high levels. Meanwhile Ambow is cooperating with University of Science and Technology of China to develop MSE to meet industry needs.

This paper will present Ambow's study and research in the application of e-learning concepts and the development of MSE.

2. E-learning and Distance Learning in China

A few years ago China launched "Modern Distance Education" project. Open education network came into being and so did life-long learning system. Formulated by Ministry of Education on December 24th of 1998 and approved by the State Council on January 13th of 1999, the 21st Century Education Invigoration Plan clearly states the following:

1. Implementing Modern Distance Education project and making full use of existing educational resources is a significant strategy for educational development when there is a lack of educational resources in China. As an important infrastructure, the project should be strengthened.

2. Based on CERNET (China Education and Research Network) and satellite transmitting system, transmitting capacity and network of CERNET will be further expanded. Integration information systems of distance recruitment of university students, student information management and online employment services will be established.

3. The satellite TV education will be continued in distance education. Current satellite education network will be renovated, central station will be built and connected with CERNET at high speed to reconstruct network of some distance learning centers.

4. High quality education software products are to be developed. Priorities are to be given to establish national distance educational database and some education software development bases. Educational development of China will gain momentum from all of the above actions.

CERNET has established many mirror sites of international resource websites when CERNET was first established. However, educational platform, including online teaching, virtual classroom, virtual lab, course management, is a must for e-learning.

The various demands for education put forward by the information society of the 21st century can be summed up to the following talents development model:

- The development goal is talents, who are highly innovative and very informed (able to acquire, analyze and process information) with all around development of moral, intellectual, and physical education.

- The content should emphasize on teaching students to learn how to learn, making them capable of obtaining and upgrading knowledge by themselves, but not on imbuing them with a lot of knowledge. High quality and high efficiency teaching should be ensured so as to accommodate the explosive development and rapid upgrading of knowledge.

- Varieties of development modes, free from constrains of time and space and fit for every subject, can meet the needs of life long education and national education.

It should be stressed that the goal of online education is not to enable teachers and students to learn to use Internet (which, of course, is the basis for online education), but to explore new educational system and teaching modes by making use of powerful functions of computers and network so as to develop talents, who can meet demands of the information times. If traditional school means chalk, blackboard and teaching by personal example as well as verbal instruction, modern

intellectual network school, with information technology as the basis, will lead to tremendous changes in teaching concepts, teaching means and content in traditional schools. Modern video & audio technology and multimedia courseware will enormously change information delivery model. Online delivery system will speedily transmit information, making interaction between teachers and students free from constraints of time and space. Not needing to go to school, people can study anywhere, any time, as they like.

Education mode includes teaching means and teaching methods. Teaching means refer to applying teaching instruments and media in teaching. Modern information technology provides a variety of teaching instruments and tools for teaching, e.g. multimedia classroom, electronic teaching plan, which help teachers be free from such traditional tools as chalk, blackboard and teach more flexibly and effectively. Explanation, formerly based on induction or deduction, may be changed to new patterns, including a multitude of teaching methods, such as context simulation, initiative quest, collaborative study, sense construction.

Therefore, the new generation online education platform will play a key role.

3. E-learning standard and support platform

3.1 Standards

Sharing of online education resources and communication make it necessary to set down online education technology standards to ensure sharing of online resources and interoperability between systems. Currently many institutions around the world are committed to formulating and promoting of online education technology standards. Such as standards of teaching management by computer by AICC (Aviation Industry CBT Committee), SCORM (Shareable Course Object Reference Model) by American Ministry of Defense, Learning system standards by IMS (IMS Global Learning Consortium) and IEEE1484. IEEE (Institute of Electrical and Electronics Engineers) 1484 is a set of online education standards formulated under the direction of IEEE (IEEE LTCS). Many organizations, including IMS took part in its formulation.

Instructional management systems put forward by IMS Global Learning Consortium has become one of the most influential industry standard. EDUCOM launched a research project of Instructional Management Systems in 1996, which later developed into non-profit IMS Global Learning Consortium.

Given current situations of and development demands for online education in China, research in this field has been begun. DLTCSC () has formulated Distance Learning Technology Standards Systems and divided distance education standards into 26 sub-standards, learner standard, teaching environment standards, educational service quality standards, localization standards, etc. The Committee also started some follow-up projects and set priority rank to formulate sub-standards. The draft of the standards has been formulated.

Ambow Corporation became a member of IMS in 2000 and participated in discussing some projects. Ambow was also involved in some work of DLTCSC.

3.2 E-learning platform

E-learning can be further divided into synchronous learning and asynchronous learning models. Asynchronous e-learning does not take place simultaneously. Students can study at their convenience. Examples of asynchronous training include self-paced computer-based training (CBT),

Web-based training(WBT), bulletin boards, and email, Less technical forms include audio/video cassettes, and mail order programs.

On the other hand, synchronous distance learning takes place for all students at the same time and information is accessed instantly. This form of distance learning provides more interactivity. Examples of synchronous e-learning include satellite broadcast, video teleconferencing, Internet conferencing, and chat rooms.

All of these technologies extend learning beyond traditional classrooms to encompass homes, museums, libraries, and workplaces. They also extend beyond the traditional school-age population to support life-long learners. Recently, e-learning has migrated more toward the Web, providing a wide range of services anytime, any place, for anyone.

Online training includes two teaching models, centralized teaching and decentralized teaching. A general training management platform is required, which is powerful in functionality and flexible in structure and multi-system supporting. The platform also provides such functions as training management (trainee information management, course management, instructors management, and graduation management, etc), courseware (stream media & non stream media) management and system administration.

The training platform system is composed of a central teaching site and many other outer sites, which are connected by Internet. The central site is at the core and other teaching sites assist to solve the bandwidth problem possibly encountered during the transmission of stream media courseware. The central site stores and administers all related data, documents and plays a key role in teaching, learning and managing of the training organization. Individuals and teaching centers with ideal bandwidth can study and work through the central site. The outer sites only store a copy of course documents from the central site. Students/trainees at the teaching centers can access the course documents at the local teaching site. It thus thoroughly tackles the bandwidth problem of transmitting stream media courseware from the central site.

Ambow online education platform, which is course-based, supports international and national educational industry standards and power a variety of teaching models, such as synchronous teaching, asynchronous teaching, instructor-guiding teaching and student self-paced learning. The platform also provides powerful and flexible functions of organization administration. Ambow platform mainly consists of 3 modules: courses (teaching/learning/management), organization administration and system administration. There are platform users with different access, including students, instructors, course administrators, organization administrators and system administrators.

Characterized by ease of administration (application of BROWSER/SERVER ensuring entire upgrading by one maintenance), high scalability, ease of further development and stability, Ambow platform, applying JAVA & J2EE, supports modular structure, multi database, multi operating systems and application servers.

The features of the platform are summarized as follows:

1. Supporting multi operating models

The platform supports diversified security strategies, ways of fee administration and user organization, which makes customization for clients possible as they need. The platform can be used on campus online education and off campus distance education. It can also be used for free online education and pay education.

In addition, a variety of course strategies enable course administrators (instructors) to decide

whether s/he enrolls students into the course or s/he permits students to enroll by themselves. The administrator (instructor) can also decide whether the course is free or not, how much students have to pay if it isn't free. S/he can also decide which part of course documents and when will be available to students. The platform also supports multi strategies in setting of specialties, schools and departments so as to support multi operating models.

2. Course centered teaching is possible in teaching system

Ambow platform enables all teaching activities between instructors and students center around the course. The activities include teaching, learning, assignment, question and answer, discussion, course tools (e.g. making notes), assessment and other real-time and non real-time communication. In this way, course users and the course interact closely, with distinct relationship between instructor and students. The teaching content organization, communication, question and answer, assessment and evaluation are much more pertinent with teaching objectives to result in more efficient teaching.

3. Supporting multi teaching/learning models

The model of students self-paced learning under instructor's guidance is advised. The platform also supports synchronous and asynchronous teaching.

4. Desirable personalized teaching can adequately represent instructor's importance and arouse their enthusiasm.

Instructors have absolute access to their courses and manage their students. On their own they can manage the course content, make teaching plans, answer students' questions, give assignments and assessments according to their experience. They can also improve their teaching on the basis of evaluation results and statistics. Different teaching outcome may be gained if different instructors teach the same course (e.g. courses the university purchased). This is where importance of the instructor's experience lies.

5. Course management system is a powerful online course editing and management system

The course management system makes online editing and management possible and the content includes course structure, course information, staff information, course documents, FAQ, external links, assignments, assessments, notes.

6. The platform enables teaching management to separate from courseware making so as to make use of a variety of courseware from different sources.

The separation of teaching management from courseware making enables instructors to choose authoring tools (e.g. online authoring tools and any other editing tools) they know well to make courseware. On the other hand, the platform is capable of effectively managing courseware in any format (e.g. doc, ppt, html, swf, asf, bmp, gif, mp3, etc). Thus, more teachers can easily teach via Internet and various courses can be managed on the platform. Additionally, the platform can facilely integrate courseware developed by the third party.

7. Plenty of study and communication tools

Tools available on the platform include notes, course calendar, assignments, discussion board with editor, virtual classroom, chatroom, email, whiteboard.

8. Powerful real time delivery and communication tools.

Ambow's real time interaction classroom is currently the only tool of its kind in China. This tool, for Internet-based multimedia synchronous teaching and communication, was developed with cutting-edge two-way stream technology. The one-to-many communication model enables thousands of students to simultaneously attend one class, and to share documents of various formats, applications,

web pages, whiteboard and desk. The online real time communication can be conducted through writing, audio, video, and digital white board. Instructors can supervise the teaching by online hand raising and online exam. The function of class recording can record the whole process of the online teaching to form a digital document for archive or review.

9. Integrated assessment system

Instructors can edit various test papers online, including a variety of questions. Instructor can insert images or animations in papers and supply many more answer choices for multiple choice questions as needed. Such properties as availability and immediate response can be set. Objective questions (e.g. multiple choice) can be automatically evaluated and marked to speed up paper marking and lessen instructors' working load. Subjective questions (e.g. options of short answer/essay, fill in the blank) have to be evaluated manually. The results will be automatically recorded in the gradebook for instructors and students to review.

10. Practical assignment system

Assignment tools on Ambow platform help instructors to give and correct assignments in any format and students to submit assignments in any format they like.

11. Excellent tracking system to facilitate supervision of teaching and to improve teaching.

The tracking system can help instructors to understand the frequency and time that students use various tools and access course components. Instructors can also collect statistics of overall summary of course usage to adjust their teaching with a definite object.

12. Multi models of organization administration

The platform provides multi models of organization administration of various levels, including university, school, department, specialty and teaching centers. Clients can customize their model of organization administration, as they need.

13. Flexible role and authorization system in organization administration system

It's easy to add new roles, modify and remove roles in organization administration system and assign corresponding access. The adaptability of organization administration system is greatly improved in this way.

14. Support international and national online education standards with broad prospects

The platform, supporting main international and national online education standards (e.g. IMS, AICC), enables instructors to make use of various standard course resources in and out of China.

Technology features of the platform are summarized as follows:

1. The application of J2EE-based technology and MVC architecture ensure the system's interoperability (operation systems can be Window or Unix server, application server can be Weblogic or JBOSS), scalability, capability of expansion, security and reliability.

2. The application of B/S (browser/server) network computing format makes the system end user free from maintenance and facilitates the update of the system.

3. Information transmission through event mechanism among layers. Coupling of layers is reduced and independence of different layers is enhanced so that each layer can be individually developed and maintained.

4. Connection between business layer and data layer through DAO. The application of DAO, ensuring the separation between business logic and database, enables the system to power a variety of database server, e.g. SQL server, Oracle, MSSQL.

5. The application of Cache. Presentation layer can cache frequently used data so as to lessen access to database and to enhance the performance of the entire system.

6. The application of front controller at the front end allows batch management of user requests, e. g. choice of response interface, security check, code switch, log to improve the security and capability of expansion of the system.

7. The establishment of a stable architecture, capable of being expanded on J2EE platform ensures the stability, reliability and capability of expansion of the system.

8. Modular design enables the platform to independently separate or combine modules as needed.

9. User management of various levels and reliable security verification.

10. Robust capacity of load balancing.

11. Outstanding expansibility with user-friendly interface, convenient for further development with expansion capability.

12. Follow and support international and national standards.

13. The platform is capable of switching between Chinese and English version.

Ambow platform, tallying with international standards and conforming to the reality in China, was developed with the application of first class architecture in Silicon Valley after detailed and scientific demand analysis and research in and outside of China. The platform is equal to similar international platforms of high class in terms of technology, functionality, teaching concepts and supporting online education standards. The platform, with the open J2EE-based architecture that is entirely up to international online education standards by IMS, was accredited by Central Audio-Visual Education Center. The platform is evaluated as a platform, which fills a gap in online education platform in China and leads in products of its kind and is characterized by advanced design concept, well-defined structure, super stability, expansibility and flexibility.

4、 Software engineering education in China

Information industry has become the main driving force for global economy development. At the core of information industry lies software industry, which is profoundly impacting the way we live and the way we think. Software industry is one of the industries with the highest return on investment and is constantly transforming the planet where we live. It is estimated that software and information market of China will increase at an annual average growth rate of more than 30% and provides wide opportunities for software professionals to realize their ambitions. However, traditional education is seriously divorced from social demands, which result in a great lack of software professionals and improper talents structure in China.

According to a talents demand survey in 10 big cities, such as Beijing, Shanghai, Guangzhou, demands for talents in software industry came first by a big margin. The annual lack of software professionals is about 20, 000. With the increasing modernization, the problem is becoming more and more severe. The lack of software professionals has badly restricted the software development in China.

Conforming to the trend of the times, education should be combined with software industry for development, with software development trends and demands of China in consideration. The main goal of software engineering education is to develop talents, who are professional, standard and international with practical knowledge and are urgently needed in software industry and national

economy development. What the society demands is what the students learn, which is what is needed in businesses.

Given the above situation in China, Ministry of Education of China approved 35 universities to cooperate with world top companies or universities to recruit MSE and to develop high quality and internationally competitive software engineering talents for technology and management in unusual way. The totally new pattern of developing MSE advocated by MOE of China aroused intense responses in the society. The cooperation in education is to solve the problem of lack of software professionals.

MSE focuses on developing senior talents for design, development and management in software engineering and talents who can work independently and have innovative spirit. The first MSE students recruited by Ambow Corporation and University of Science & Technology of China has begun their study in Beijing and Guangzhou.

University of Science & Technology of China (USTC), a comprehensive national key university and subjecting to Chinese Academy of Science, is mainly focusing on frontier science and high-tech and subjects in management and humanities as well. The guiding principle of “the whole academy supporting and institute & department collaborating” is brought into effect at the university. All teaching and research resources are devoted to education. USTC first recruited graduate students in 1964 and established graduate school in 1978 after approved by the State Council. The graduate school was ranked as one of the top 10 graduate schools by MOE.

The University can currently accredit doctorate degree in 13 first level subjects, master degree in 3 specific subjects, 60 specialities for doctorate degree study and 79 specialities for master degree study. There are a great number of supervisors for graduate students and many of them are very young. Currently there are 280 doctorate supervisors; among them are 15 academicians of two Academies (Chinese Academy of Science and Chinese Academy of Engineering). Ambow, located in Silicon Valley, and USTC explore vigorously and fruitfully in education cooperation. Making full use of first class technology and teaching resources to ensure delivering the latest knowledge and developing students to completely suit China market and IT industry, the cooperation between these two parties perfectly integrate international and local resources.

5. Development of software professionals---Our concepts and attempt

Practice is a necessary step for developing software engineers. Ambow Corporation, with branches of Beijing Ambow Info Race, Beijing Ambow Online and Suzhou Ambow and such business partners as Sun and BEA, provides excellent environment for students to practise. It's an entirely new model for businesses and universities to cooperate in developing talents. Particular emphasis is placed on practice in this model, where students are to be involved in management, project/product development before they finish their formal study. This model greatly reduces time needed to develop talents to some extent. The development plan we are using is to integrate with international software, to be the first in software engineering, and to take advantage of internationally excellent talents in technology and management.

In order to develop software professionals, who are internationally competitive, world oriented latest technology, clear education aim, strict quality assurance and supervision are required. The development plan of software talents is permeated with new ideas and development models. Unique characters can be found in compiling & design of teaching plan, course offering, introduction

& further development of foreign courses, selection and collaboration between chief expert professors and assistants for face-to-face teaching, supervision of entire teaching process, international learning environment and practice.

To develop software into a huge industry, it's necessary to standardize software development and follow international practice such as CMM (CMM: Capability Maturity Model formulated by Carnegie Melon University. CMM, with 5 levels, is mainly to improve management of software companies).

Headquartered in Silicon Valley, Ambow has a great number of software engineers, who, with abundant experience in IT industry, obtained their master or doctorate degree in computer science in America and are familiar with management, organization and operation models of Silicon Valley. These engineers are also experienced in software outsourcing and developing software engineers.

Development plan of software engineers of Ambow and software education system provide authoritative IT course in their course offerings, such as CMM & RUP, OOA/OOD, software project management, UML/Rational Rose, templates & document at different stages of software engineering, JAVA/J2EE.

Meanwhile, given the deficiency in current software engineering education in China, the development plan also covers latest professional certificate system, in line with international standards. Practical courses, such as MS, Oracle, Sun certificate programs are also included in software education.

There is a gap in levels of process management and integration between Chinese software businesses and International ones. Software education by Ambow will bridge the gap, because courses by Ambow, such as software engineering templates, management analysis of software projects, stress the development and training of students' integration ability. In addition, foreign textbooks and other teaching materials (audio & video) will be directly introduced in some specialized courses so as to help students to adapt to international environment, which is becoming more and more open to make them more competitive.

Teaching of MSE co-recruited by Ambow and University of Science & Technology is conducted in Beijing and Huaruan Software Park in Guangzhou. Students study at immersion school, which is intended to develop senior talents in software design and development. Students can practice at Beijing Ambow and Shanghai WebEx. Those graduates, having learned the most prevalent software courses and practiced in software companies, will be competitive and quickly adapt to working environment and meet companies' demands.

E-learning is an important means in software engineering education. In order to take advantage of teaching resources of China and Silicon Valley in Beijing, Guangzhou and Shanghai, online education is necessary. One significant connotation of online software engineering education is organizing various online teaching activities, online courses and online lab.

Currently there are quite a lot of online courses, which link documents, images and animations by hyperlink, plus a little of synchronous or synchronous online questions and answers. They are far from enough for developing software talents. Our goal is to explore a entirely new teaching model, which will utilize network to create ideal interacting and learning environment.

Problem Solving, a teaching assistant experiment, was organized after delivery of fundamental software engineering courses.

Professors raised practical questions in software engineering design and told students about clients' requirements and standards for software design. All students, individually or in-group, would participate in the Problem Solving experiment. No matter where they are, after about one week, they sent their functionality design and detailed frame to professors and their peers through e-learning platform. Professors and students from anywhere evaluated the design and frame and commented on different designs. Professors encouraged students to express their different opinions about the problem at this stage.

Next, groups began their coding on the basis of their design and data structure, and sent their program to professors and other groups after finish coding. All programs would be evaluated according to their running time and performance.

Then, correct solutions to problems, functionality design and structure design by different groups would be analyzed, discussed through e-learning platform.

Most students, who participated in the experiment, showed great interest 3 reasons.

First, problem resulting from practice more easily stimulate students; interest and imagination. Second, more than one solution could be tried to solve a problem. Finally, it is exciting to communicate and contest with others via Internet. Professors also said that their students were enthusiastic about the experiment.

Additionally, classroom was connected with professional engineers through e-learning platform, which enables students and engineers to work together on problems, to which solutions are urgently required in industry.

The above development model is based on two prerequisites. One is that students and engineers study and work together, and that computer network improves their work efficiently. The other is that students program by themselves and share their work with engineers and their peers through communication network.

In short, it is worthwhile to do further study on the following topics, how to establish an effective model for developing software engineers, how to teach and learn efficaciously through online education platform, and how to take advantage of resources in developed areas (e.g. Silicon Valley) to develop a great number of talents. We will continue to work on them.

GM CHINA ENGINEERING EDUCATION

Keh Tung

Training and Development Director for China

General Motors University

Shanghai GM Training Center

Shanghai, PRC

GM's vision is to be among the top three automakers in China. Prior to 1999, GM was primarily a vehicle importer. With a major presence on the ground through its three manufacturing joint ventures, GM expects sales to exceed 200,000 units per annum. GM's primary brands in China are Buick and Chevrolet. In addition, it imports vehicles with the Cadillac, Opel and Saab nameplates.

One of the crucial elements for GM's sustained success in China is an ongoing dedication to supporting its employees through "lifelong learning." Our resource allocation and cumulated learning hours and activities have been second to none in the past and will remain so in the foreseeable future.

A key to GM achieving its lofty vision is the development of its domestic workforce. Among its primary goals in this area is the development of competitive talent for premium brand deployment. One of the strategies being adopted is Training-the-Trainers (T-3). GM is localizing GM's treasure trove of knowledge, skills and materials through the T-3 process.

GM China is a pioneer in this area. Thus far it has provided benefits in the form of lower costs through the optimization of local university professors, who have an added advantage of a unique insight on culture, language and learning efficiencies. As a result, quality is equal to and often better than learning events conducted by foreign subject matter experts with jetlag. In addition, delivery lead time is greatly reduced and flexibility enhanced without the international travel constraints.

GM also is cooperating with leading Chinese educational and research institutions through programs that are win-win for GM and its academic partners. GM has established joint programs with Beijing's Tsinghua University and Shanghai Jiaotong University. These programs – which are integrated with GMU - are focusing on knowledge transfer, training, facilitation, education and research. Over the past seven years, some 5,000 individuals from GM, our joint ventures and local suppliers, and academic institutions have received high-quality practical learning experience at these two institutions.

The quality of the programs is helping GM deliver on its goals of quality, service, technology and price. In the area of quality, GM seeks to reach a level equal to or higher than GMU satellite sites. In service, it seeks to achieve a 48-hour lead-time pull service. In the area of technology, it seeks to successfully utilize GMU courses and the PACE program. In the area of price, it seeks to be economical.

Just like elsewhere around the world, GM adheres to the Plan, Do, Check, Action and Continuous Improvement Processes in China. It is fully committed to the long-term involvement and investment in engineering education.

MERGING OF SCIENCE AND ENGINEERING EDUCATIONS: CONCEPTS AND PRACTICE

Xiaomin Ren

Beijing University of Posts and Telecommunications

The merging of science and engineering educations (MSEE) is a trans-century issue for higher education in China and the world over, where various reforms are being carried out intensively. In recent years, Beijing University of Posts and Telecommunications (BUPT) undertakes a reform project of higher education of the 21st century named Study and Practice on an Education Mode Featuring the Merging of Science and Engineering Educations and the Relevant Course Systems in the Disciplines of Electricity, Electronics and Information, which was authorized by the Education Ministry of China and a loan has been provided from the World Bank. This project aims at establishing new concepts and theory of MSEE and demonstrating a typical mode of MSEE in BUPT. Many efforts have been made to conduct this project.

I . Concepts

Concept 1: MSEE is of imperative necessity

Over a long period of time, as a common pattern of the higher education of science and engineering in our country, the disciplines of science and engineering are separated and engineering gains more attention. This has caused apparent defect in the education of genius, especially in bringing out the initiative and practical talents in students to some extent. In the world's perspective, with the acceleration of the development of science and technology, the trends of discipline infiltration and merging have become increasingly evident, thus further study is required on the relationship between the education of engineering and the education of science.

Therefore, according to the demands of the development of science and technology and the advance of the society, following the law of education itself, we find it our duty-bound historic task at the beginning of the 21st century to scientifically define the education of science and the education of engineering, to correctly understand and coordinate the relationship between the two, thus to make a strategic adjustment in the pattern of the education of both science and engineering in China with an expectation of a brand-new model of MSEE.

Concept 2: MSEE is of actual operability

The basic adoptable ways to carry out MSEE should be as follows:

1) Pre-condition – Making both science and engineering disciplines powerful in one university

The pre-condition of MSEE is to set up and reinforce both science and engineering disciplines at a same university to achieve a kind of organic promotion and mutual benefit.

2) Current trends – ‘Science for engineering’ and ‘engineering for Science’

‘Science for engineering’ means emphasizing academic potential in engineering education through reinforced study on fundamental sciences, which enables the students in the discipline of engineering to acquire a solid grounding in theoretical knowledge, a good quality in science and a staying power in the development of their life-long pursuit of engineering practice.

‘Engineering for Science’ means incorporating engineering training in science education to establish a certain kind of engineering background for the students in the discipline of sciences, by means of which they are cultivated with a spirit and style of study in putting theory into practice, and their advantage in the knowledge of sciences can be fully brought out with the help of the engineering consciousness.

3) Forward-looking move – Science-engineering integration

In some fields, there is less and less distinction between science and engineering. Integrating some science specialties with some engineering ones in these fields according to their internal relationship and establishing some new cross-disciplinary specialties is undoubtedly a forward-looking move.

Concept 3: MSEE should provide more liberty for students

Our present course pattern cannot timely meet the needs of the new trends of infiltration and integration of disciplines, nor can it meet the special needs of development of individuals. Therefore, it is necessary and reasonable to begin with the small proportion of students with special potentials and interest, and encourage them to design independently their own specialties of individual characteristics. It is regarded as ‘recruiting men of all talents’.

Concept 4: MSEE is referred to the merging both in feature and in nature

Whether it’s above mentioned ‘current trends’ or ‘forward-looking move’, they all involve in them the problem of the structure of knowledge and the problem of education of methodology (including scientific methodology and engineering methodology). The former problem includes in it the carrier of the connotation of disciplines and it’s the “feature” of academic education. The latter problem includes in it the spirit of discipline training and it’s the “nature” of academic education. In the practice of MSEE, we should make the science and engineering educations merging together not only in feature but also in nature, and the merging in nature is more important. To put it in another word, we find it not only the necessary content but also the essence of the MSEE mode to reinforce the education of scientific methodology and engineering methodology while special knowledge structure designs are performed.

II. Practice

1. Setting up a framework of disciplines to achieve organic promotion in both science and engineering

BUPT is a multidisciplinary key university with information science and technology as its special feature, with engineering disciplines as its major pursuit, with the combination of disciplines of engineering, management, humanities and sciences as its common target of development. It is among the first 61 key universities authorized by Ministry of Education as members of ‘211 Project’.

BUPT presents its strength in the field of communications and information with four national key disciplines (communication and information system, signal and information processing, electromagnetic field and microwave technology, electric circuit and system), two municipal key disciplines (physical electronics and computer applying technology), a national key laboratory

(information switching and networking) and a number of other leading laboratories. But these disciplines and their research orientations are all confined to engineering. Disciplines of science are comparatively less developed. This phenomenon cannot meet the needs of the practice of MSEE education mode. Therefore, the top priority task in the reform and construction of BUPT is to set up a framework of disciplines to achieve organic promotion in both science and engineering.

For this reason, BUPT set up its first school of sciences in history in the year 2000. Meanwhile, BUPT devotes major efforts to bring to their full play the tradition and style of emphasizing both science and engineering disciplines in School of Information Engineering; to explore the accumulation of experience in the education of applied sciences in School of Electronic Engineering, to enhance the scientific quality in School of Computer Science and Technology, to encourage the teaching and research work in School of Telecommunication Engineering to extend to some degree to the fundamental level, to summarize and popularize the theoretical contributions made by the professors from School of automation. BUPT has also brought up on the agenda the establishment of the discipline of biological information. All these efforts have made a meaningful step on the way to setting up a framework of disciplines to achieve promotion in both science and engineering.

2. Attempting different patterns of MSEE

As has been discussed previously, MSEE can follow several patterns such as ‘Science for engineering’, ‘Engineering for Science’ and ‘Science-engineering integration’. We have made a choice of some undergraduate programs of typical significance, worked out a relevant curriculum and started the pilot reform on them.

‘Science for engineering’ pattern: Following this pattern, the pilot specialty is Electronic Information Engineering, which, as its name indicates, is typically engineering. This pilot specialty puts into effect the principles of ‘strengthening the foundations and broadening the specialties’; furthermore, a training program called Initiative-Enhancing Experiments was started and noticeable results have been achieved.

‘Engineering for Science’ pattern: Following this pattern, we chose three specialties of science as pilots – Mathematics and Applied Mathematics, Applied Physics, as well as Information and Computing Science. As a feature of the first two, the undergraduate programs of science will be followed up with graduate programs of engineering. In the last specialty, a ‘3 years + 1 year’ undergraduate plan attaching more importance to practice has been adopted by undertaking research and development training in almost the whole last year ,

‘Science-engineering integration’ pattern: The pilot specialties following this pattern are Electronic Science and Technology (engineering), Optical Information Science and Technology (science), and Biological Physics and Information Technology (individual program). Among them, the individual program has attracted special attention in higher education circles in China and the society for its novelty.

3. Implementing the education of both science and engineering methodologies

We’ve fully realized the importance in implementing the education of both science and engineering methodologies.

At BUPT, teachers are encouraged to embody the education of methodology in the process of every teaching hour, in every textbook and in other teaching materials. Students are also encouraged to read literature of science and engineering methodologies. Meanwhile, lectures concerned are often conducted on campus.

Based on the principle of teaching the students according to their aptitudes, BUPT has for long adopted the methods of graded teaching when giving the basic courses such as College Physics and Higher Mathematics. It now adds to it the courses such as Mathematical Analysis for the purpose of laying an even more secure foundation of sciences for the engineering students and helping improve their understanding and observing of science methodology. BUPT has also sponsored the relevant textbook compiling. The textbooks like Higher Mathematics and Linear Algebra have embodied in them the concepts of MSEE.

While teaching specialized courses, a combination of the introductory courses of disciplines and a series of different specialized courses not only broadens students' view of specialties, but also ensures their training in engineering methodology.

All these aspects of practice are gaining more and more approval from both professors and students.

As a new educational theory and education mode, MSEE represents the orientation of development in the higher education of science and engineering of the 21st century. It is imbued with great vitality. We'll carry it on and deepen and improve it on its way to perfection, with the ultimate goal of turning out more and more highly qualified students of science and engineering and making contribution to the reform and development of higher education of science and engineering in China.

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A BLUEPRINT OF MAKING ENGINEERING EDUCATION IN CHINA IN LINE WITH INTERNATIONAL PRACTICE

Bi, Jiaju

Tongji University

Shanghai 200092, China

How can the engineering education in China be internationalized? What is the route it should take?

“Be internationalized” means that the engineering education should have the common characteristics of internationally recognized engineering education, especially its standard and quality.

“Be localized” means that the engineering education in China should have the local individuality, especially the culture and humanity spirit of the country, and the devotion to serve the country.

The engineering education in China should be both internationalized and localized, but in this paper the emphasis is put on internationalization.

1. To establish an internationally comparable standard for engineering education in China

To examine the level and quality of engineering education in one country, firstly you should review its standard. For the new century, the standard for engineering education in China should meet the needs of the new era and be comparable to those of developed countries.

In many countries, new standards for 21 century have been established. For example, a new standard for engineering education in US is the new accreditation criteria published by ABET, and a new standard for engineering education in UK is presented in a series of documents published by QAA, namely, qualification framework, subject benchmark, program specification and others.

There is no such standard particularly for engineering education in China. The only academic standard published in “Regulation of the PRC on academic degrees” (1981) is available generally for all branches of learning.

The expected standard for engineering education should be unique in China. It should be the only standard applied by the government, higher education institutions, professional societies, accrediting agencies, registration bureaus for engineers and also for students and employers.

The unique standard will certainly help to raise the level and quality of engineering education as a whole, to improve the educational administration, and to make easier for foreigners to know and understand the engineering education in China.

2. To strengthen the innovation and development of engineering education to meet the needs of the standard.

The innovation and development include reduction of the number of programs and broadening of the contents of them, referring to the international practice; revision of the curricula; strengthening of the international cooperation in engineering education with strong partners; and establishment of life long learning system.

Now there are 72 different programs in engineering field in China. It will be difficult to realize international mutual recognition of the same or similar programs. For example, in 1998, about ten narrow programs were merged into one civil engineering program in China. It removed the barrier for the conclusion of an agreement entitled “Mutual Recognition of First Degree Courses Accreditation” signed by the Ministry of Construction of China and The Institution of Civil Engineers of UK.

Tongji University and many other institutions in China have revised their curricula of engineering programs. The courses of basics of science and engineering are broadened and renewed. The engineering professional courses become more varied and optional, and reflect further the frontier of engineering.

The courses of social science and humanity should be adjusted according to the knowledge and ability a practicing engineer should possess. The knowledge and ability should cover the field of politics, economics, philosophy, ethics, communication, management, culture and so on. The teaching hours of foreign languages should be reduced when the standard in secondary schools is raised.

The experience of Sino-German College (CDHK) and Sino-French Institute of Engineering and Management (IFCIM) of Tongji University and also the experience of other institutions show that the international cooperation in education is advantageous to the raising of quality and standard, and to the more rapid and thorough integration of engineering education in China into international practice.

3. To establish a national quality assurance system for engineering education

Quality assurance system is nowadays adopted in higher education of many countries. It has been proved to be an effective method to maintain and enhance the quality and standard of education. In general, an engineering organization is authorized by the government to be responsible for professional accreditation in engineering field. This organization usually will cooperate with different societies of engineers to exercise accreditation for different programs. Such organization in US is ABET, which involves 20 societies of engineers, and in UK is Engineering Council (EC), which covers 36 institutions of engineers.

Engineering organizations such as ABET and EC usually know and judge the quality and standard under the other jurisdictions through their quality assurance systems, and recognize the accreditation conclusion and the degrees of one another through mutual agreements. Washington Accord is a typical model of international mutual recognition agreement in engineering field.

The above-mentioned quality assurance system includes: internal self-evaluation system; external professional accreditation system; accrediting agencies in particular engineering disciplines, namely civil, mechanical, chemical, electrical, etc.; and an umbrella organization covers all

accrediting agencies in engineering field. Unfortunately there has been no such sound national system in China so far.

It is in urgent need to establish such a national quality assurance system in engineering. A number of engineering programs should be accredited according to the internationally comparable standard. An authorized engineering organization should contact and discuss with counterparts in other countries such as signatories of Washington Accord. It will take several years to get successful results!

4. Engineering education should provide a solid foundation for the Chinese engineers to enter the world market

Most of the engineering graduates will become practicing engineers. In many countries, registration or licensure systems are applied for most of the disciplines in engineering field to manage and control the quality and quantity of engineers. The requirements for registration include: education requirement, experience requirement, and examination or review requirement. The typical education requirement is a first degree granted from an accredited engineering program. It shows again the importance of accreditation, and the responsibility of engineering education.

As regards the mutual recognition of the qualification of engineers, ten signatories, namely, Australia, Canada, Hong Kong SAR, Japan, Korea, Ireland, Malaysia, New Zealand, South Africa, United Kingdom and the United States signed to the Engineers' Mobility Forum Agreement last year. The purpose of the EMF Agreement is to establish and maintain an EMF International Register of Professional Engineers and this Agreement intends to provide a framework for the recognition of experienced professional engineers by responsible bodies in each of the signatory economy.

A national multi-disciplinary registration system for engineers has not yet been established in China. There are only registration organizations in a few engineering disciplines under the guide of Ministry of Construction.

5. The conclusion

In one word, if China wants to make its engineering education in line with international practice, it must raise its standard and quality first. In the mean time, it must establish a national professional accreditation organization for engineering programs of different disciplines and a national registration organization for engineers of different disciplines. They are the basic conditions and indispensable foundation for taking part in the international mutual recognition of engineering programs, degrees and qualification of professional engineers.

Almost all the issues above mentioned are at the national level. They are beyond the power of one institution or unit. So the key problem at the moment is who will play the leading role or which organizations representatives from are suitable to form a preparatory group for solving these problems. Can we submit a suggestion to the central government? I would like to have your comments and suggestions, and I have great expectations of the Academy of Engineering.

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INNOVATION AND CREATION IN ENGINEERING EDUCATION

Zhou Zhewei

Shanghai University

In the law of Chinese higher education, the sixth item said, the school of higher education should cultivate students with innovatory spirit and the ability of practical work. How to cultivate the students with innovatory spirit becomes a topic of hot discussion in Chinese universities. Engineering education occupies a significant position in Chinese higher education. So it is not unnecessary to discuss how to cultivate the students with innovatory spirit.

This paper explored this topic from the relation of engineering education and basic courses, the atmosphere engineering education should create and the cooperation between universities and society.

I. Engineering education should be based on comprehensive basic education

The innovation designed as the main task of higher education means the contributions making the progress of social sciences, natural sciences and engineering techniques, or the preparation accumulated for the progress. This kind of progress cannot be made by some sudden inspiration or tricks. It has to be based on the deep understanding of the present situation. In the contradictions in the present situation involve the results of the historical development and the factor brewing the future development.

Without the knowledge of history, the analysis of the present situation, one cannot find the factor brewing the future, and will not make the progress. If we look at those brilliant successful people in engineering, it is not difficult to notice that their success and the unique idea different from ordinary people did not come from certain knowledge or skill, but from their deep understanding of the situation, even their decency including their well cultured with liberal arts.

So the comprehensive basic courses are indispensable for the engineering education cultivating innovation. The crucial issue is to provide a vivid developing course of development, let our students enjoy the elegance and brilliance, but not confuse them with a huge amount of rules and conclusions.

The students should understand how these courses make progress by breaking various limitations, and much more important should know there are still limitations waiting to be solved.

It is even a redundant to emphasize the importance of **inter-discipline** to engineering education. The knowledge structure of basic education should be more comprehensive. But it is still a critical task to set up **propriet** basic courses to cultivate comprehensive developed people rather than simply prepare for the later courses.

II. Engineering education should encourage the desire to create beautiful things

Innovation is breakthrough. For thousands of years, the mankind makes progress because of their incessant struggle for improving their living condition. With this purpose, people try to understand the world, to change the world, to make a better condition for their lives. To encourage youngsters having wishes of creating beauty should be an important goal of education.

The glory, splendor, wealth and rank always attract people, especially in those rapid growing period, but they are just the surface waves of historic tide, they never decided direction.

Thus the guidance to young people's ethnic value is very important. Without the pursue of creating beauty and the ultimate care of the mankind fate, it will be very difficult to stand with the lonely path, to against various attractions. The right guidance is crucial to younger generations, since they will tend to follow the fashion, the surface glory and the instant interest.

III. Engineering education should provide opportunity to try

Fighting for success is most natural thing for young people. The test system in schools provides with the students a ladder that can show their success continuously. In schools and universities in China, the student who can climb this ladder successfully will always be taken as the best student. When students climb up on this ladder, the most important thing is to follow the existing rules, don't make any mistakes, which result in the strangle of youngsters' innovation. For engineering education, such system may cultivate some engineers who are very familiar with **criteria**, but will never produce masters who will create brilliant structures.

Engineering education should provide students with opportunities to try, and encourage their immature impulse of creation. If take the mistake simply as failure, the goal will be making mistakes as less as possible. With the purpose of innovation, the goal should be changed into not making the same mistake twice. Never made any mistakes means the loss of opportunity and the new way.

In the process of education, we should urge students try new ways and thinking. Tests are necessary, but the marks should not only give to correct results, but more importantly also to right method. The innovatory way of thinking should get higher marks than correct answer.

IV. Engineering education should be carried on cooperatively by school and society

We were used to the saying, "Universities are the cradles of engineers". It cannot be heard recently. Everybody knows that a qualified engineer cannot be formed without the experience of practicing.

Nowadays, the speed of new developments in engineering and techniques exceeds that of any passed time. It is almost impossible to catch up such development in education just count on universities. To promote the innovation and creativity in engineering education, we have to combine the resources of universities and society together.

One possible model may be, universities should emphasize the comprehensive education in first two years. For the more professional courses in later two years, university should introduce the **R&D** of business into the campus, the new products and techniques into the classroom. The engineers may be the more competent instructors of professional courses. Some companies have already set the rules that if any engineer wants a promotion; he or she has to teach certain amount of courses in schools. This is a very clever idea, which will raise the level both for teaching in schools and ability of engineers.