Implications of Curriculum Changes in the USA and Japan for World-Class Education in Developing Countries

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Abstract

A detailed study, including personal visits to the counties involved, was performed assessing the current curriculum changes in the USA and Japan for world-class engineering education in the 21st century. The new engineering programs in Japan are compared with those in the USA and marked differences in the educational strategies between the two countries are noted, reflecting the differing educational objectives and cultural backgrounds. Implications of the curriculum strategies and initiatives by the Developed Countries are discussed in the context of the different challenges facing the Developing Nations, using the case of China. The necessary socio-technological ingredients for world-class education of engineers in the 21st century are identified.

Introduction

Profound changes are currently taking place in engineering curricula at universities across the United States. Invigorated by the NSF-funded centers for innovation and enhancement of engineering education, such as the ECSEL coalition led by Penn State, and others at the University of California, Berkeley and at Cornell, both the public and the private schools are reviewing their curricula with an eye on the perceived different societal needs in the 21st century. In particular, the new role of design and its integration over the four years of study, an emphasis on understanding the impact of engineering on society, and the need to think in terms of global markets and foreign cultures, has brought about unprecedented challenges. To meet these challenges, it is no longer sufficient to re-engineer university education, one must also include reforms in high school curricula as well as in post-degree continuing education for life-long learning and professional growth.

Based on a detailed study and personal visits by the author to Europe, Japan and China, it is evident that the United States is in the forefront of this new curriculum thinking which attracts considerable attention in Far East countries, both developed and developing. Is there a model for the necessary academic ingredients for world-class education of engineers in the 21st century?

Curriculum Changes in the USA

The United States has some of the finest universities and colleges in the world. Its engineering universities numbered 269 in 1994, of which 204 have been regularly evaluated and rated each year ***by U.S. News and World Report.*** Over 60% of high school graduates in America go on to some college. In 1994, there were 14.3 million students enrolled, of whom 55.1% were female ***(Chronicle of Higher Education).*** The comparable figure for Japan is 37%, Germany is 30%, France 28%, and Britain 20%. However, the attrition rate among college students is enormous. Only 15% of entering students complete a bachelor's degree four years after high school, while 46% do after six years. In engineering, the figure is 36%.

To determine the status of engineering education, one should first answer a question: 'What is good education?" One institution (MIT) defines good undergraduate education as one which "provides graduates with the attitudes, habits and approaches to learning that would ensure a lifetime of technical competence, social contribution and personal fulfillment." Thus, undergraduate engineering education should be broadly conceived while graduate education at a master's level should allow students to learn in-depth the technology of their specialty and the elements of professional practice. This is necessary because while European engineering graduates complete a five-year program consisting entirely of science and engineering, U.S. engineering students take 20% or more of their courses in arts, humanities and social sciences, due to poor high school preparation. This means that out of a total of 128 semester-credits typically needed for graduation in the USA, less than one-third are in the engineering specialty (typically 31 credits in "the major").

A recent study (Bieniawski, 1995) included a proposal for the integration of engineering design throughout the curriculum based on the following five design fundamentals: (i) Product realization processes in business organizations, (ii) Design of components by systematic design theory and methodology, (iii) Design for manufacture, (iv) Concurrent multifunctional team design, and (v) Case studies of best design practice. However-this proposal was aimed at satisfying the current industrial needs as appropriate for this decade, Will this be good enough for the next century?

In a stimulating paper *"A Curriculum for the Citizen of the 21st Century,"* Kline (1995) argued that current curricula at Stanford and other research Universities are essentially "coreless" and do not cover several kinds of materials that every citizen of the 21st century needs to know to create better societies and more livable conditions. In his opinion, we *"owe our children and our children's children an explanation of the world that is understandable, realistic, forward-looking and whole."* There are principles of thought created in the 20th century that are important for the citizen of the 21st century to know, such as: the vital concept of the distinction between constraint and determination when dealing with complex systems; the concept of feedback; the concept of systems as opposed to unintegrated elements; the value of human judgment in engineering; and the probabilistic approach to engineering design rather than deterministic factors of safety.

A more specific proposal defining a world-class engineer for the 21st century has been recently put forward by the Penn State Center for Enhancement of Undergraduate Engineering Education. The following qualities were identified (Kearns *et al.*, 1995) for this purpose:

1. ***Aware of the World:*** sensitive to cultural-differences, environmental concerns, and ethical principles; alert to market opportunities.
2. ***Solidly Grounded:*** thoroughly trained in the fundamentals of engineering and science; having a historical perspective of advances in science which can impact engineering prepared to continue life-long learning.
3. ***Technically Broad:*** understands that real-life problems are interdisciplinary; sees issues in a context of various alternatives and probabilities; is conversant with several disciplines; is trained in systems modeling.
4. ***Effective in Group Operations:*** co-operative in an organization of individuals working toward a common creative goal, effective in written and oral communication; willing to seek and use expert advice, cognizant of the value of time; understands the many facets of business operations: management marketing, finance and costing, law, human resources, service and especially quality.
5. ***Versatile:*** problem solver decision maker; innovative in the development of products and services.
6. ***Customer Oriented:*** finding and satisfying customers, assuring cost-effectiveness in the global market place.

The need for globalizing engineering education is evidenced by the fact that in 1994, no less than 465,850 foreign students from 193 counties were enrolled in American universities, while only 73,154 American students were studying abroad and more than 90% of them were undergraduates. Of these, 1,100 students were in engineering.

In essence, the main elements that mark engineering curriculum development across the United States are: (1) introducing engineering and design experience early in the curriculum, starting with the freshman year (i the past only 50% of first year students at Penn State specified a department major and one-third of them would switch in the first year, another quarter in the second year); (2) requiring relevance of basic math and science (taught by non-engineering faculty) to the engineering science subjects; (3) identification of a fundamental core, involving engineering science, design experience and critical professional skills; (4) flexibility in the curriculum to choose depth for professional practice and develop breadth for interdisciplinary competencies; (5) reducing the total credit requirements to about 120 credits to enable a true four-year degree program; (6) complement the B.S. curriculum with direct entry to a professional Master's program as the "fret professional degree;" and (7) explore broader multi-disciplinary frontiers where engineering, science, liberal arts, languages, economics and business meet. Engineering curricula that encompass these elements have the potential to become the general education of our high-tech future and provide a strong professional foundation for the 21st century.

It must be emphasized that the above efforts are fully realizable in America due to the uniqueness of the U. S. higher education system which has no equal in other countries: namely, the independence and flexibility of American universities. In Europe and Japan, universities are answerable to a Ministry of Education which sets academic standards and distributes money, as well as appoints the professors. American universities and colleges are the envy of the world because they can devise their own programs and educational materials without any government interference. There is little competition for innovation in Japanese higher education because there is so much government control. In Germany, students rarely come into direct contact with professors until they reach graduate-level studies. In France, an engineering degree is a state diploma controlled by a government body and this requires five years of engineering studies. French students are commonly expected already at age 16 to select both a university and a specific field of study. In America, educational flexibility is taken for granted.

Curriculum Changes in Japan

For the purpose. of this_ study, one month was spent in Japan visiting five major corporations and the . Universities of Tokyo, Kyoto, Kobe, Nagoya and Hiroshima, and having discussions with MITI officials. In addition, a premier private high-school in Tokyo, Musashi School, was visited. Most of all, the author had the rare privilege of being invited to two Japanese homes and spent weekend outings with three Japanese families and their children. This, combined with numerous visits to museums, gardens, kabuki theater, tea ceremonies, and even sumo and baseball games, provided a great insight into Japanese society, history, and culture.

Engineering education in Japan is a career-long process. In discussing the Japanese system we must look at the total educational, cultural and professional environment that affects Japanese engineers. The purpose of a Japanese university is to provide the student with a general academic background. It is the responsibility of the employers to offer graduates specialized professional training.

In the Japanese educational system, those not intending or able to enter the university may leave the system at age 15; many others attend a two-year junior college. Students may also attend private "cram" schools, throughout the entire pre-university schooling, and private trade schools, after high school. The ability to fit well into a group effort is taught from the first grade. The curricula in elementary and high schools are prescribed by the Ministry of Education and the textbooks used must be approved by the government. Only one textbook per subject, e.g. history, is used throughout the country and its interpretation of events must be taught. In fact, curricula are regulated so closely that the same subjects are taught on virtually the same day everywhere.

There is a quality ladder for Japanese universities with the public (state) University of Tokyo being the undisputed leader. Three other public universities, Kyoto, Tohoku and Osaka, and two private universities, Waseda and Keio, are highly respected, followed by "the rest": 472 other state universities and 340 private universities. Top corporations employ mainly graduates of the University of Tokyo. No curriculum changes are possible at any public university until the University of Tokyo has experimented with a proposal which, in any case, must frost be approved by the Ministry of Education. University entrance examinations are very tough and doing well is vitally important. Once admitted, however, Japanese engineering students have a lighter work load than their American counterparts and follow a highly standardized curriculum. The first two years at the University of Tokyo is spent at a different campus for basic science and math courses. Engineering starts at the Tokyo campus with the third year of studies.

Most Japanese engineers do not think their four-year university education was very useful in preparing them for real engineering work because teaching of subjects specifically conceived as "design" or "manufacture" is uncommon in Japan. The general view is that university life is "a well-earned four-year vacation between adolescence spent in 'examination hell' and a future lifetime of regimented employment." Thus, on-the-job training schemes are standard practice in larger Japanese firms and the focus is on practical knowledge. Career opportunities are excellent once employed and hard work is expected (10 hrs. per day) and rewarded with life-time job security. However, retirement at 58 is generally mandatory, even at 55 in some companies. Due to a large retirement turnover, large numbers of new engineers are hired each year and starting salaries are almost identical throughout the industry.

It is a fact that despite Japan's economic success, its universities do not measure up to those in the United States, even the University of Tokyo. Due to the perceived hierarchy of quality, the top ranked universities have an attitude of complacency that makes constructive self-examination and change unlikely. However, the universities are effective in preparing young people for their future lives in Japan, teaching them the two most important virtues for a Japanese: patience and conformity.

Recently, a new mechanical engineering curriculum was proposed at the University of Tokyo. This represents a change from the tightly prescribed courses of study into a curriculum of three core courses with an increased number of electives (total of 140 credits). This is an experimental undertaking limited so far to mechanical engineering. As for private universities, curriculum changes are perceived as expensive and only one major effort is on record. The Kanazawa Institute of Technology introduced in 1995 an engineering design program by hiring five international design teachers (mainly from the USA) who on a full time basis, would train the Kanazawa faculty as well as teach undergraduate and graduate students. While currently in the United States centers for innovation and engineering design integration across the curriculum are an accomplished fact, no such initiatives exist in Japan even at the University of Tokyo.

Most of all, life in academia in Japan is highly organized into a system considered very satisfactory by the professors and administrators. The national universities are fully funded by the Ministry of Education which pays the salaries and expenses of a system of "laboratory units" - each typically consisting of five persons: full professor, associate professor, post-doe, secretary and technician. Also included are students (some on fellowships but most self-supporting): 2 Ph. D.'s, 5 MS, and 2-3 undergraduates (writing their final year thesis). Professors may not consult for private gain (being state employees) but may direct consulting fees to improve their laboratories and obtain support for travel, supplies, and graduate and undergraduate students. They do not have to "hunt" for research grants as in the USA.

Teaching is not regarded as a high priority and is usually done by the "chalk and board" method with computer enhanced teaching being a novelty. Most teaching is left to the post-doctoral instructors. In fact, relatively few computers can be seen on Japanese campuses. It is not surprising therefore that sponsored by their companies or the government, Japanese graduate students are pouring into America (48,000 studied in the USA in 1994) because Japanese graduate programs are not of the caliber found at American universities. In fact, the Ministry- of Education quota for doctoral students of 1,515 in 1992 went largely unfulfilled when only 852 enrolled. Japanese companies prefer to send employees abroad for graduate studies as needed. Also, they heavily sponsor research at US universities.

So, if university education in Japan is not on a par with that in the United States, what makes Japan such an economic power-house and the world's prime creditor while the US is the world's prime debtor? There are many reasons and they ARE related to education but not in the sense of college education: (1) Japan has a highly educated work-force as a result of its comprehensive elementary-to-high school system: (2) people work incredibly hard, 10-12 hours per day, in return for life-time job security; (3) it is a producer-oriented and not customer-oriented society, and the welfare of the country is always placed ahead of the welfare of the individual; (4) Japan works by consensus and team work so if the majority is happy with the status quo, few individuals will want change; (5) Japan is indeed a protectionist state as its markets are essentially closed and they take advantage of every trade loop-hoi% (6) they have a co-operative relationship between labor and management instead of an adversarial relationship, leading to strikes, as in the US; (7) their industrial system of *"keiretsu"* ensures preferential treatment, materials, and parts, so that foreign competitors are at a major disadvantage; (8) the role of the government is to assist industry, as evidenced by the Ministry of International Trade and Industry (MITI) which actively promotes Japanese products abroad, unlike the US Department of Commerce which does nothing of the kind; (9) the major corporations train their employees "on-the-job" and execute continuing education by sending their engineers to study at the best institutions abroad and attend "en masse" industrial and research conventions; (10) Japanese corporations, with their long-term objectives, outspend their US counterparts in research and development by a factor of 5:1 and are constantly on the look-out for research findings elsewhere which could be adapted to their work, (11) in terms of living conditions (expensive housing), working conditions (same cubicles for all), salary previsions (lower than in the US) and family life (not a priority in Japan), the Japanese are much less demanding than Americans in terms of their remuneration and quality of life. (There is no question in my mind that my three sons and two daughters have far superior careers, living conditions (housing, cars, furniture) as well as family life than anything I have seen in Japan); (12) the Japanese study foreign cultures and languages before they invest or do business with other countries. This includes a knowledge of law, tax breaks and investment incentives while Americans are poorly versed in the Japanese industrial system and culture, let alone the language; and (13) their exquisite manners, etiquette respecting seniors and mentors, love of things beautiful, and pride in the motto: *"we adopt from other nations, improve it, and make it our own"* makes the Japanese excellent students of foreign developments and adaptation.

A Curriculum Model for Developed Countries?

The two most important developed countries, the USA and Japan, clearly have quite different educational philosophies and curriculum changes planned for 21st century engineers reflect cultural differences and societal needs in the two countries. One curriculum model will not serve all developed countries, even the European community cannot agree on one, but for a changing world, good education is the best preparation for being able to adapt. An education that emphasizes general problem solving skills and life-long learning ability will be important and as the economy shifts, people and societies who are appropriately educated will do best.

The United States has taken more definite steps toward a concept of world-class education of engineers in the 21st century than Japan. Many initiatives are evident at several universities in the US: Penn State, University of California, Maryland, Arizona State, Cornell and Harvard, to mention a few. In Japan, only the University of Tokyo (mechanical engineering) and the Kanazawa Institute of Technology (engineering design) could be identified with pending changes. But, then again, Japan likes to wait for others to take the lead, select the most successful approach, improve on it, and adopt it for their own. However, unlike America, Japan keeps tight control of its technological know-how, particularly with respect to its Southeast Asian partners.

So, what are the implications of the above changes for world-class education in developing countries? For this purpose, the case of China was studied.

Implications for Developing Countries

Developing countries can learn much from the developed nations, by studying both the successes as well as the major mistakes made even by the most powerful countries, such as the USA. Note that during the Cold War, the "keiretsu" system and powerful government controls prevented the penetration of Japanese domestic markets by foreign firms. American manufacturers were permitted to participate in the Japanese market primarily through technology sales. This strategy allowed technology flow into the Japanese economy while investment restrictions excluded foreigners and foreign control. Meanwhile, American business people, eager to reap short-term profits through sales of technology to Japan, inadvertently sold off their competitive advantage in high technology products without gaining significant market access in return.

Japan learned important lessons from these US experiences and is determined not to repeat American mistakes. Japanese firms currently investing in Southeast Asia focus on market penetration and the control of outward flows of technology. Moreover, the Japanese government co-ordinates foreign aid with direct foreign investment to support Japanese penetration of a local market, to ensure successful but united technology transfer, and to help business ventures profit.

In the meantime, US firms may be in danger of soon finding themselves excluded from a Japan-centered regional economic block. In fact, in Thailand, Japanese manufacturers already control 90% of the automobile market. In Malaysia and Indonesia, Japan is the principal trading partner, manufacturer, and financial market leader. However, the country at the top of the developing nations ladder, South Korea, being an economic power-house of its own, does not allow -by law - any Japanese penetration of its markets. But South Korea can do little to stop the Japanese juggernaut in Southeast Asia. All of the above is not lost on China.

Engineering Curriculum Changes in China

In China, contemporary higher education is the result of a series of historical experiments that combined various foreign models with a rich Chinese scholarly tradition. The missionary universities of the late 19th century were replaced by the Soviet-model of controlled higher education up to the 1960s. All universities were closed during the Cultural Revolution of 1966-1976, so the Chinese revival of higher education started less than 15 years ago. Yet, tremendous progress has been made to date and reforms have taken place in the last few years to accommodate the economic growth marked by free-enterprise initiatives. This led to curricular experiments combining mechanical and electronics engineering, introducing research at engineering institutions, and starting increased interaction with Western countries. Today, over 45,000 Chinese students are studying at American universities, the largest national group of foreign students in the USA.

The educational reform document of 1985 defined the new role of universities as: "training advanced personnel" as well as "developing science, technology, and culture" with a promise of less government control to ensure "the initiative and ability to meet the needs of economic and social development." As a result, starting in the late eighties, engineering curricula were extended beyond the narrow topics for production related knowledge (e.g. vehicle design, railways, etc.), to a wider range of fields (e.g. mechanical engineering or chemical engineering). It should be noted that in China engineering is not part of a university system but is organized as a specialized, separate institution of higher learning: e.g. Polytechnic University of Railroads or Coal Mining or Vehicle Construction or Smelting and Metallurgy.

Today, with 1.2 billion people, China is rich in population, poor in natural resources, and backward in science and technology (except where foreign technology and capital are provided in "joint-ventures"). With 22% of the world's population, China can meet only 7% of its needs for fresh water and cropland, 3% of its forests and 2% of its oil. While Japan and South Korea have overcome similar dilemmas by importing much of their resources while exporting manufactured; China's size precludes this option. By its own admission, currently over 70 million Chinese are undernourished and poverty-stricken, mainly in the rural areas. The annual per capita income was $361 in 1995. Yet, the Chinese SAVE a quarter of their income! Enrollment in primary education increased from 50% in 1952 to 97% in 1990 but secondary school enrollment is far lower, at 44% it is higher than in India, but lower than in Mexico. Only 1.7% of the Chinese population has attended a college, however, this is very large in numbers: 20.4 million people - more than in the US (14.3 million students).

Based on personal visits to Chinese universities and discussions with college students in China and those from China studying at US universities, their university education is very good. In addition, numerous Chinese students applying for graduate admission at Penn State, provided the writer with their transcripts, in mechanical and mining engineering, which were more comprehensive than those of many US students.

So, what are the curriculum challenges for China? In essence, science and engineering professors desperately need to improve their living and working conditions as well as their status in society. For example, a professor of engineering earns only $200 per month but a drop-out student can make $600 selling goods in the street. There is a saying in China: *"the person who is engaged in research on atomic energy is much poorer than the person who sells boiled eggs in the streets."* Generally, professors' salaries are lower than those of their children who work in joint ventures just after graduation from college. Moreover, most universities and institutes of science and technology are lacking funds to buy instruments, books, journals, and teaching equipment. Computers are hardly seen. The condition of university buildings and offices is poor though this is, surprisingly, also the situation in Japan and South Korea - well below conditions at American universities. Most of all, major Chinese engineering projects lack critical techno-sociological assessment the Three Gorges Dam is a case in point.

Furthermore, China lacks a systematic approach to the problems of technological innovation. For instance, the market in China is underdeveloped and cannot guarantee fast market competition, therefore businesses lack the capability to select and absorb technological innovation. At the same time, the work ethic in China is vastly different from that in Japan and South Korea: the Chinese do not work long hours and devote their free time to their families. At present, productivity levels in China are among the lowest in the world.

Under these conditions, Chinese engineering education for the 21st century should be directed to: (1) thorough training of professional engineers capable of dealing on a par with those from the developed countries, (2) incorporation of sociological issues into engineering curricula, and (3) improvement of living and working conditions for the educators to ensure their continued participation and professional development.

One thing China does not need is to maintain its unfair trade policy of closed markets and taking advantage of well intentioned investors, particularly from America, which already resulted in an excessive balance of payments with the USA of over $50 billion. Typically, for a joint venture in China, the US firm must bring in all the equipment and starting capital, train the Chinese workers, pay for land and construct the buildings with their own materials and promise to sell all the products abroad. All this for only 49% ownership and a half of the profits which cannot be taken out of the country. What a bad deal for the venture capitalists! Compare the conditions for US. businesses in China with the treatment Japanese businesses get when establishing their factories in Temessee or Kentucky! Hopefully, the American global engineer in the 21st century will be better prepared than to accept bad deals in China.

It is unlikely, however, that recommendations for a change in attitude will be implemented in the current political situation in China. During the author's visit in October '95, the pronouncements of the 5th Plenum of the Communist Party of China made interesting, if disturbing, reading (and should be carefully studied by US business people and our bureaucrats): China's purpose is to improve its communist system by taking what the market will bear from the West, by playing one country or company against the other to secure the best deal, by keeping its markets closed, by disallowing any criticism of the government, by sending thousands of Chinese students for training abroad at the West's cost, and by improving the quality of its products and education.

In the meantime, China is taking a tough stand on the international scene. It is extending its reach deep into the China Sea, claiming the Spratly Islands hundreds of miles away. A sign of things to come: my wife visited a kindergarten in Beijing, where four-year olds performed for the visitors marching around with wooden rifles singing about "fighting for our country and dear leaders!" At the university or elsewhere, acceptance of meager conditions is widespread because of the Confucian attitude of respect for higher authority and devotion to one's country. The individual must strive for inner perfection.

Conclusions

Understanding of the social structures and cultural backgrounds, including the educational systems, in the developed and developing countries with which the 'United States deals is absolutely essential to maintain US competitiveness in the global marketplace of the 21st century. In view of the US trade deficit with nearly all of our partners, and our diminishing market shares in Southeast Asia (Indonesia, Malaysia, and Thailand) and the Far East (Japan, Korea, and China), combined with the lack of a coherent US government trade policy and foreign aid directed to promote American interests, the ingredients identified in this paper for world-class education of global engineers in the 21st century can ensure a better understanding of foreign practices, the development of innovative ideas for dealing with foreign competitors on a "level field" basis, adherence to the rights of having the largest and open consumer market in the world, and being prepared to learn from other countries - given these attributes we can possibly overcome the current weakness of being the protector of all while our protégés are taking advantage of us wherever possible.

It is indeed fortunate that at present the US is far ahead of Japan, the top developed nation, in curriculum initiatives for engineers in the 21st century and, for once, we are taking a long-term view, albeit only in university education and not in government policy. It is also fortunate that China, the prime developing nation, is facing many economic problems due to overpopulation which may make it willing to be more co-operative.

So, now is the time to move ahead swiftly to implement the proposed university curricula changes in the United States. Perhaps, this will be our best investment for the future.

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