

**REFORM IN ENGINEERING EDUCATION
- A MIRROR OF THE INDUSTRIAL EVOLUTION -**

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Abstract - The basic mission of university education has not changed since its birth in Europe in 13th century. Universities have been serving as the places, where people gather for exchanging and creating new knowledge. Despite this invariable mission of universities, education, especially engineering education, has undergone continuous reform. The present paper intends to crystallize the motivation of past educational reform in engineering education from the viewpoint that the reform reflected the evolution of industries. The examples are taken from Japanese experiences. In the same context, the changing industries toward 21st century suggest us what reforms are needed in the engineering education of tomorrow.

1. Introduction

Figure 1 is a line sketch of an oil painting drawn in 14th century by Albertus Magnus. The painting described how a classroom of German university looked like. A theology professor is giving lecture on a pulpit -tall platform- in front of a thick precious book. Students are sitting packed on narrow couches and are listening and taking notes. What is interesting to observe is the behavior of students. Those in the first row look quite diligent, however, a little relaxed atmosphere prevails in the second row. We find students chattering each other or even taking a nap in the backward rows, an amazing similarity with the scene of present classrooms. The essence of university education has not changed in the past 800 years in principle. Universities have been serving as the center, where knowledge of the highest level is taught and created.

Despite the invariable mission of universities, they have experienced continuous reform in their organization, composition of disciplines and curricula of education in the past. It is a relatively new reform that engineering education was authorized as a part of higher education about 150 years ago.

There are a variety of disciplines in universities and educational reform has been pursued with the top priority in every discipline. However, the energy and passion poured into the reform of engineering



Fig. 1 Classroom of German university in 14th century

education have been exceptionally intensive, compared to those of other disciplines. Why is engineering education exceptional? This is only because industries have been developing and changing with enormous speed. Engineering education has been reforming itself in accordance with the demand of the industries of respective nation.

In order to crystallize a clear correlation between educational reform and industrial development, the present paper divide the post-war industrial development of Japan into three phases of changes, hereafter called tide, and characterizes the features of each tide.

The last tide started in 1991, at the beginning of the last decade of 20th century. It requires the most drastic reform of engineering education in the years to come. Triggered by the collapse of cold war structure dominated by two superpowers, the world is becoming borderless. The engineers we educate will work under a quite different environment of 21st century and have to confront new problems and tasks. The prediction of their future work environment will suggests us what reforms are needed in the engineering education of tomorrow.

2. Industrial Evolution - Three Tides -

Prof. H. Itami (1994) of Hitotsubashi University, Japan, reviewed the history of social, political, economical and industrial development of post-war Japan and found that these developments can be classified into three big tides with unique characteristics. Followings are the description of each tide based on the opinions of Itami and the author.

The First Tide: Age of Expansion 1955-1973 (18 years)

Ten years were needed to escape from post-war chaos and to regain social stability of defeated and occupied Japan. In 1955 Liberal Democratic Party took the political power and continued to hold the government till recent years. Japan-US Security Treaty was signed in 1951 and put Japan under US nuclear umbrella, the basis of firm political and economical ties of two nations across the Pacific. The government started "Double the Income" plan to accelerate economical development and the domestic market grew accordingly.

Japanese style management, featured by company oriented labor union, lifetime employment, pay increase by seniority, in-house training, etc., became common practice. Heavy industries, such as steel, petrochemical, synthetic fiber, ship building, automobiles and heavy electric machinery, took the leadership in expansion. Export increased rapidly and the international trade balance turned from minus to surplus in spite of huge import of oil and raw materials.

The Second Tide: Age of Conversion 1973-1991 (18 years)

The first oil crisis in 1973 terminated the success story of the first tide. The industries found that they thrived mainly by consuming huge amount of oil and raw material. They forced to reform themselves to be less dependent on the supply of energy and material. Conversion from "Heavy-Thick-Long-Large" to "Light-Thin-Short-Small" became a typical slogan of Japanese industries.

Information age started about this period with accelerated proliferation of computer and communication technologies. Products featuring the application of micro-electronics and precision-processing, such as VCR, DRAM and LCD, became the front runner of exports, replacing previous heavy products like steel and ships. Industries achieved the conversion far quicker than expected and regained the strongest competitiveness in the world market.

The GNP grew again rapidly and Japan became No. 2 economic power with huge trade surplus. Japanese style management collected world attention and numerous books were published on the secret of industrial competitiveness, especially of highly efficient production technology.

Booming economy and surplus money triggered finally an overheated invest-

ment rush on stocks and lands, leading to a spree called bubbly economy. The bubbles started to burst in 1991 and the second tide terminated. The history may make clear that the essential and hidden cause of the collapse was the end of the cold war.

The Third Tide: Age of Mega-Competition 1991-

The end of cold war relieved mankind of the horror of nuclear massacre but initiated a new war, competition of industries on the global scale. Leaders of every nation are now clearly aware that science and technology are the key force to maintain competitiveness and sound development of industries, thus assuring people employment and growing income. Every industrialized nation started to enhance "Strategic Research" with the determined object of keeping leadership in industrial development.

In mega-competition age just started, Japanese industries are facing many difficulties: High cost of products due to the overrun evaluation of currency, shift of production plants abroad, hollowing of domestic industries, turning point of Japanese style management, decrease of young generation and so on.

The most competitive of Japanese industries has been mass production technology of standardized products such as automobiles and electronic devices. These technology can be transferred abroad together with transplanted production facilities. Industries need urgently new products which substitute flown-out products and fill large hollows of domestic factories.

What would be the products which represent the third tide? Who would innovate such products? As the last tide just started, we do not see clear answer at this stage. What we can see today is that information and borderless may be the main key words; that venture spirit of individuals may play major role in innovation; that CPU and OS, hard and soft cores of computers, imply two major directions of future possibilities. CPU is the symbol of man-made products which are available exclusively from limited suppliers, as crude oil is supplied only by oil-producing countries. CPU belongs, in its nature, not to artificial but to natural resources of the present day. OS, the crystal of human intelligence, is another symbol of future possibilities. Integrated system technology that makes the most of available information, manpower and assets is the target of the next challenge.

3. Correlation with Educational Reform

Past educational reforms are correlated with the social, economical and industrial evolution of each tide as follows:

The First Tide: 1955-1973

As industries started to expand rapidly, the shortage of engineers became an urgent issue. The plea of industry leaders for more engineers evoked a national consensus and the government launched plans to double the number of graduate engineers. This expansion in quantity had its peak around 1965 and the target was hit in relatively short period as indicated in Figure 2. Expansion of enrollment was materialized by the increase of quota of existing departments, setting up of new departments, faculties or even colleges of engineering disciplines. Technical colleges that combine engineering education of high school and junior college levels, were introduced as a new education system during this period. The object was to produce practice-oriented engineers through 5-years integrated training.

As the gates for higher education became wider and lower, universities, once called ivory tower secluded from trivialities of external world, turned to the paradise of mass education. Popularization of higher education and the subsequent perception gap between tradition-ridden university authorities and new generation with a sentiment to anti-establishment, triggered ever sharpening confrontation inside universities. The flame of students riots in campuses ignited in USA in late sixties and propagated worldwide. The surge of campus unrest shook all Japanese universities with its peak

around 1970. It took several years to heal the wound, physical and spiritual destruction, especially the lost respect between teachers and students. The flames that burned all universities could be the bonfire of farewell to the first tide, period of quantitative expansion.

**The Second Tide:
1973-1991**

The influence and im-pact of electronic computers grew steadily since their debut on market around 1955. When this new tide started, there was no doubt that the driving force of the new era was the proliferating application of computers. When industries were forced to reshape their vulnerable constitution that was heavily dependent on the stable supply of energy and resources, the key words of the reform seemed to be in; computer, information, system, intelligence, micronization, and so on. The symbol phrase adopted at the 90th Anniversary of JSME - "From Mecha of Power toward Mecha of Intelligence"- suggested the direction of needed reform clearly.

Once the trend of industries' reform after the oil crises became obvious, the curricula of engineering education looked quite obsolete. The fundamental framework of mechanical engineering curricula, for example, had been kept unchanged for some 50 years, placing four mechanics - solid mechanics, fluid mechanics, thermodynamics and machine dynamics - always at the center of the discipline.

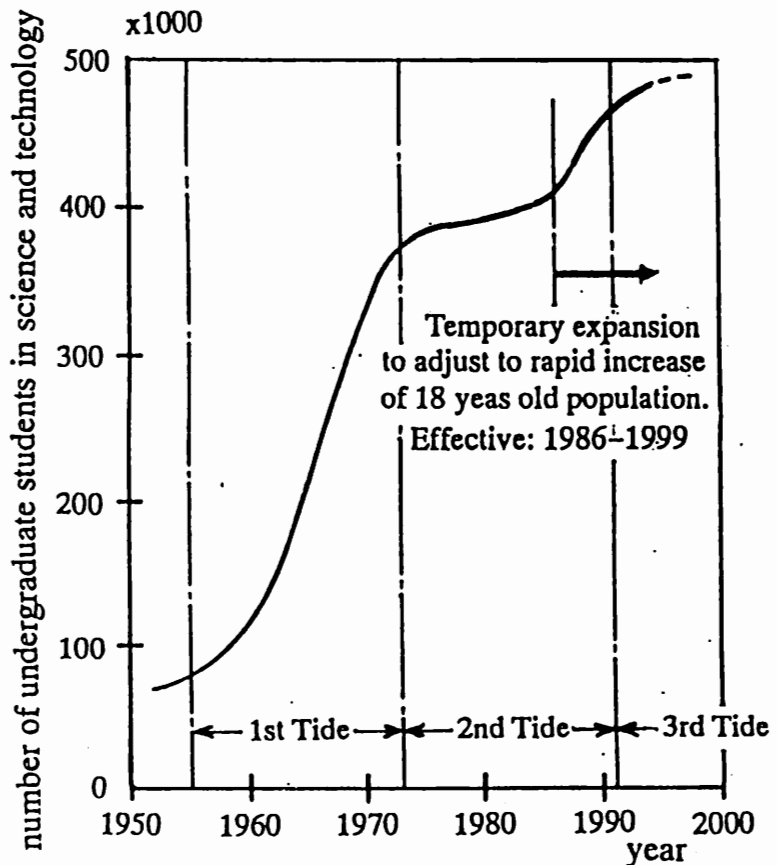


Fig. 2 Number of undergraduate students enrolled in science and technology related faculties

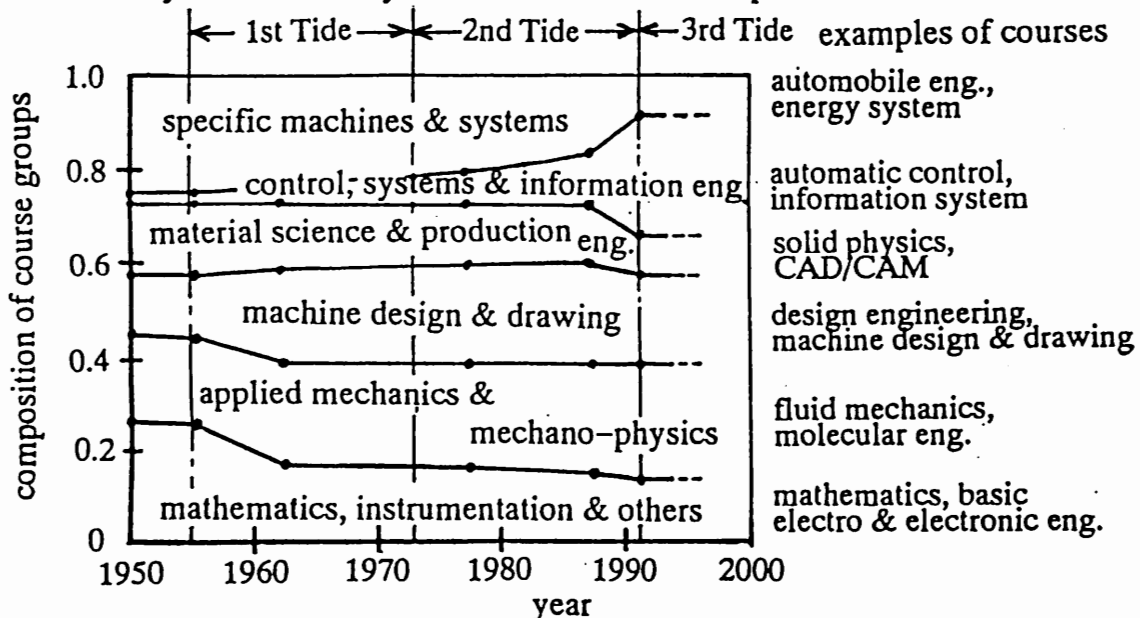


Fig. 3 Composition of course groups at the University of Tokyo

The focus of the curriculum reform was to enhance courses on artificial sciences such as computer science, systems engineering, information engineering, software engineering, artificial intelligence, mechatronics and so on. Figure 3 shows how the contents of mechanical engineering education at the University of Tokyo have changed, cf. Ohashi (1992). All courses are classified into six groups, that is, (1) mathematics, instrumentation and others, (2) applied mechanics and mechano-physics, (3) machine design and drawing, (4) material science and production engineering, (5) control, systems and information engineering and (6) specific machines and systems. The composition of these six groups is evaluated on the base of required study hours, and its past change is plotted against years. As clearly seen from this figure, the sixth group, artificial or soft science related courses, indicates a remarkable expansion during the second tide. This curriculum reform of the University of Tokyo is not a special example but represents general trends of this period.

The reform was not limited to the curriculum renovation within an existing department, but also promoted the birth of new departments with such names as; department of machine systems, mechano-systems, mechano-informatics, mechano-electronics, mechatronics, mechano-intelligence, etc.

As far as undergraduate education was concerned, the feature of the second tide was not the expansion in enrollment but the reform in the contents of engineering education. To the contrast, quantitative expansion took place in graduate education. It took two decades till industries started to recognize that master degree in engineering is just what they need as the work force for research and development.

In spite of long lasting economic boom in which both individuals and companies enjoyed wealthiness, the government continued to tighten expenditures by putting strict ceiling on the university budget. National universities suffered the hardest blow by this policy. The discrepancy between poverty-stricken university research facilities and utmost modern corporate facilities exceeded a tolerable limit. Public opinions for "Revive Universities" grew steadily and urged government to improve this situation.

Under bubbly economy money-related industries such as banks, securities and insurance companies attracted brilliant engineering students who otherwise found job in manufacturing industries. Declining popularity of science and technology among young generation provoked a nationwide apprehensions and was considered as an emergency signal for the future of the nation.

The Third Tide: 1991-

In mega-competition age, science and technology are key factors to maintain the competitiveness of industries on global market. Government is now very keen to improve the quality of university education, to fortify university-based research activities, to excite the interest of young generation in science and technology. Followings are examples of recent government actions for the survival as an industrial nation.

June 1991: Liberalization of regulations on university curriculum (Ministry of Education). Each university may now decide the composition of general and speciality education according to the object of the education.

July 1994: Action plan to increase the attraction of science and technology education in universities (Ministry of Education)

December 1994: Comprehensive basic policy for recruiting scientific and technological personnel (Prime minister's Office).

July 1995: Action plan to develop personal creativity in university education (Ministry of Education).

As seen in the previous tides, educational reform must reflect the change of background like a mirror. The major changes we encounter in this tide will be; globalization, fading Japanese style management and popularization of higher education.

Globalization: The time when salesmen sold domestic products worldwide has gone. Now is the time when engineers move abroad and manufacture goods in cooperation with the people of consuming countries. Education of global engineers, though its definition is still uncertain, has not been considered at all in the past object.

To introduce aspects of globe-able engineers into engineering education, quite many problems must be solved. To mention a few; communication skill and technical writing in foreign languages; understanding of foreign regulation, standard and customs; establishing equivalence of academic degrees and professional certificates for international recognition, and so on.

Japanese style management: It features lifetime employment and in-house training. New graduates are hired as raw material which can be shaped and reshaped by in-house education and on-the-job training by the instruction of employers. Industries have never expected job-readiness for new graduates and universities have been concentrating on teaching of fundamentals and principles. As Japanese management undergoes revisions for survival, the subtle sharing of engineering education between academia and industries must also change. Quality of education, or quality assurance of graduates, will become the target of severe competition among universities.

Popularization of higher education: The decrease of birth rate results in 20% reduction of 18 years old generation every decade. The admission rate for 4 years universities and colleges is expected to jump from 30% at present to 50% in two decades. University students will be no more elite but just ordinary. University education must cope with this qualitative change of students with realistic eyes.

The role of general education will increase as the means of building "self" of each student. As freedom of choice in high school education expands, the basic knowledge of admitted students will vary from person to person. Supplementary courses to compensate missed choices, for example, physics for mechanical engineers and chemistry for applied chemists, will become an indispensable part of university education and must be introduced systematically.

As popularization proceeds, method of education must be so arranged that majority of students keep willingness and can finish study. The sequential study now commonly adopted begins with fundamental subjects like mathematics and physics and proceeds gradually to applied subjects like machine design and combustion engines. At the beginning students cannot see why such fundamental subjects are necessary and how they will be applied to real problems. By the filtering process of sequential study, a lot of students may drop out by the loss of interest. To improve this situation, integrated study could be a resolution, which pays largest attention to keep students' interests and objectives, cf. Bordogna, et al (1993).

The role sharing between undergraduate and graduate studies must be re-checked. Undergraduate education should be devoted mainly to "self" building, basic skill in communication and writing, computer and information literacy, and finally fundamentals of specialities. Professional education should be completed in graduate education. Graduate schools are also the places for those who wish to refresh and expand their professional knowledge.

The last tide requests multilateral reform in engineering education as described above.

4. Conclusion

The correlation between educational reform and evolution of industries was analyzed using the example of Japanese experience. Whole changes were classified into three tides and it was found that the educational reform in each tide was materialized in accordance with the social, economical and industrial demands.

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