Trends in Engineering Education in the United States and Opportunities for Engineering Education in Korea

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With the development of engineering and technology, we are living in a high-technology society which is changing our daily life and society as well as related industries. Engineering education is thus moving into a new era of development as a result of major changes occurring in modern society throughout the world.

Academic engineering programs have experienced a significant redirection after World War II to link engineering more closely to its scientific roots. Experiment-oriented engineering education became more analytical and required strong mathematical capabilities for modeling and simulation. Engineers were trained to solve problem analytically and to work independently. Because of modern technological innovations and the complexity of the engineering problems, interdisciplinary education, teamwork and good communication skills are being emphasized nowadays. Understandings for environmental, social and market issues are also being required in designing and manufacturing products. Major end uses in engineering education are industries. They lead the international competitiveness in economics and contribute highly to the development of the country. The roles of engineers are also changing. Once engineers were involved mainly in the design of product and plant and the production of the product. Recently with the development of engineering and technology, more social issues are related with engineers. Important characteristics of engineers compared to natural scientists are, in general, that engineers are trying to analyze the system and to solve the problem of the system in a systematic way and with economics background. Thus engineers are expected also to contribute to socio-technological issues, education issues, policies on technology development and industries etc. Also the realm of engineers, once involved in local issues, should cover global issues, which requires better communication with foreigners and deeper understanding of the foreign cultures. Recently, requests on engineering education are given from industries to meet more severe international competitiveness. Following figure shows one examples of such request on engineers quality from industry.

New goals in engineering education is to produce the finest scientists and engineers for the 21st century are being established. To achieve this goal, following strategies were suggested.

(1) Teaching and learning must be reinvigorated as the primary mission of academic institutions.

(2) Policies governing federal support for academic research must explicitly recognize the importance of such support to the education and training of scientists and engineers.

(3) Graduate education in science and engineering must better reflect the many profound changes in the economy generally.

1. Quantity in engineering education

Total number of employees is expected to increase by 20.7% in 2005 compared to those in 1990, the rate is 26.5% for the number of employees in engineering field. The numbers of graduates students and MS and Ph.D. in engineering discipline are shown in Table 1-2.

Undergraduate students: The average number of BS in engineering discipline was 36, 932 from 1967 to 1971 and 61,069 in 1991 which was a 65% increase as shown in Table 2. In 1991, the portions of students in electrical, computer and mechanical engineering fields (including aerospace engineering) was 64.1%, and those in civil and chemical engineering were 12.9% and 6.4%, respectively. Especially, the portion of students in computer engineering was 6.4% in 1991 which was a drastic increase compared to 0.9% between 1967 and 1971 and the portion of students in biochemical engineering was 1% in 1991, which was 5 times increase compared to 0.2% between 1967 and 1971. Those in biochemical engineering field were larger than those in nuclear and mining engineerings and approached those in materials engineering.

Graduate students: In 1991, the number of MSs was 45% and those of Ph.D. was 10.0% compared to the BS students as shown in Table 1. Total numbers of students increased but the rate did not change greatly compared to those between 1967 and 1971. The portion of

A Proposed Learning Structure for Engineers[1]

Draft Report of 10/24/94 on the Second Boeing-University Workshop on
"An Industry Role in Enhancing Engineering Education"
July 18-19, 1994, The Boeing Company, Seattle, Washington
Prepared by J. H. McMasters and B. J. White

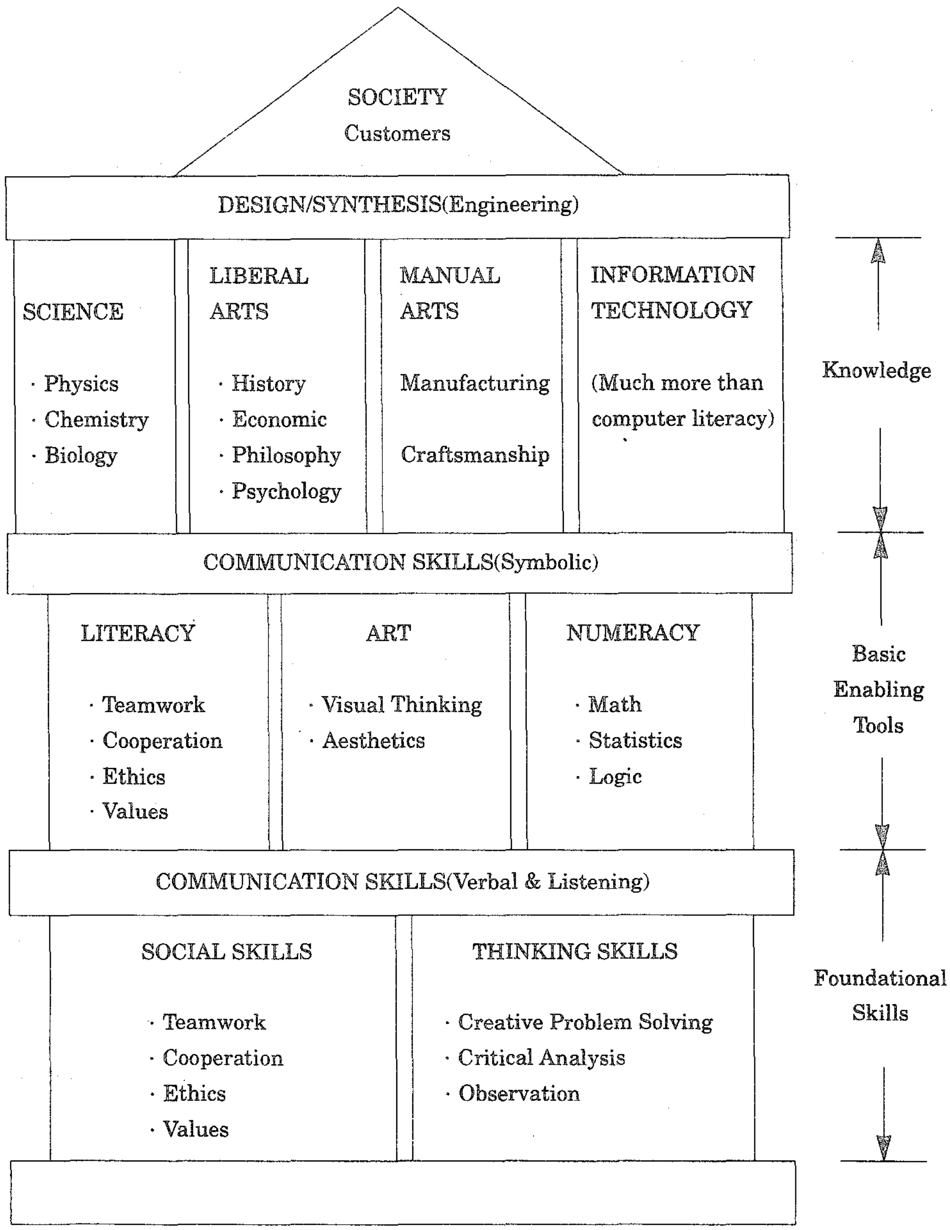


Table 1. The numbers of BS, MS and Ph.D. in engineering fields in America

Year	BS	MS	Ph.D.
1991	61,069	27,628	6,104
	(100%)	(45.2%)	(10.0%)
1967~1971	36,932	15.611	3.572
	(100%)	(45.2%)	(9.7%)

Source: J. Eng. Education, 31-40, Jan 1995

Table 2. The numbers of BS, MS and Ph.D. in engineering fields in America

	Year	aerospace	biotech.	chem.	civil	computer	electrical
BS	1991	2,842	626	3,879	7,891	3,930	17,852
	(%)	(4.7)	(1.0)	(6.4)	(12.9)	(6.4)	(29.2)
	67-71	1,693	58	3,152	5,614	313	9,736
	(%)	(4.6)	(0.2)	(8.5)	(15.2)	(0.9)	(26.4)
MS	1991	930	4421	1,075	3,454	2,797	7,996
	(%)	(3.4)	(1.5)	(3.9)	(12.5)	(10.1)	(28.9)
	67-71	605	64	1,084	2,328	329	4,008
	(%)	(3.9)	(0.4)	(7.0)	(14.9)	(2.1)	(25.7)
Ph.D.	1991	303	150	670	617	407	1,524
	(%)	(5.0)	(2.5)	(7.0)	(10.1)	(6.7)	(25.0)
	67-71	164	31	394	432	48	875
	(%)	(4.6)	(0.9)	(11.1)	(12.1)	(1.4)	(24.5)

	Year	industrial	materials	mechanical	nuclear	mining	total (person)
BS	1991	3,757	1,058	14,512	248	193	61,069
	(%)	(6.2)	(1.7)	(23.8)	(0.4)	(0.3)	
	67-71	2,288	660	7,404	274	224	64,800
	(%)	(6.2)	(1.8)	(20.1)	(20.1)	(0.6)	
MS	1991	1,759	803	3,976	215	98	27,628
	(%)	(6.4)	(2.9)	(14.4)	(0.8)	(0.4)	
	67-71	1,059	451	2,311	326	74	15,611
	(%)	(6.8)	2.9)	(14.8)	(2.1)	(0.5)	
Ph.D.	1991	225	501	938	125	32	6,104
	(%)	(3.7)	(8.1)	(15.4)	(2.0)	(0.5)	
	67-71	132	271	494	117	14	3,572
	(%)	(3.7)	(7.6)	(13.8)	(3.3)	(0.4)	

Source: same with Table 1.

MS in computer and electrical engineering disciplines was 39.0% and 17.8% in mechanical and aerospace engineering discipline. The portion of MS in civil engineering was 12.5% and 6.4% in industrial engineering discipline in 1991. In 1991, the portion of Ph.D., in computer and electrical engineering disciplines was 31.7%, 20.4% in mechanical and aerospace engineering discipline. The portion of Ph.D. in chemical engineering was 11.0% and 10.1% in civil engineering discipline. Especially, the portion of Ph.D. in biotechnolgy was 2.5%, which indicated that its importance is gradually increasing as shown in Table 2.

2. Quality in engineering education

Engineering education are experiencing many changes in recent years. Among many practices in the United States, some examples which are not introduced and/or practiced much in Korea are described as follows.

1) ASEE

American Society for Engineering Education(ASEE) was founded in 1893 to respond the needs of engineering students to learn more efficiently and of engineering instructors to do the best possible teaching. Since its founding, the society has provided leadership in all aspects of engineering education worldwide.

2) ABET

The Accreditation Board for Engineering and Technology (ABET) was founded in 1932 and has worked to promote higher professional standards of engineering education. ABET is the world model on how the engineering profession responds to its obligation to ensure emphasis on quality, ethics, responsibility, and concern for the welfare of humanity.

3) Engineering education coalition

The Engineering education coalition program was developed by NSF to stimulate innovative and comprehensive models for systematic reform of undergraduate engineering education. Universities and colleges of different characters have collaborated to experiment and implement for better engineering education. Following are the goals of the Coalition.

▷ to design and implement a comprehensive, systemic and structural reform of undergraduate engineering education;

- to provide tested alternative curricula and new instructional delivery systems that improve the quality of undergraduate engineering education;
- to create significant intellectual exchange and substantive resource linkages among engineering baccalaureate-producing institutions; and
- to increase the number of baccalaureate engineering degrees awarded, especially to women, underrepresented minorities, and people with disability.

Four coalitions are being supported. Each of these coalitions has been awarded Õ15 million over five years to pursue its goals.

4) Teaching centers

Teaching centers are being operated at college level, university level and state level to assist faculties teaching assistants for better education. Followings are the examples.

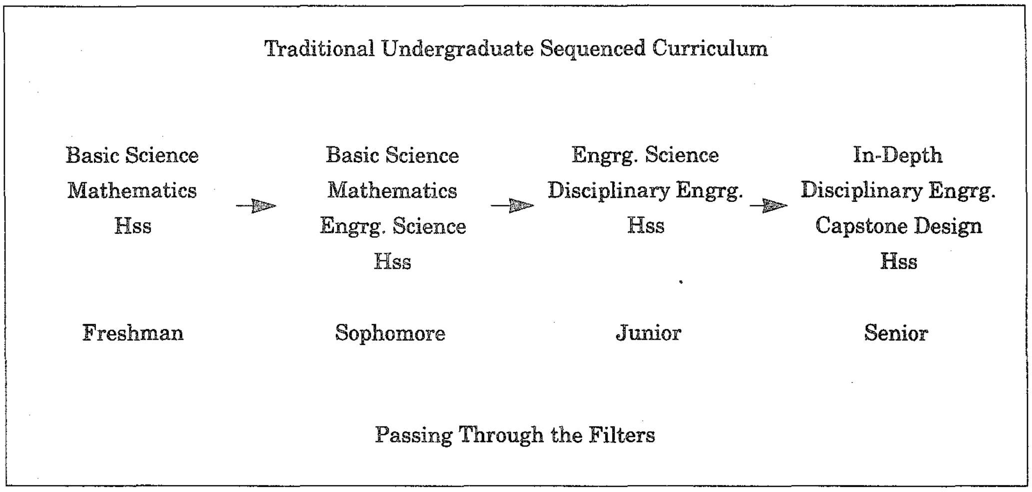
Table 3. Engineering education coalitions

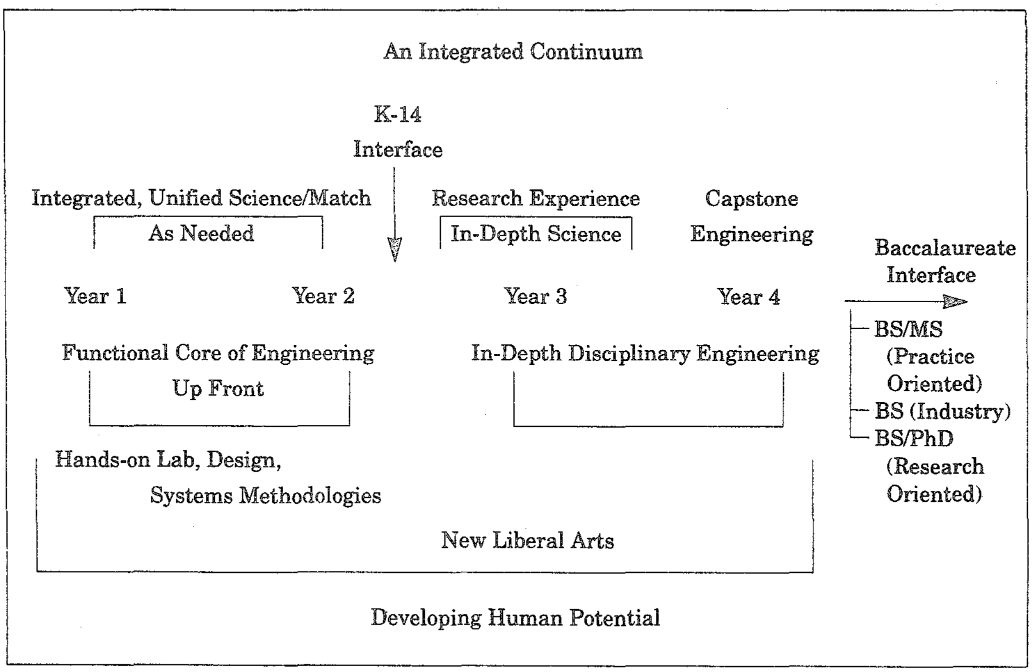
Coalition	participants	theme
ECSEL	7 institutes ex: MIT U. of Maryland U. of Washington Penn St.	Design across the curriculum
SYNTHESIS	8 institutes ex: Cornell U. Stanford U. Hampton U. U. of California	(a) Synthesis of knowledge for problem-solving (b) National Engineering Education Delivery System
GATEWAY	10 institutes ex: Columbia U. Ohio State U. New Jersey Inst. of Tech. U. of south carolina	Opening new "gateway" for learning by altering engineering education to an integrative process
SUCCEED	8 institutes ex: Florida State U. Georgia Inst. of Tech. U. of North Carolina Virginia State U.	Develop “CURRICULUM 21” emphasizing the process of engineering and the engineering education process

(1) Undergraduate Teaching Improvement Council

This council was established in 1977 to pursue the excellent and innovative teaching throughout the University of Wisconsin system.

- Encourages the exchange of ideas and information on teaching improvement through its conferences grants, Teaching Fellows Program, and publications
- Assists each System institution in its own teaching improvement efforts through





Teaching Improvement Grant Program and Teaching Fellows Program.

▶Advises System administration on matters of policy that affects undergraduate teaching

(2) Searle Center for Teaching

Since its founding in September, 1992, the Searle Center for Teaching Excellence has helped to maintain teaching excellence at Northwestern University. The Searle Teaching Center is a University-wide program, reporting to the Office of the Provost. Its operations are supported by the endowment from the Searle Family. The Center engages in two broad types of activities. First, it promotes an ongoing discussion about teaching and learning matters, striving both to facilitate that conversation and to contribute to it intellectually. What do we expect our students to be able to do intellectually, physically, or emotionally as a result of our instruction, and how can we best encourage and assist the development of those abilities? That discussion recognizes that while the various discipline, including the learning sciences. Accordingly, the Center attempts to help and encourage faculty members both to engage in a careful and systematic examination of their own attempts to help and encourage student learning and to explore the literature on and substantial difference in the way students think and act. To achieve this goal, the Center offers a variety of activities and services:

▶forums and workshop

▶publications

▶grants for innovative teaching

▶teaching-improvement programs

▶individual assistance with teaching

-class videotaping project

-small group analysis and consultation service

5) Engineering Education for K-12

The purpose of introducing engineering concept to K-12 is to promote national awareness of the power of technology and provide the chance to become familiar with engineering and technologies in K-12. Since this chance can provide understanding and knowledges on engineering and technology, potential applications of scientific knowledges to engineering and technology and future career decisions can be beneficial. One example of the engineering education is the summer program organized by Washington State University, where selected science teachers spend their summer time in the engineering college to study engineering and technology.

6) Other issues

In general, efforts for engineering education are much higher and systems for education are more flexible in the United States than in Korea. Examples of such characteristics are shown in the following Table 4.

3. Opportunities in Korea

Engineering education can be improved highly through the efforts from the government, university faculties and industry especially in engineering education. Recently, Korean Society for Engineering Education (KSEETT) was founded in May, 1993. and Korea Academy of Engineering is expected to launch from 1996. Also education reforms initiated by the Korean Government are in progress, where efficient system and financial support are mainly considered. In improving the quality of engineering education, practices in the United States are good references even though cultural and social backgrounds are different from each other. Reflecting the experiences in the United States, following suggestions, not limited to these issues, should be realized to improve the engineering education.

Table 4. Comparison of major engineering education systems

	USA	Korea	remarks*
entrance qualification	overall quality	written exam	overall quality
discipline decision	from sophomore can change easily	from freshman difficult to change	
student quotas	flexible	fixed	flexible system
students/faculty	7-10	41.7(eng.) 29.8(total){{	
expenses($) (/college student)	27600(1990)	4000(1993)	
society for education	ASEE(102 years)	KSETT**(2 years)	
faculty evaluation	teaching+research	mainly research	

*guidelines for education reform in Korea

** KSETT: Korea Society for Eng. Education &Technology Transfer

1) More budget and support from the Government are required to have enough faculties and facilities and to cover the expenses.
2) The education system should be more flexible for the changing environments such as requirement of engineers in quality and quantity aspects.
3) Evaluation on teaching should be emphasized comparable to research. To achieve this purpose, center for engineering education is to be established and research money for better engineering education are to be provided. The research results can be used for better teaching and to evaluate faculty performance through publication.

Reference

1) M.L. Good and N.F. Lane, Producing the Finest Scientists and Engineers for the 21st Century, Science, 266, 741-743 (1994)
2) L.P. Grayson, The Making of an Engineer, John Wiley, New York (1993)
3) Engineering as a Social Enterprise. H.E. Sladovich ed. National Academy Press, Washington D.C. (1991)

〈제1부 토론〉

Bo-Hyung Cho(Professor of Electrical Engineering, SNU)

Competitive countries like Europe and Japan had all their infrastructures destroyed during World War Two. Basically, there was no competition for the US. For instance, one specific aspect concerning consumer products, it was a free ride for America. Europe and Japan started to emphasize science and math programs. And I believe that its still the strongest. As I know it, engineering is no different, though, I may be biased.

Professor Noh also mentioned choosing a major after a year of studies. The question is, is this practical in a very rapidly evolving technological society? The engineers that are produced now are what we call renaissance people; meaning that they have to do everything. This means that we have to educate them not only the basics of science and knowledge, we must teach them to think and how to design. This is not only limited to engineering, rather, it encompasses non-engineering fields.

My question is how can we train engineers in two years if they choose their majors after their sophomore year? This maybe one of the reasons that the Massachusettes Institute of Technology proposed a five year program. But this is not feasible, or actually, possible for other universities. The reasons are few and simple and perhaps the most significant is that it comes from parents. They do not want to pay an additional year for their childrens' education, where the tuition is already high. This is more true for private universities or colleges. I think engineering is a field and concept which takes four years of training and learning because students need to be exposed to new fields and basic engineering concepts from their freshmen year. Thank You.

Dong Il-Cho(Professor of Control Engineering, SNU)

I actually spent 19 years in America. I went to high school and college there and came back to Korea two and a half years ago. In dealing with this sections topics, I don't want to deal or comment on the specifics of science education. I would rather discuss the generalities surrounding science education in the US.

I think that we are going through the same pains that Korea is going through in America. I was a professor at Princeton University for six years, and we often talked about changing our curriculum. With this in mind, I would like to comment mainly on two problems of Korean education. First, "Vision", or lack of experimentation. As far as I have seen in the last two years, Koreans are very reluctant to change. In America, when I went to undergraduate school in the 1970's, engineering departments put greater emphasis, or at least try to emphasize writing and communication skills to engineers. Then in the late 80's and the 90's, the big change was the integration or incorporation of design components or hands on experience beginning from a student's first or second year, rather than waiting until their junior or senior years. However, in Korea, the engineering education in Korea has not changed a great deal in the last twenty years. And as I speak, we are going through some changes. For example, there is discussion at SNU about reducing the credit requirement to 36 hours for a major so that students can double major, which is similar to American universities. Personally, I hope that this gets implemented and I hope that we introduce writing skills and design components to our students.

To do that, we need "Vision" and we need a system that allows you to do that. The Korean system, as it exists today, is not as flexible- so changes are very difficult to implement. The second issue is "money." I saw in the newspaper that we spend around $8, 000 dollars per student for engineering majors. According to the 1991 figures at Princeton, we spent $45,000 dollars per student per year in education, this also includes liberal arts. The startling issue is that Princeton has a total of 6,000 students and only 18% of them are involved in engineering. Where does this money come from? The answer is that Princeton's research overhead covers about half and interests income from endowment cover the other half. Now, to my best "guesstimate", Princeton and MIT spend about $60, 000 per student per year. With this disparity, how can we compete. Korea is in the process of undergoing major changes. We are now a transitional nation so I think in time we will come up with a solution. If you were to ask me if the US education system is more efficient and optimal, my answer is NO. As I have seen, there are a lot of inefficiencies in America, but they are better funded to deal with such inefficiencies. In closing, I think that if we did some studies on how to most effectively raise money, endowments, and how to most effectively spend the money on education, we should be able to find a good solution without spending $60,000 dollars a year. But the reality is that we desperately need more funds. That's a fact. Thank you.