

Education of Science and Technology in Japan

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Synopsis

The present status and possible reforms of the education of science and technology on the high school and university level in Japan are reported with a discussion about future trend in the undergraduate and graduate education. A unification of traditional sciences and related engineering is anticipated on both pure and applied science sides of the university education.

1 An overview of educational system and social environment in Japan

We start with a brief overview of the educational system in Japan to point out several characteristics which may distinguish between Japan and United States. Three general characteristics of the educational system in Japan may be mentioned first of all, 1) strict division of education by age-group, 2) entrance examination of university, and 3) distinctions among national, prefectural or municipal and private universities.

After reaching the age of 6, one goes to an elementary school for six years and to a junior high school for subsequent three years; the nine year education altogether is obligatory. About 95 percent of graduates of junior high schools go to senior high schools for three years. Though the senior high school education can be replaced by passing a nationwide qualification examination, successful applicants must wait until the age 18 to apply for university in case they are younger.

Each university gives an entrance examination. Since the subjects of the examination are generally different for different fields of study, an applicant is required to choose more or less the field which he wants to study in university

at application; even in the case of broadest choice one has to choose either of natural science, humanity, social science and medicine, and in some universities including leading ones the choice is required to be in more detail in such a way as physics, applied physics, mechanical, electrical, chemical engineering, etc. It is difficult in general to change the field after being admitted to university.

There are 98 national universities which are branches of the central government from a legal point of view. There are universities belonging to local governments, prefectural or municipal in a similar way. In addition to the universities of these categories we have more than 300 private universities. Table 1 shows the distribution of students among these three categories of universities; we note that three national universities have graduate schools only. Table 2 shows the distribution of freshmen in various fields in the year of 1992 for national and private universities which can represent the general trend. As far as science and technology are concerned, the majority of graduate students are in ten national universities which are leading in both education and research on both undergraduate and graduate levels.

The distinction between the faculty of engineering and that of science may be mentioned also as another characteristic; the latter is for basic sciences and the former for applied sciences and engineering which are categorized as engineering in Table 2. We may note in the Table 2 that the number of students in the faculty of engineering is much larger than that of the faculty of science.

Traditionally technology was highly appreciated. The education of engineering was carried out on the university level immediately after the adoption of western civilization which started in 19th century. The Faculty of Engineering of the University of Tokyo was established as early as the Imperial College of London. Graduates from the faculty of engineering have a high social status and a path to top executives including CEO is open for them in most companies of manufacturing industry. I note that science and technology have been regarded as inseparable from each other in general. In other words, science has been appreciated as the basis of technology only and the notion, science for the sake of knowledge has existed only among scientists of the faculty of science. In fact the faculties of science of leading national universities were established to provide the industry with necessary knowledge of basic sciences. A typical example is the Faculty of Science of Osaka University which was established in 1931. The department of physics of the Faculty was chaired by Professor H. Yagi, a well-known figure in the field of electrical engineering. He invited, however, many ambitious young physicists to form a national center from which the first Nobel prize work in Japan made by Professor H. Yukawa emerged. The department has, on the other hand, Mr. A. Morita of Sony corporation among its alumni. Incidentally graduates from a faculty of science who go to industry seem to be able

to enjoy a similar status to that of those of a faculty of engineering.

2 Efforts to attract young people to science and technology

The necessity of making efforts to attract high school students was felt in the field of chemistry as early as 1970's when pollution problems surfaced. Since chemical industry and consequently chemists were assumed to be responsible for them, the number of students who wanted to study chemistry and chemical engineering decreased conspicuously at that time.

The Chemical Society of Japan which covers pure and applied chemistry with more than 30,000 members started various activities to change the atmosphere.

- 1) Since 1984, a full day meeting for reading research papers by members of 'chemistry clubs' of junior and senior high school students has been created as a part of the annual meeting of the society. Participants range from 150 to 300.
- 2) Since 1985, a short laboratory course for high school teachers has been opened.
- 3) Since 1984, delegating speakers to several local teachers meetings has started.
- 4) Since 1983, a visiting teacher program has been carried out to delegate more than 10 lecturers to high schools and elementary schools for a short course for teachers.
- 5) An open laboratory is available at the National Science Museum for students of junior high and elementary schools in Saturday afternoon 12 times a year.
- 6) Since 1982, branches of the Society have started 'Invitation to Chemistry' program which comprises lectures, laboratory courses, and visits to university for general public. The total number of the courses is increasing each year; altogether 18 courses were held in 1988.
- 7) Since 1978, exhibitions showing how chemistry contributes to the promotion of better life have been held each year in various cities in Japan.

In cooperation with other societies related to chemistry and chemical engineering, the society forms a committee named Dreams! Chemistry (in) 21th (century) which promotes the campaign 'Chemistry Makes Our Dreams Come True'. The decrease of the number of applicants for chemistry courses has stopped, while the pollution has let up.

The statistics of distribution of university applicants in recent several years shows clearly a tendency of declining in the field of science and technology and an increase in the field of humanity and social science. Economy of Japan was in boom in this period. However, the coming of the recession which was felt by

people since the last fall has changed the situation. Though I cannot present precise statistics, the number of applicants of this year in the field of technology has taken an upturn. Dismissal and lay-off have become for the first time a real problem which mostly white-collar workers have to face. The anticipation that graduates in the field of humanity and social science will have difficulties to find jobs seems to have produced the change of trend.

Nevertheless, the tendency that students keep away from the courses of science prevails particularly in those high schools in which applicants for leading national universities are rather rare. However, many universities including leading ones have started various activities to stimulate young peoples' interest in science and technology. For example, the Faculty of Engineering Science of Osaka University gives a summer course open to public to explain recent developments in science and technology. A similar one on mathematics is given by Kyoto University. Promoting a campaign similar to that of the Chemical Society is attempted or under discussion in other fields.

3 Introduction of more flexibility in education on the high school level

The Japanese education in elementary and junior high school seems to lay slightly more emphasis on mathematics and science compared with other countries. Since I know some statistics only, I shall not discuss it here. Turning to the senior high school education, the primary problem seems to be how to deal with the mass of the students which amounts to 95 percent of the age-group of the population. The need to have more flexibility in the curriculum has been discussed for long time. A new curriculum which has a more variety of courses in the fields of natural sciences, some with more emphasis on laboratory work and less theoretical contents will be introduced next year.

For the leading national universities which have been able to attract good students, the flexibility or relaxation of the discipline intended for the education of average students is not very interesting, though reforms such as introducing more laboratory work will be certainly welcome. On the other hand, the entrance examination of universities will be a key-factor which has a strong influence on the high school education. Though the examination should be based on the high school curriculum, it is left to universities to choose the subjects in the examination. Thus an entrance examination which lays an emphasis on science will either force high school students to study science or scare them away from

the university, producing a dilemma.

The need to introduce more flexibility in the age-group restriction on the high school education is the subject which has been discussed at a committee headed by Professor Suematsu within the Ministry of Education, Science and Culture. After rejecting the idea of removing generally the restriction of the lowest age 18 for entering a university, the committee recommends that high school students of high ability should be given an access to university education. It says that this possibility should be explored in particular for those who want to study mathematics and physics. For mathematics the removal of the lowest age restriction is recommended to be studied seriously.

Another attempt to encourage students' interest in science is to create a special course whose curriculum has an emphasis on mathematics and science. In Osaka such a course has been opened recently in two public senior high schools. Osaka University is cooperating with these schools by offering a short summer lecture meeting and visits to University for students.

4 University education

As was mentioned before, the choice of the fields where students want to study is made more or less when they apply for admission. In other words the entrance examination secures the number of students. The danger that the number of applicants is not sufficient is still a remote possibility for leading national universities.

The number of university students altogether reaches about 28 percent of the age-groups of the total population (if we include those of colleges of two or three years, the figure becomes more than 35 percent.) First of all the variety of the high-school education introduced by the above-mentioned new curriculum will pose a general problem. Even when we confine ourselves to leading universities, a diversification of the entrance examination which is intended to take a wider view in the selection gives rise to the problem that freshmen may lack a basic knowledge of science. Recently the University of Tokyo have created a special course of physics, chemistry, etc. for those students in science and technology who have not studied the courses in senior high schools.

A more fundamental problem is to develop the creativity of students. Of course the problem is shared by the graduate students and professors themselves.

The university education was subject to a regulation of the Ministry of Education, Science and Culture which divided it into general education and professional one, each for two years. The general education was subdivided further into humanity, social science, foreign languages etc. with minimum lecture hours for each. In 1991 this regulation was repealed. Since then each university has been discussing about a new curriculum and reorganization of professors. In many universities modifications of the general education and removal of the strict distinction between the general education and the professional one have been made or will start soon. Generally the reform is intended to activate the general education to give students a wider view and more understanding of the interrelation among sciences. There is a misgiving that the professional education which can start in the first year after the reform may take a larger share in the university education to produce engineers and scientists lacking a basic culture.

In the field of technology it is generally felt that the professional education on the undergraduate level has been too specialized. A report published in 1991 by the Deans of the Faculties of Engineering of leading national universities has given guidelines on possible reforms. A faculty of engineering consists of the departments of two categories. The first category comprises departments such as electrical, mechanical, and metallurgical engineering, applied chemistry, etc. whose division may correspond to the difference of the sciences and methods used in the engineering; on the other hand, the second category comprises departments such as civil engineering, architecture, shipbuilding, atomic power, etc. which reflect the objects which the engineering aims at. The report of the Deans argues that the strong emphasis laid on the usefulness and practicability of engineering resulted in a closed domain of thought and education for each subdivision of the engineering. The report emphasizes that recent advances in the engineering are making the subdivisions obsolete and producing also its own science which should be distinguished from traditional reductionistic basic sciences. Thus a more unified professional education will be a future target.

The necessity of a reform of education is felt also in the field of basic science where, particularly in physics, a new trend of recognizing the capability of complex systems has started. In my opinion the new trend is not very different from the new science of engineering mentioned in the report of the Deans quoted above. In physics of complex systems a model of interacting elements can give rise to a new concept as a whole. Thus designing becomes important as equally as analysis, suggesting disappearance of the distinction between basic science and technology. A good example is the brain science where approaches based on the computer technology may be combined with those of traditional biological ones in near future. An effort to bring together basic and applied sciences was made as early as 1960's in Osaka University by creating a new Faculty of Engineering Science in addition to the Faculties of Science and Engineering. I can say that

the plan has been a success, producing many excellent graduates and giving a new model to the faculty of engineering. Progress in science and technology may require us a reorganization of university staff in near future.

New curriculum in the professional education in science and technology is under discussion at present in many universities.

5 Graduate school

A graduate course in the field of science and technology is divided into master and doctor courses in most universities. A master degree is required to enter the doctor course. A master course is for two years usually. In rare cases where certain conditions are fulfilled, a student can get a master degree in one year. The principle of dividing students by age was strictly applied to applicants for graduate school until 1991 by requiring them to finish an undergraduate course of four years. It meant that the lowest age for admission was 22. Since 1991 the regulation has been relaxed to allow students to skip the fourth year of undergraduate course.

A student stays in a doctor course usually for three years before obtaining Ph. D. In exceptional cases the period can be shortened to some extent. The opposite cases where a student spends more than three years in the course occur much more often. In any case a doctor thesis is required.

There is a bypass for getting Ph.D. One can apply for it by presenting a thesis and passing an examination to test his knowledge. Usually it is required that the applicant should be old enough, spending more than five years after graduation. This is a convenient system for those people who went to industry after graduation or finishing the master course. However, it may be regarded as a cause to lose students of doctor course to industry. A compromise such as requiring a schooling as a part-time student along with the thesis is being discussed.

In leading national universities, majority of undergraduate students in the field of science and technology go to the master course. The skipping of the final year of the undergraduate course is becoming not very rare, though not popular. In the case of basic science more than half master students want to continue their study in the doctor course. On the other hand, in the case of engineering most of them go to industry, resulting in a scarcity of Japanese students in the

doctor course in most universities.

A general trend in leading national universities is to lay more emphasis on the education of the graduate school with an increase of the number of students. Reorganization of professors on the basis of graduate school is being made in several leading universities; the professors have been grouped so far according to the department division of undergraduate education. The central problems of the graduate school system in Japan are, however, to attract more young promising students to the doctor course in the field of engineering and to produce more creative researchers in both basic and applied science.

In my opinion the education given in the present graduate schools in Japan is too specialized. Generally students are supposed to follow patterns set by professors and study within their realm. Of course there are many broad-minded professors to whom the present argument does not apply. Nevertheless a reform of the graduate school which encourages students to extend their study beyond walls dividing the fields or constructed by their teachers and gives them information and inspiration about what are going on in a wide range of science and technology is needed.

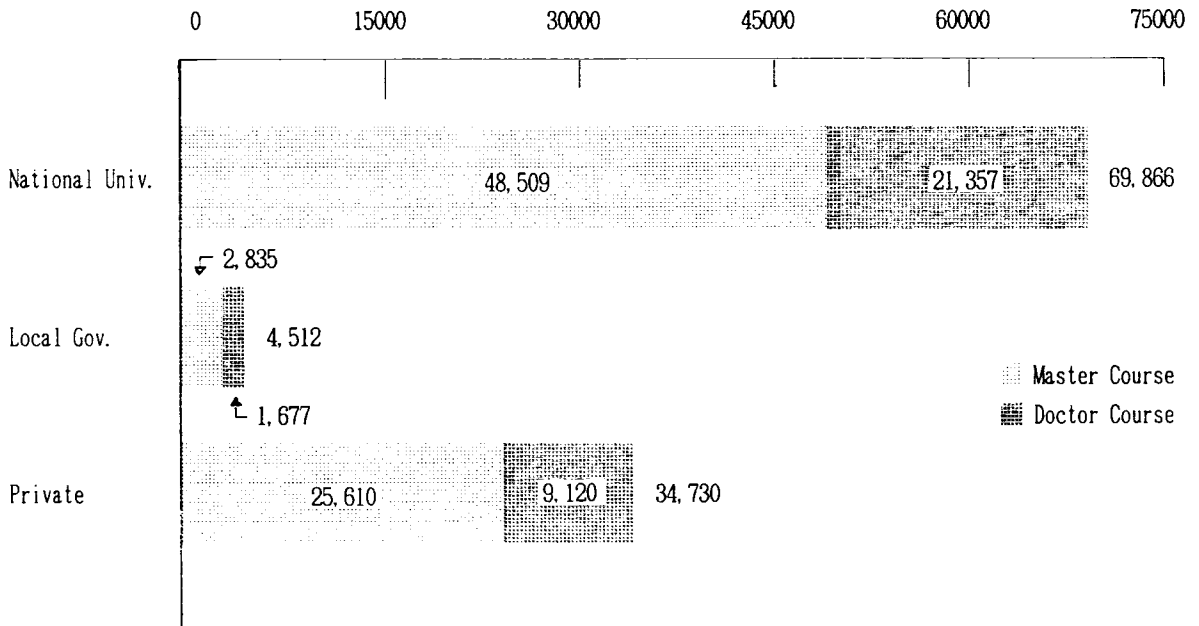
An improvement of education along the line mentioned above and a more budget which should not be forgotten will make the Ph.D. course of engineering more attractive and establish eventually a mutually benefiting relation between universities and industry. To achieve it we need of course various practical measures which are now under intensive discussion in many universities.

Acknowledgment

I would like to thank Professor M. Aso of the Faculty of Human Sciences of Osaka University for a valuable discussion and informing me about the high school education and for Professor T. Shiba, Emeritus Professor of Osaka University for informing me about the activities of the Chemical Society of Japan.

— Table 1 —

Distribution of Graduate Students (1992)



	National Univ.	Local Gov.	Private	total
No. of Univ.	9.5 (18.3 %)	4.1 (7.9 %)	38.3 (73.8 %)	51.9 (100 %)
Undergraduate Students	44.6 (21.0 %)	6.1 (2.9 %)	162.1 (76.2 %)	212.8 (100 %)
Graduate Students	7.0 (64.0 %)	0.5 (4.1 %)	3.5 (31.8 %)	10.9 (100 %)

Number of students is given in the unit of 10,000 ; the statistics is for 1992

— Table 2 —

Distribution of Freshmen in Various Fields (1992)

	National Univ.		Private Univ.	
	Student No.	%	Student No.	%
Humanity	6,871	6.5	76,945	18.3
Social Sci.	16,987	16.1	196,000	46.6
Basic Sci.	6,947	6.6	10,624	2.5
Engineering	31,093	29.4	71,428	17.0
Agriculture	7,469	7.1	8,662	2.1
Medicine	4,681	4.4	4,850	1.2
Pharm. & Nurs.	1,110	1.1	8,196	1.9
Education	22,094	20.9	13,058	3.1
Others	8,346	7.9	30,865	7.3
total	105,598	100.0	420,628	100.0

FLOODS, HURRICANES, AND CLIMATIC CHANGE IN AMERICAN RESEARCH UNIVERSITIES

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(A discussion paper prepared for the sixth U.S.-Japan Science Policy Seminar on "Promoting Basic Scientific Research in Universities: The Changing Relationships with Government and Industry," November 7-10, 1993.)

The past several years have brought several unusually severe natural disasters to the United States, including floods and hurricanes. These events have engendered discussion about their possible relationships with climatic change and speculation about future weather and climate patterns. Analogous events have occurred in American higher education, events that have stimulated similar speculation about the future of our colleges and universities in general, and our research-intensive universities in particular. As we address the issues before us in this seminar, we need to consider whether these events portend important changes in American research-intensive universities, or whether they are merely transient perturbations in a generally stable steady-state system.

It is my contention that our American research-intensive universities are now in the throes of a transformation that will switch many of them onto trajectories significantly different from those on which they have moved since World War II. If that is really so, it is obvious that this transformation must be a major factor in any consideration of the relationships among universities, government, and industry. It will not be sufficient simply to examine trends in the funding of basic research in our universities or in collaborative industry-university research programs, while assuming that the universities themselves are a "constant of the motion" and will continue to exhibit the basic structures and functions they have had over the past half century. If universities are really in the midst of profound and pervasive change, then this must also be taken into account.

Let me therefore begin by making the case for the existence of a transformation in progress, so that my readers or listeners can judge for themselves whether we need to think about things more profound and far-reaching than changes in research funding patterns.

What are the symptoms of the transformation? There are several indicators of long-term "climatic change" in progress. The American student body is steadily diversifying along many dimensions. Not only is its composition changing in terms of race, ethnic origin, and gender, it is also aging and becoming both more episodic and persistent in its engagement with the educational process. Three quarters of all

American college and university students no longer have the traditional characteristics of traditional undergraduates, e.g., ages between eighteen and twenty two and full-time enrollment. The "non-traditional" student has already become the norm, the "new-majority" student.

Such students' academic needs are most likely to be met by community colleges and four-year institutions outside the realm of the small minority (three or four percent) of our nation's 3600 institutions of higher education that are research-intensive universities. That has implications for the allocation of public funds in support of institutions of higher education. Because institutions that are perceived to be effective in meeting broad public needs tend to attract popular support, we may well see a shift of public priorities and financial support away from our major public research-intensive universities and toward other types of institutions.

If such a shift occurs it will affect directly the ability of our public research-intensive universities to join with governments and industries in economic development efforts. This possible consequence of a shift of resources is probably less well recognized by our citizenry and our public policy makers than it should be. It is commonly (and mistakenly) believed that our public universities receive the majority of their revenues from their state governments, and that these revenues are used almost entirely to support the teaching of students. If the university's research enterprise is recognized at all, it is commonly thought to be an avocational occupation of the faculty, funded by the federal government.

The fact is that the state revenues of a public research-intensive university contribute significantly to the support of the university's research enterprise and thus to its effectiveness as an economic development tool. A substantial redirection of a state's higher education funding away from research-intensive institutions and toward institutions thought to be more effective or efficient in meeting the academic needs of "new majority" students will have the (perhaps unintended) collateral effect of compromising the research-intensive institutions' capacity to contribute to the state's economic development. The growth of the "new majority" student population can thus be viewed as a challenge (or even a threat) to the stability and vitality of the academic research enterprise.

Another indicator of "climatic change" is the surging tide of information technology. Universities are in the information business, and their characters, cultures, and structures are profoundly influenced by the information technology they use. For more than half a millennium, that technology has centered on the printed word, on physical artifacts called books and journals. The management of such artifacts requires physically localized institutions called libraries staffed by professional information managers called librarians. The character of our universities has been fundamentally shaped by libraries; a university can aptly be defined as a community of scholars gathered around a great library.

What then if our information infrastructure becomes globally delocalized and libraries as we know them vanish into cyberspace like Alice's Cheshire Cat? What will happen to our traditional university campuses? They will surely change in ways difficult to foresee. One thing is obvious, however: A delocalized information infrastructure more closely parallels and better matches the spatially and temporally delocalized new-majority student body than do traditional campus units like computer centers and libraries. One is compelled to ask whether that most traditional of our higher education institutions, the research-intensive university, can survive the information technology revolution now in progress in anything like its present form.

Amid these concurrent demographic and technological climatic changes there has occurred a geopolitical phase change that is yet another portent of "climatic change" in our research-intensive universities. The Cold War has ended and the familiar bipolar post-World-War-II world has vanished. The American research-intensive university is one of the most benign and successful byproducts of the Cold War era. During that era it increased ten-fold in number and much more than ten-fold in wealth, influence, and prestige. These changes occurred in part because the research-intensive university was popularly thought to make important contributions to the nation's military security.

National concern has now shifted to economic security and to domestic problems such as pre-college education, health care, and crime. If they are to continue to enjoy the public's support, the research-intensive universities must now successfully argue that they are essential to the nation's economic development and to the solution of the nation's most pressing problems.

That's a tough sell! The public is understandably skeptical about the economic value of basic research. The United States continues to garner Nobel Prizes regularly, but it is Japan that sells television sets to the world. Our pre-college education and health care systems are commonly considered to be in crisis, and everybody knows who educated the teachers and health professionals that have helped make them so.

As if these climatic trends were not enough, our universities have suffered budgetary floods and hurricanes. Many of our leading public institutions have experienced substantial (e.g., twenty percent) decreases in state funding. Most of our colleges and universities, both public and private, are feeling the pinch. While many believe these budget difficulties are temporary, more like sudden violent storms than long-term climate changes, there is little reason to expect that we will return to anything resembling our past circumstances in the foreseeable future. Structural changes in our public and private economies, coupled with increasing competition for limited resources to deal with pressing social problems make a return to the *status quo ante* unlikely.

In short, our universities are experiencing some of the dramatic environmental impacts that have forced draconian changes on some of our leading industries. Some universities are still in the denial phase and have yet to respond effectively to their

changed circumstances. Others have begun to restructure and reengineer themselves, with consequences that certainly will include survival but that remain uncertain otherwise.

Like American industry, American universities find themselves in a circumstance aptly described by Peter Vaill as "permanent white water." As they strive to negotiate the rapids and rocks they find themselves in, they can rely on many fundamental strengths. It is widely recognized that in a world that places a premium on knowledge and on knowledge-based skills, our universities occupy key positions. Over the past decade our research-intensive universities have steadily increased their market share as performers of basic research in an expanding national R&D enterprise. They remain one of the most competitive and adaptable institutions in our society.

What remains to be seen, however, is how well and how quickly our universities can adjust to the combined impacts of climatic change and unexpected floods and hurricanes. From the inside, that looks like an almost insurmountable challenge. Nevertheless, I think the world's gamblers would be well advised to bet on the side of the American research-intensive university.

**Improvement of Various Conditions for Able Postdoctoral Researchers
(e.g. Salaries, Mobilities of Researchers, etc.)**

Session Four

Where will the people come from to do research?

How can we strengthen science education to foster scientists and engineers?

Opening Statement

Hiroshi Sakurai

Until about 50 years ago there was a widely known saying in Japan to flatter parents of a very bright boy. That was "Sue wa hakase ka Daijin ka" literally translated that "He may be a doctor(of science) or a (cabinet) minister in the future." It was considered that a doctor of science is one of the most desired goals only conceivable by the few who were exceptionally bright. At that time if a university graduate was suggested by his professor to continue his study through the graduate level, he felt it an honor and usually had no hesitation to follow the suggestion if his situation permitted. Before World War II, the number of doctors were very few and they were considered as men of accomplishments and not only respected but also commanded reasonably good income to keep relatively high living standard.

After World War II, the situation has been changed dramatically. The status of doctors who are more or less considered equal to university professors has been deteriorated mostly by the proliferation of universities.

More egalitarian pay structure prevalent in Japan after the war downgraded the salary level of the best professors while their average pay level which has been near equivalent or sometimes less than that of industry, is applied to almost everybody in education. In other words, graduate study has become not as attractive as before.

To induce the best and brightest to graduate schools for their Ph.D's, there are basically two requirements. Those are the attractive school and promising future career development. In both factors we cannot forget the financial side of the picture as in the case of doctors before WWII. As shown on the Figure I which is from the latest labor statistics by the government, medical doctors and financial staff are appreciably better paid than educational employees and metal industry employees. Most of the scientists and engineers in manufacturing industries are paid near the level of the metal industry. That is why there are enough applicants to very high tuition private medical schools and the brightest students compete for admission to low tuition public medical schools.

There are many young students who would succeed as scientists or engineers opt to enter to nontechnical departments of universities aiming to join in financial industry without graduate study. The reason for their move is clear. The financial firms pay more than manufacturing industry and there is no higher income by post graduate degrees in any industry. The situation for PH.D.'s is the worst. If there is no income differential with their undergraduate classmates after 5 years of costly, hard graduate study, who would be willing to enroll

himself in a graduate school? Sample checks in companies and interview with the staff of Salary Department of the Federation of Employers' Association concluded that there is no preferential salary for Ph.D.'s expected in the foreseeable future. There are many reasons cited by those in personnel management who have usually no engineering or science background. Among those are:

1. Public perception of Ph.D.(Doctor) as a degree of accomplishment, not a degree of competence or advanced education.
2. Preferential treatment for a few will downgrade the morale of the majority in the teamwork which is essential in today's industry.
3. Capability of a Ph.D. is not always worth for a premium. He is not necessarily well educated.
4. A Ph.D. is usually too academic and too narrowly focused to adapt in the new environment.
5. A doctor's degree can be obtained without formal graduate education when the title is required or desirable for specific assignments, if an employee is bright and is given proper research environment.

When I look for what is available in statistics on salaries, in the United States and in Japan, I found there are conspicuous differences in the grouping of salary earners as shown in Table I. For starting salaries, the structure is also quite different in two countries as shown in Table II. Data for statistics are usually collected when the resulting statistics are useful. From Table I, we see the importance of the years of employment for the level of salary in Japan while higher degrees are more important in the United States.

Figure II indicates average salary of BS or higher in all industries in three age groups namely 35-39, 40-44 and 45-49 with their years of the employment in the

reporting organizations extracted from the statistics of the Ministry of Labor. As the figure indicates there are appreciable handicap for those who did not work for a single organization for their life time. The number of employees with their years of employment are shown in Figure III. From these figures, it is easily concluded that about 20-25% of total employees who moved at least once to different employers are getting 20 or more per cent less than those who have stayed with the same employer. There is no statistics of this nature available for scientists and/or engineers but the situation would be similar for all employees with BS or higher education. It means the curves on Figure I should be higher by about 5% for those working for one organization in their life time.

In the United States there is a clear difference between average salaries of BS's and Ph.D.'s. Examples are shown in Figures IV and V. If we want to strengthen graduate schools in Japan to do more higher level basic research, there are two fronts we have to work. Those are to make institution more attractive to prospective students and to make their future after Ph.D. more rewarding. Considering Japanese public perception and socioeconomic environment, it seems more difficult to change the salary and promotion system than to improve the school system itself. Anyway Japan needs a long way uphill battle to improve its graduate education to meet the requirement of the future society.

The mobility of researchers can only be improved when the movement does not jeopardize their income or status. The current situation will only change when the shortage of scientists and engineers forces the employers to hire middle career staff in a mass. Without an economic boom, this seems unlikely in the foreseeable future due to total payroll costs constraints and strong social resistance to flatten the service year/salary curve, because of high household cost for housing and university education which is felt more acutely by the middle aged.

Nevertheless, Japanese employment situation is changing by economic and political necessity against social resistance and the time of better income for those with higher academic degrees and salary increase more by experience and improved competence and less by mere length of service will come. The question remaining is not "if" but "when".

Table I

Available Salary Statistics

	JAPAN	U. S. A.
<i>By Industry</i>	Yes	Yes
<i>By Age Group</i>	Yes	Yes
<i>By Level of Degrees</i>	<i>up to BS</i>	<i>BS, MS, PhD</i>
<i>By Years of Service</i>	Yes	No
<i>By Years of Experience</i>	No	Yes

Table II

Starting Salary Structure

(Difference in Same Employer)

	JAPAN	U.S.A.
Level of Degrees		
HS + 4 / BS	S~M	M~L
BS + 2 / MS	0	M~L
BS + 5 / Ph D	0	L
By School	0	M~L
By School Department	0*	M~L
By Grade Average	0	S~M
By Job Level	0~S	(NA)

* *Some exceptions such as MD*

Figure I

Average Annual Income Salary + Bonus of University Graduates

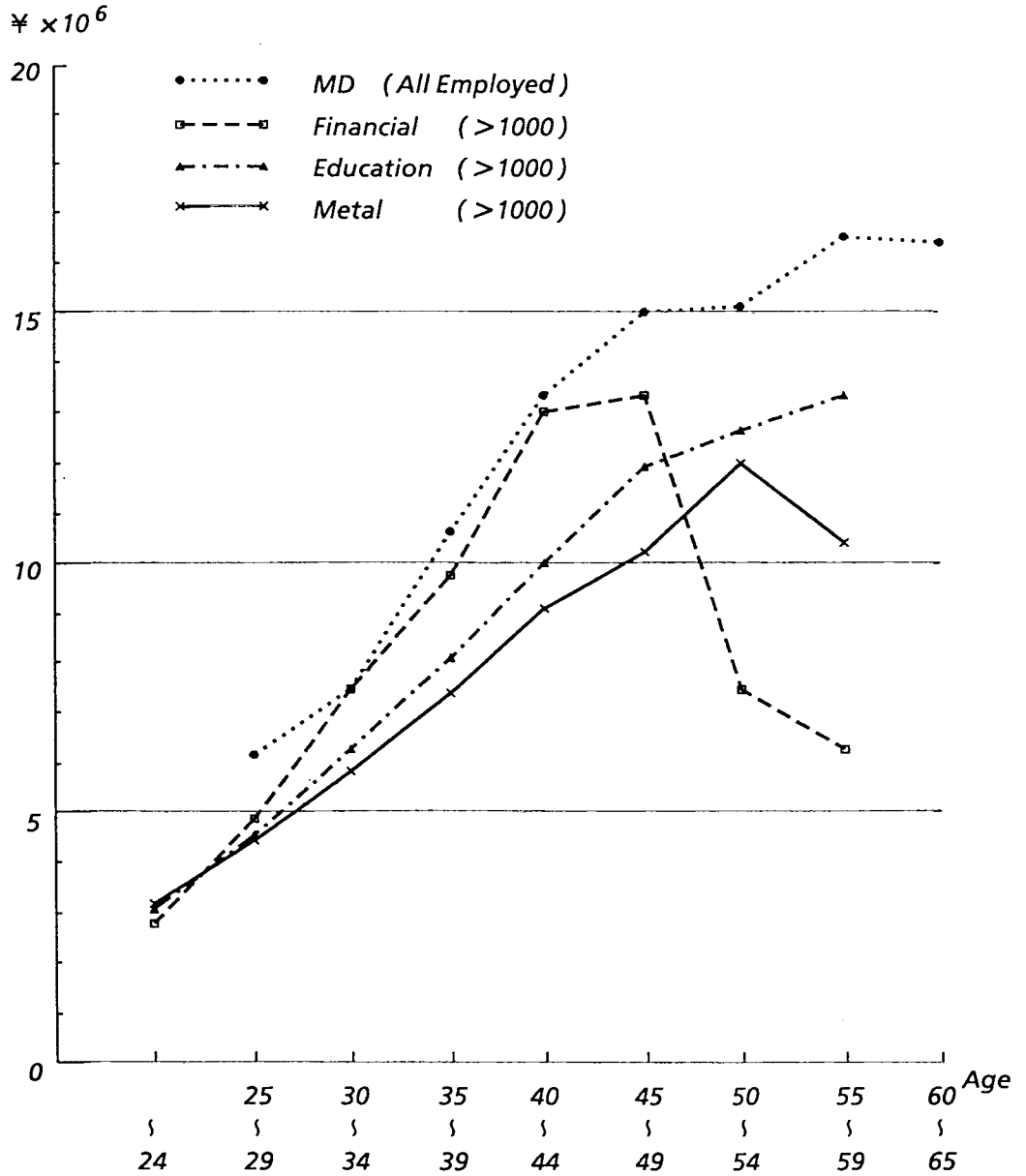


Figure II

Salary by Years of Service

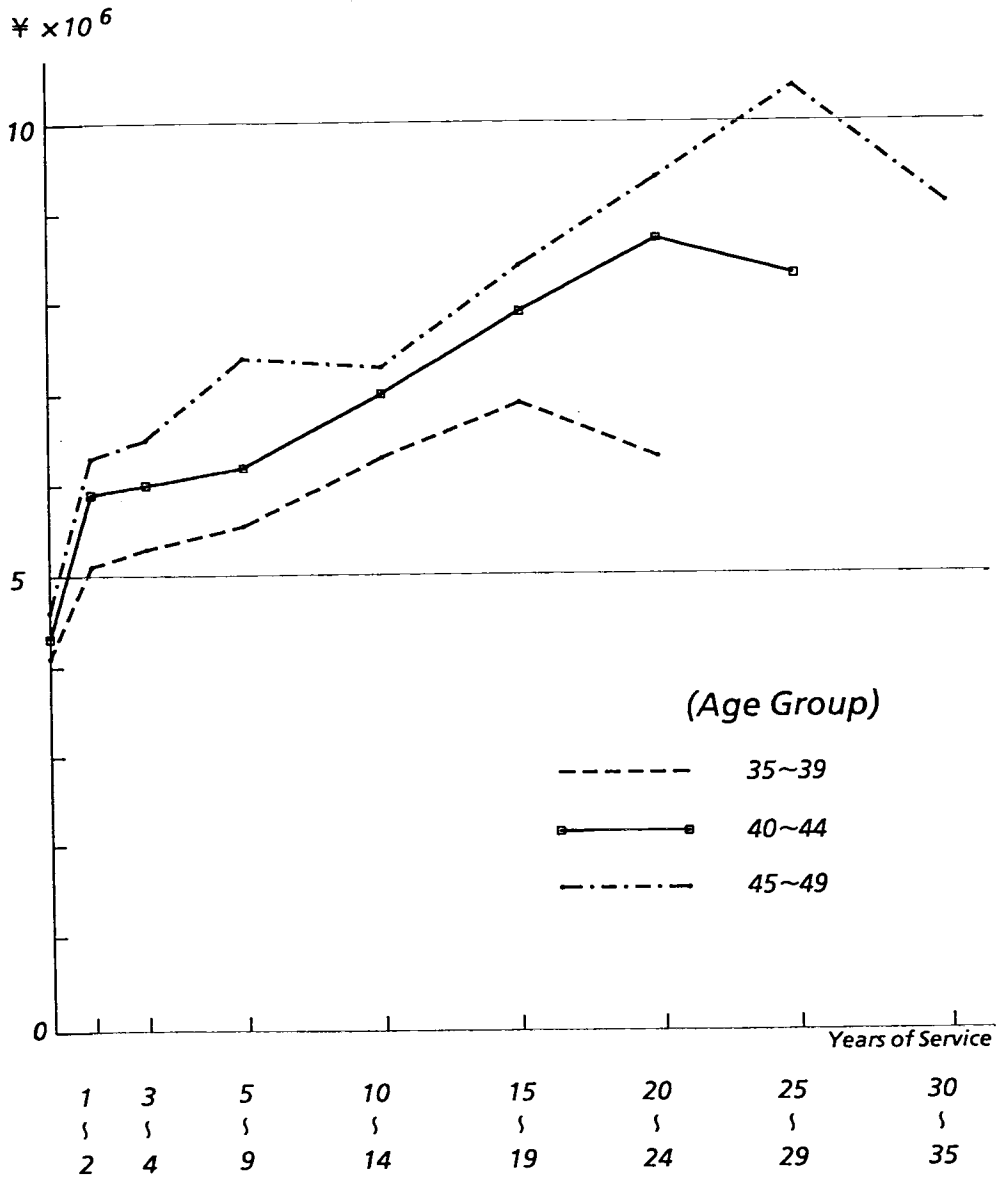


Figure III

Number of Employees by Years of Service

Total Number Reported

(Age Group)

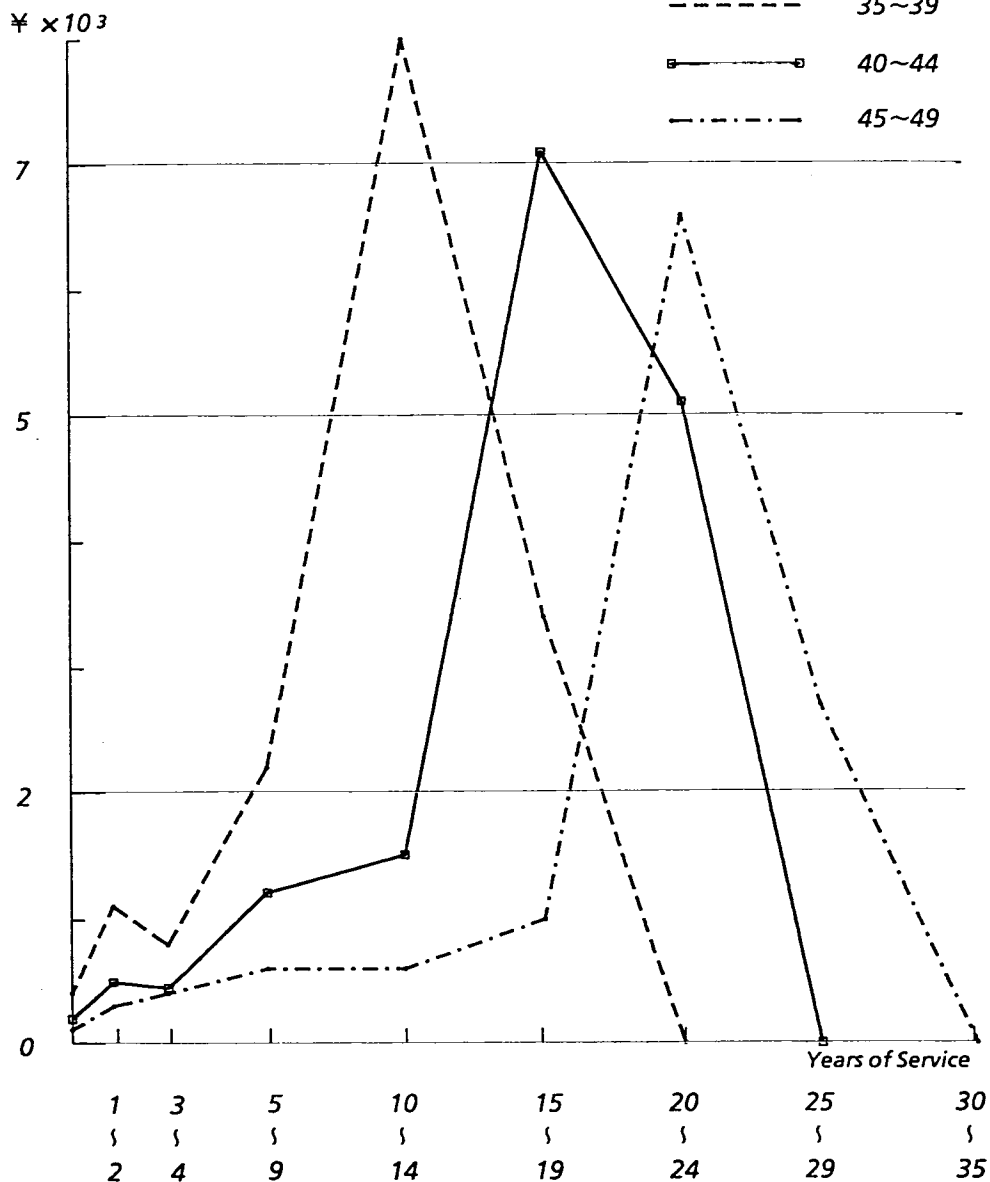
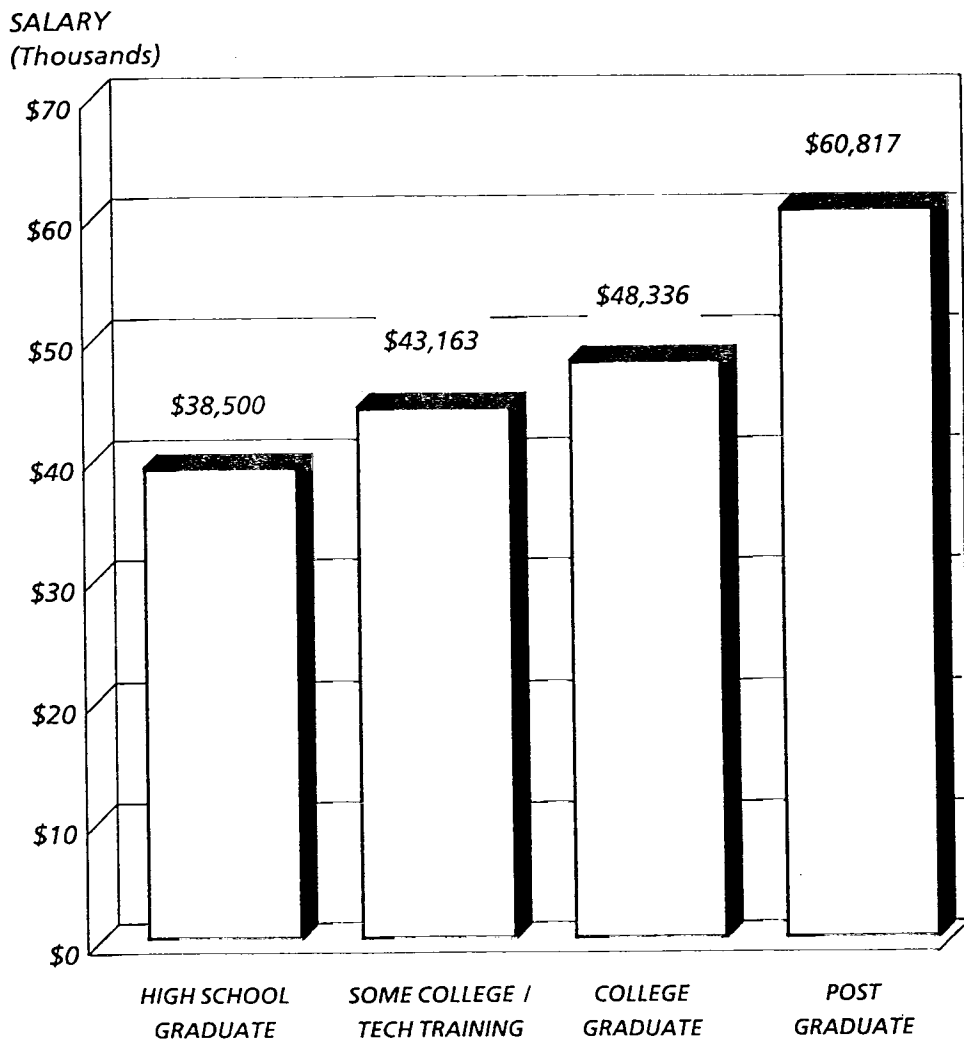


Figure IV

Salary of Members of ASM International (From ASM News, Sept. 1993)



HIGHEST LEVEL OF EDUCATION

Comparison of average salaries of respondents grouped by their education level.

Figure V

*Median Annual Salaries for Engineers Based on Experience,
Company Size, and Level of Education (in Dollars)*

Employer	Number of Years after B.S.						Median
	0	5	9-11	15-17	24-26	33+	
Large Companies *¹							
B.S.	35,150	42,600	49,600	56,150	61,100	62,000	49,400
M.S.	0	45,200	53,100	60,250	64,800	64,550	57,150
Ph.D.	0	49,350	60,250	68,100	72,300	73,200	67,300
Medium-Size Companies *²							
B.S.	34,200	41,950	49,150	56,300	62,900	65,900	50,600
M.S.	0	45,650	54,500	62,300	66,400	64,850	57,100
Ph.D.	0	46,600	57,650	67,850	75,200	76,850	71,400
Small Companies *³							
B.S.	30,100	37,500	44,750	51,550	56,350	56,550	44,000
M.S.	0	41,900	50,400	57,500	60,350	57,800	52,450
Ph.D.	0	0	50,550	61,600	73,800	80,750	62,900
* ¹ More than 5,000 employees. * ² Between 500 and 4,900 employees. * ³ Less than 500 employees.							

Data by AAES from JOM (April 1993)

INTERNATIONAL SOURCES AND DIVERSITY IN THE SCIENCE AND TECHNOLOGY WORKFORCE OF THE FUTURE

by
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at
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Kahuku, Oahu, Hawaii

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CONVERGING TRENDS

Analyses undertaken on scientific and engineering personnel in the United States and Japan converge quite remarkably. They forecast decreases in the number of citizens from each of these nations who will pursue careers in science and engineering. Demographic changes account in part for the forecasts. The United States and Japan anticipate having fewer people in the age cohorts that traditionally have entered college. The population between the ages of 16 and 18 continues to decrease, as it has in the United States from the middle of the 1970s and in Japan, from the late 1980s. The age group -- 18-24 -- that colleges in the United States usually have tapped will have one million fewer persons in the year 2000 than were counted in 1990. The drop for Japan over the same period: one-half million.¹

Demography is not the only force, however. The "college-age" population of the United States was larger in 1984 than in 1991; yet colleges and universities awarded more degrees at the bachelor's degree in the later year. The reasons: more and more college-age students chose to attend college, as did significant numbers of students who were older than college enrollees of years past.

The growth in overall enrollment has not meant a growth in the degrees granted in the sciences, nonetheless. Consider the case of the physical, life, and engineering sciences. The numbers of bachelor's degrees awarded in these fields fell in the 1990s, continuing the trend begun in 1986 (Chart 1). Attitudes toward science seemingly count. In both the United States and Japan, signs point to a declining interest in and growing skepticism about science among young people.

Projections about the future promise to be highly inadequate if they ignore developments internationally. It might seem cliched to speak of scientific and engineering personnel as increasingly global in character; but the cliché fits. The global or international character of scientific and engineering personnel counts in two ways. First, the routes to higher education in science and engineering for the United States as for Japan include travelers from elsewhere on the globe. Second, Japan and the United States -- as well as others similar in economic standing -- contain an ever declining share of the scientific and engineering workforce in the world.

This paper considers some evidence of the "internationalization" of science and engineering for the U.S. It examines changing rates of foreign participation in the system of higher education within the United States. It then sketches trends in higher education for countries that have sent large numbers of students to American colleges and universities.

The discussion ponders, finally, the implications of that "internationalization" for programs and policies in the United States. The discussion suggests that the United States cannot rely exclusively on an international cadre of scientists and engineers. For one thing, the U.S. is not the only nation experiencing dramatic changes in its scientific and engineering workforce. Thus, there can be no assurance that personnel located elsewhere in the world can be called upon to meet the needs of this nation. For another, attention exclusively to international sources diverts attention from the sources located within the borders of the United States.

THE INTERNATIONAL CHARACTER OF HIGHER EDUCATION IN SCIENCE AND ENGINEERING

The United States

The United States holds a significant place in the worldwide theater of higher education, especially at the graduate level. An overview of trends since the mid-1960s shows a continued rise in the number of professional and doctorate degrees granted by American colleges and universities (see Chart 2). But significant variations obtain across fields. The growth of graduate degrees in the professions -- law (doctor of jurisprudence), medicine, and business -- outdistances greatly the change for the sciences and engineering. Aggregations for the latter disciplines, covering the social, behavioral, physical, life, and engineering

sciences show only moderate growth from 1966 to 1990 (see Chart 2). In the decade between 1982 and 1992, the annual production of doctorates in this set of disciplines grew from 18 thousand to 24 thousand (not on chart).

Students from other nations accounted for much of the increase in the doctorates granted. In 1980, just under 4,000 foreign students received doctorates from institutions in the United States; by 1992 that figure exceeded 9,000 (see Chart 3).

The number of doctorates offers only a partial picture of the impact foreign enrollments have had on education in science and engineering within the United States. In fact, it was the presence of foreign students -- and women from the United States -- that spurred a steady growth in enrollments for several fields from the 1970s onward. One should note that non-U.S. nationals consist of two groups: students on permanent visas (persons residing permanently in the U.S.), and persons on temporary visas. The second category contains nearly five times as many students as does the former, however.

The two categories comprise about one-third of all graduate students enrolled in science and engineering throughout the United States. That figure has remained steady for the aggregation of the sciences and engineering but has fluctuated within it. The largest fraction of foreign students (20 percent) enters engineering, although in slightly smaller numbers than prevailed a decade ago. The physical sciences now attract about 18 percent of the foreign

student population, up somewhat since the mid-1980s. The social sciences enroll less than 10 percent of the students -- unchanged over the decade.

Particularly noteworthy are the differences found within the physical sciences and mathematics. Students from other nations comprise nearly half of all full-time graduate students in computer science, just over 40 percent of those in mathematics, and over 70 percent of enrollees in petroleum engineering (see Charts 4 and 5).

In contrast, foreign students constitute only about one-third of persons enrolled in biomedical engineering -- although that figure exceeds the one from a decade ago. Worth noting are the small numbers these percentages involve. Petroleum engineering in 1991 had 30 more foreign students -- and 52 fewer U.S. citizens -- than had been the case in the mid-1980s.

Asia accounts for most of the growth in foreign students. More than one-third of non-U.S. graduate students come from the Asian region. Asian students gravitate primarily to the natural sciences and engineering. Chinese students, now the largest group of foreign enrollees, move especially into the physical sciences and engineering. A larger fraction of Japanese students (second after the Chinese) selects programs in the social sciences and business administration.

The doctorate pool reflects an enhanced international presence. International students now earn over one-third of doctorates that the United States grants in science and engineering.

The science and engineering labor force draws increasingly on an international pool -- trained in the United States and elsewhere. It remains for the moment, nonetheless, one in which native-born citizens of the United States predominate.

Japan

Increasingly, Japanese universities serve students from other nations. At present, the 500 universities and junior colleges in Japan teach more Japanese students than persons of other nationalities. Students of non-Japanese nationality represent less than two percent of all enrollees. Their proportion rises at the graduate level, however. In 1992, the 15,000 foreign students made up 14 percent of masters and doctoral enrollees.

As in the United States, foreigners in Japanese institutions consist of permanent residents and persons who are full-time students. The latter far outnumber the former. Japan has experienced a sharp upturn in foreign enrollments, thanks principally to a decision taken in 1983. In that year, the Prime Minister announced what seemed to be a highly ambitious goal: the recruitment of 100,000 foreign nationals to Japanese universities by the year 2000. The plan proved to be far from visionary; over 45,000 were enrolled in junior colleges, undergraduate, and graduate courses as of 1992. That enrollment was three times higher than the figure ten years earlier. Over the same period, the number of all students -- Japanese and non-Japanese -- rose only one-quarter.

Let us return to the graduate student population. More foreign students pursue engineering than any other field. The social sciences, a category that in Japan incorporates business, is nearly as popular. The physical sciences serve fewer non-Japanese nationals than do the agricultural and health/medical sciences.

The international graduate students hail principally from countries in Asia -- especially China, South Korea, and Taiwan. Indeed, students from these countries account for about 90 percent of the total. Students can obtain the doctorate degree through a course of graduate study or by submitting a dissertation. The dissertation (Ronpaku) program serves a relatively small contingent. Between 1978 and 1992, 143 doctorates were awarded through this program -- mainly to citizens of Thailand, Indonesia, Philippines, and China.

SCIENCE AND ENGINEERING IN GLOBAL PERSPECTIVE

The world has witnessed in the past decade and one-half an upsurge in Asian science and engineering. Enrollments in institutions of higher education within the region have surged, as have rates of economic and technological growth. China, India, Singapore, South Korea, and Taiwan join Japan on a rapid economic trajectory.

Enrollments in higher education indicate the scope of the changes. Since 1975, the total enrollments at the university level have doubled for the region. As with other figures, these diverge from one country to another. Rates for India far outdistance those for other nations: enrollments there account for more than one-third of the total.

The region is important particularly in the production of bachelor's degrees. In 1990, Asian institutions awarded over 500,000 of these degrees -- compared with 170,000 for the United States.

Beyond the bachelor's level, the U.S. remains significant for the production of scientists and engineers from Asia. The U.S., and not Asia, is the principal site for degrees at the doctorate level. That obtains especially for Taiwan and South Korea; only a small fraction of doctorates in Japan hold degrees from U.S. institutions.

Internationalization: The Implications

The worldwide stock of scientists and engineers continues to expand. UNESCO estimates that it grew by 40 percent between 1980 and 1990. But there is an unequal distribution geographically of that stock. About three-quarters of it can be found in countries where advanced industrial and technology developments prevail. The "developed" countries contain only one-quarter of the world's population but three-quarters of the international workforce for science and engineering. The concentration is especially noticeable in North America. The United States and Canada -- with six percent of the world's population -- together have some 30 percent of the world's scientific and engineering labor force. Asia claims 30 percent of the personnel force -- but 60 percent of the world's population. Developments underway, in Asia especially, are reshaping the geography of scientific and engineering personnel.

In the developing countries -- in Asia and elsewhere -- lies the potential for growth in science and engineering that countries such as the United States and Japan cannot match. People under the age of 34 make up a larger proportion of the population in China, Thailand, and Pakistan than in Japan, the United States, Germany and the United Kingdom. The youthfulness of the population offers possibilities for growth in science and engineering. There is considerable human capital yet to be tapped in the developing countries. Rates of college attendance, rapidly rising, still lag behind those of more developed nations. Nearly 60 percent of the eligible population in the United States attends college; for India the figure is nine percent and for China, two percent.

The potential that resides in the developing countries might well be considered a resource that the United States and Japan should tap, to meet their needs for scientific and engineering personnel. Not only do the numbers reside in the developing countries, but improved transportation and communication permit movement and exchanges on a scale unprecedented. These developments imply that analyses of and policies for science and engineering should take a global and not a nation-based perspective.²

But such a conclusion merits scrutiny, particularly for the United States. First, it overlooks the reservoir of talent that exists within the borders of the nation. Second, it assumes that the talent that resides elsewhere can be accessed with ease. Third, it overlooks the possibility that the situation can change. If participation patterns for Japan and the United

States cannot be explained solely by demographic factors, so might changes in attitudes and interest alter views toward scientific and engineering careers elsewhere on the globe.

Tapping the Reservoir of Talent

Certain segments of the population in the United States -- Latinos, African-Americans, American Indians -- enroll in college at rates well below their representation within the population aged 18 to 24. Of the students who do attend college, the fields chosen differ from those that White, non-Latinos generally have selected.

U.S. citizens who pursue the physical, life, and engineering sciences come overwhelmingly from the White, non-Latino population. The three groups mentioned earlier account for nearly 22 percent of the college-age population of the United States but only 10 percent of the students who received bachelor's degrees in the natural sciences and engineering in 1991. African-Americans, who comprise over 12 percent of the total population, represent only five percent of graduate students in science and engineering. Latinos make up around four percent of these graduate students.

We have witnessed a shift in the composition of the doctorate population over the past several years. In 1975 White citizens earned 70 percent of the doctorates in science and engineering that U.S. schools awarded. By 1992, the fraction had dropped to 55 percent. Foreign nationals filled much of the gap; U.S. minorities experienced little change. African-Americans received just over one percent of the science and engineering degrees given in

1975 and about 1.5 percent of those granted in 1992. Native-Americans were but a blip on the screen for both years.

The minor perturbations result in a minute pool of doctorate scientists and engineers. Of the 6,000 persons who won the advanced degrees in the physical sciences during 1991, 57 percent were White citizens and 35 percent held citizenship outside of the United States. The degree went to 99 Latino-Americans, 53 African-Americans, and only 14 Native-Americans.³

Women, too, remain underrepresented among the ranks of scientists and engineers in the United States. Women earn nearly 25 percent of all bachelor's degrees but only 13 percent of the doctorate degrees in science. Women represent just over half of all graduate students -- but not the students in science and engineering. For those fields, men make up 60 percent of the enrollees.

Changes in attitudes and interests appear to explain the downturns in participation rates in science and engineering among males who are not Latino. For minority students, a more complicated picture emerges. The population of African-Americans, Latinos, and American Indians contains a disproportionate number of persons of meager economic means. A first-rate education proves elusive to students whose families command few economic resources, whatever their racial or ethnic background. Negative effects cumulate, producing -- among other outcomes -- poorer performance on standard measures and limited participation early on in science courses. By the time they graduate from high school, 64 percent of Asian-

Americans and 52 percent of non-Latino students will have taken a year of chemistry. The figure drops to 39 percent and 40 percent for Latinos and African Americans respectively. Tapping the reservoir requires conscious and concerted efforts.

Economic Development and Careers in Science and Engineering: The Paradox

If the evidence from the United States and Japan applies generally, there can be no assurance that the developing nations of Asia will continue to house a population prepared to make their mark in science and engineering. At earlier times in the history of both countries, careers in science and engineering won plaudits among the youth. Yet, signs now exist of a declining interest from those portions of the population that traditionally entered these careers. The National Institute of Science and Technology Policy (NISTEP) reports a drift among Japanese graduates with degrees in science and engineering away from those fields towards banking, insurance and other business careers. Significantly, these careers outside of S&T appear to attract the best of the graduates. A drift away from science and engineering appears in findings on attention to science.

NISTEP launched in 1976 what would become a series of surveys on interest in topics related to science and technology. In the first year, over 80 percent of males in their 20s reported that they kept track of news on topics related to science and technology. For none of the other groups -- all older than 20 -- was interest in scientific news as pervasive. But fewer than 70 percent of the 20-year olds surveyed in 1985 described themselves as quite interested in items on science and technology. By the 1991 survey, the figure for the same

category had dropped yet another 10 percentage points. The decline parallels trends evident in the United States -- but not those of several other nations. Results from the International Science Survey illustrates. The second of the surveys measured the attitudes of 14 and 18-year olds from a range of countries, including Japan, the United States, Thailand, Sweden, and Hungary. The survey included a question on beliefs about the societal benefits of science. Students were asked whether they thought science makes the world a better place. Among the 14-year olds, far more Japanese, Swedes, and Germans than Hungarians expressed skepticism about science. Youngsters from the United States were not as skeptical as were those from Japan; but neither did they even approximate the very positive reactions that emanated from the Hungarians.

The study found more favorable attitudes toward science among young people in countries at the beginning of industrial and technological development than among those from more "advanced" settings. If the questioning of science sometimes accompanies development, then one cannot assume that the positive views found in many developing countries will survive the drive to economic and technical prowess. If careers in science and engineering prove alluring primarily in those nations that have moved onto the starting line of technological development, then what are the likely outcomes as those nations forge ahead? There is no certainty that the perspectives and arrangements found in the contemporary world will prevail into the future.

TOWARDS COLLABORATION

If the United States cannot depend on nationals from elsewhere to meet its demands in science and engineering, then the conditions affecting the choices of its own nationals merit attention. A wealth of information already exists. The information lays out reasons why some individuals pursue careers in science and engineering while others reject that course. It explains, too, the obstacles that arise as well as the opportunities.

What remains for further exploration is the interplay between wider social and economic developments and the choices individuals make. Anecdotal information too often prevails, as do speculations about the processes through which large-scale changes impact on career decisions. Consider the matter of declining defense spending and demands for scientific and engineering personnel.

Defense spending has been a significant force for science and engineering personnel in the U.S. As of 1990, for example, defense research and development (R&D) accounted for 60 percent of public R&D funding (contrasted with six percent in Japan). The percentages have begun to shrink and are envisioned to continue to decline over the next several years. But the effects of such a shrinkage on entry into science and engineering are not likely to be direct. In fact, poor is our understanding of the processes through which such developments produce actions among individuals. The need for personnel in science and engineering will remain. It behooves a nation to work for rigorous knowledge about the individual, social, and economic dimensions that affect the availability and quality of that personnel.

Collaboration to advance that knowledge can be as important as collaboration to train a stock of dedicated scientists and engineers.

NOTES

¹ Most of the statistics for the United States come from the Division of Science Resources Studies, National Science Foundation. Key sources:

Science and Engineering Indicators -- 1993

Human Resources for Science and Technology: The Asian Region (published 1993)

Foreign Participation in U.S. Academic Science and Engineering: 1991 (published 1993)

International Science and Technology Data: 1991 (published 1993)

The figures for Japan derive from compilations of the Ministry of Education, Science and Culture (MONBUSHO), and the Japan Society for the Promotion of Science. Primary references:

The University Research System in Japan (MONBUSHO, 1993)

Statistical Abstract of Education, Science and Culture, 1993 edition (MONBUSHO)

Japan Society for the Promotion of Science, 1993 report

² For a discussion of forces changing the labor force internationally, see William B. Johnston, "Global Work Force 2000: The New World Labor Market," Harvard Business Review, March-April, 1991

³ An extended review on diversity in science appears in a special issue of Science: "Minorities '93: Trying to Change the Face of Science." Volume 262, November 12, 1993

CHART 1.

Disciplinary Trends in U.S. Bachelors Degrees

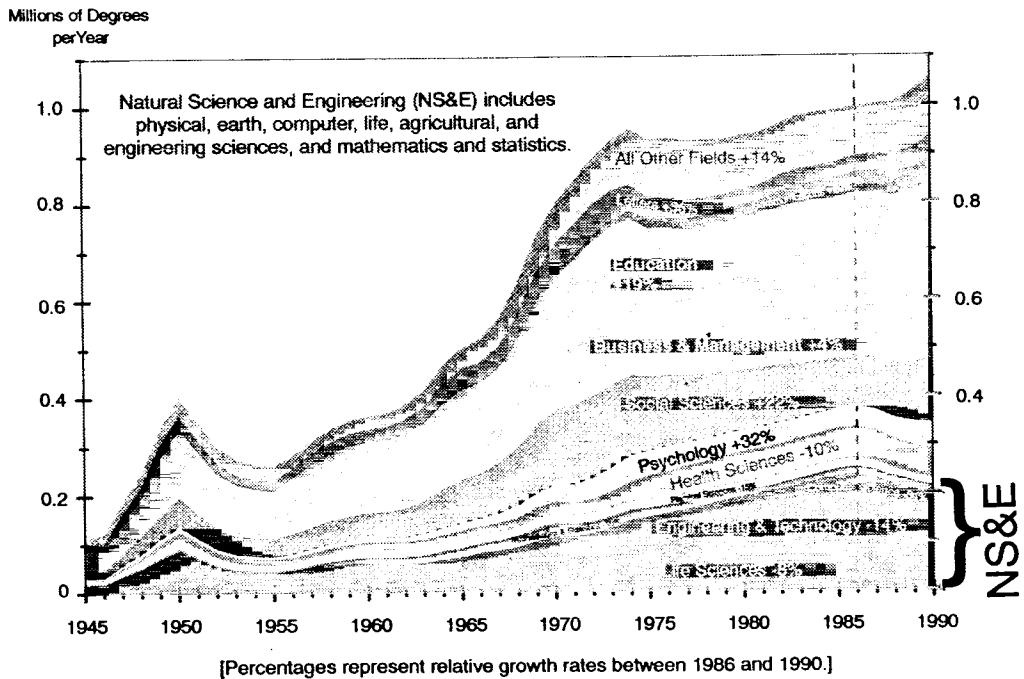


CHART 2.

Professional and Ph.D. Degrees Awarded by U. S. Universities

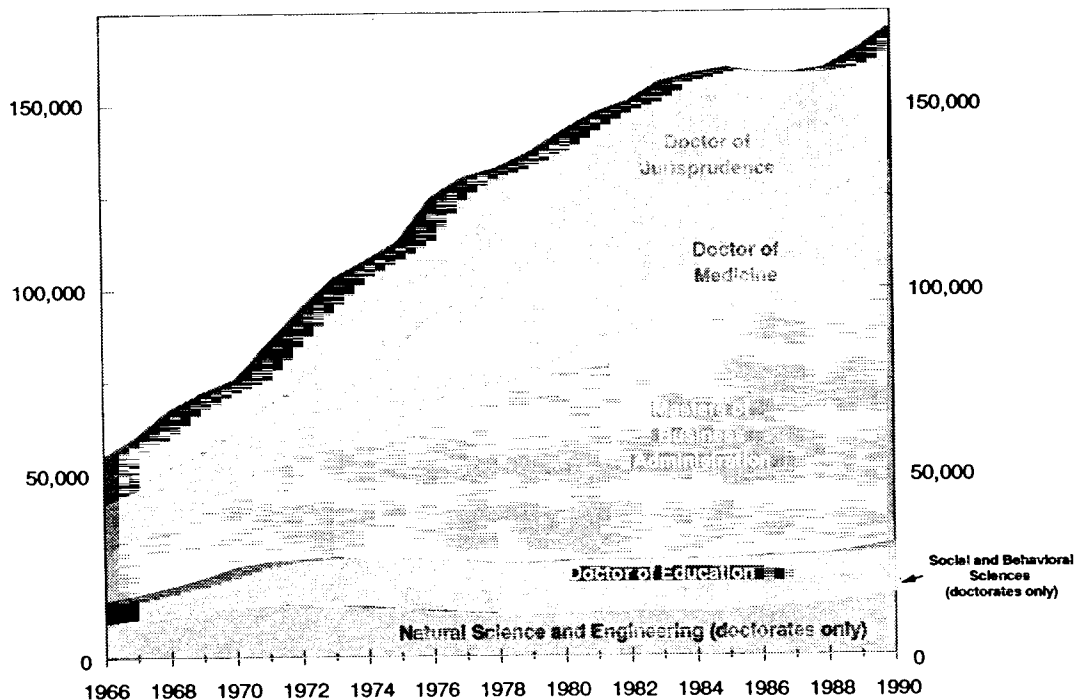


CHART 3.

Number of Foreign Citizens Granted Science and Engineering Doctorates in the United States

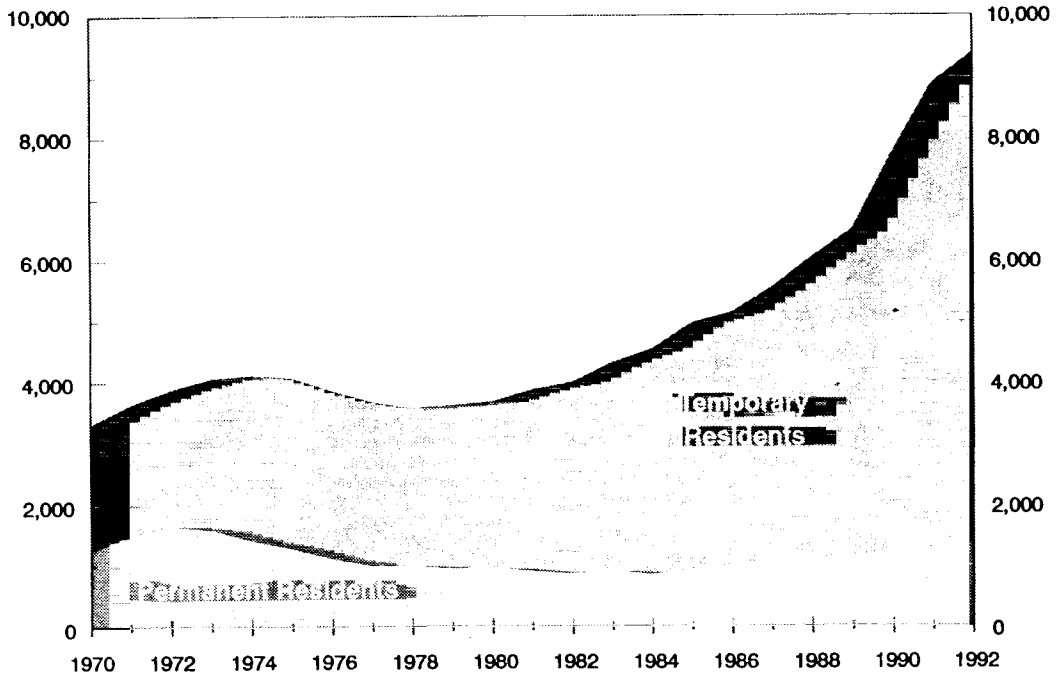
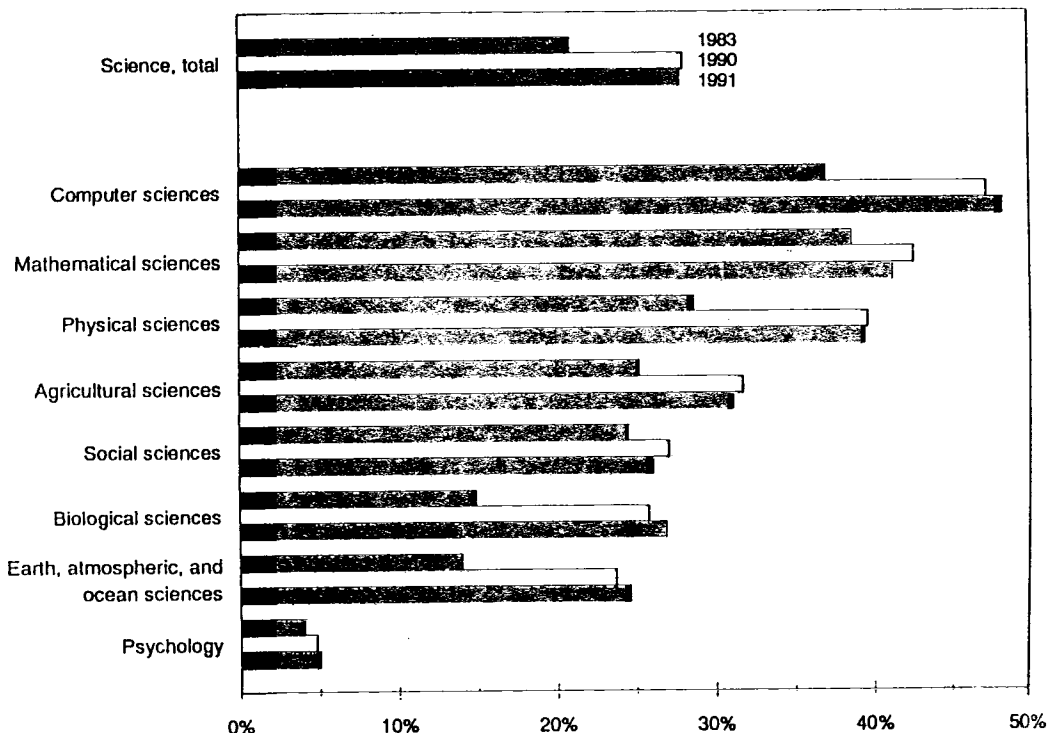
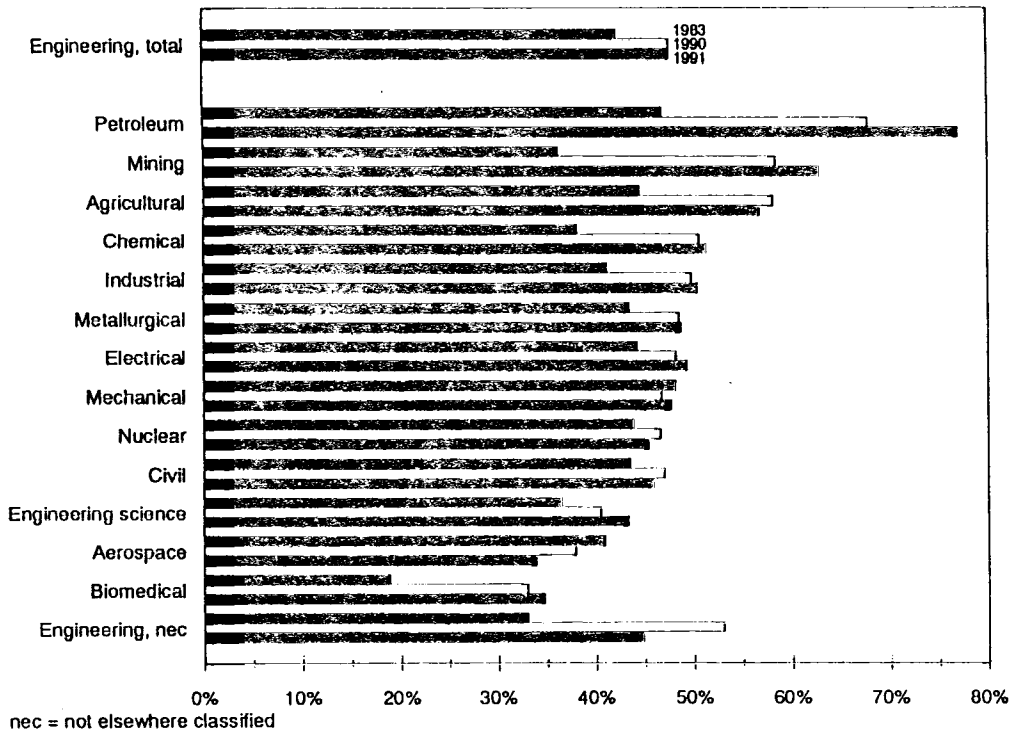


CHART 4.

Non-U.S. citizens as a percent of full-time graduate enrollment in the sciences



Non-U.S. citizens as a percent of full-time graduate enrollment in engineering



Current State of Systems for Fostering Researchers
in Japanese Universities

Hitoshi Osaki

Abstract

In the typical academic career path in Japan, scientists who have either just completed a graduate course or who have conducted postdoctoral work are hired into universities as tenured research associates. Whereas offering tenure from the entry level gives university scientists a stable base of employment upon which to perform ongoing research activities, it also tends to obligate young research associates to cater to the requirements of their seniors. At the same time, the offer of more attractive employment and work conditions is luring young scientists to the corporate sector.

The crucial issue will be how to go about providing a more flexible system that will give young researchers increased mobilities and more diversified opportunities to pursue their work. In an effort to create such a flexible system, the Japanese government established a financial support program entitled "JSPS Research Fellowship for Young Researchers" in 1985. Some 1,700 of these fellowships were awarded in 1993.

1. Career Paths for University Scientists

(1) New Scientist Hires in Universities

A Review of the 1988 records of new scientist hires in Japanese universities (inter-university transfers excepted) showed the following hiring patterns: In the sciences, 26% of new hires are people who had just completed undergraduate or graduate courses (of these, 75% had completed doctorate courses and 15%, master's courses), 58% had conducted postdoctoral work, and 16% were hired from companies or government laboratories. In the engineering field, the same review showed the following hiring patterns: 38% of new hires were scientists who had just completed undergraduate or graduate courses (of these, 65% had completed doctorate courses and 25%, master's courses), 23% had conducted postdoctoral work, and 39% were hired from companies or government laboratories.

Of the positions hired into, research associates (*joshu*) comprise the vast majority. In the typical academic career path, scientists are hired into these posts when they are about 30 years old and have either just completed a graduate course or have conducted postdoctoral work. These research associates are given tenure and are, depending on their ability, eligible for later promotions to lecturer, associate professor and professor positions. (see the attached figure.)

Among those entering research associate posts directly upon completion of a graduate course, 44% of science majors and 64% of engineering majors are hired by the university from which they graduated.

(2) Comparison with New Hires in Companies, etc.

In 1992, the hiring ratio of scientists employed immediately upon completing undergraduate and graduate courses by universities vis-a-vis companies and other institutions was as follows: Of science majors employed by universities, 83% had completed doctorate courses, 15% master's courses, and 2% undergraduate courses. Of those employed by companies and other institutions, 16% had completed doctorate courses, 39% master's courses, and 45% undergraduate courses.

Of engineering majors employed by universities, 67% had completed doctorate courses, 24% master's courses, and 9% undergraduate courses. Of those employed by companies and other institutions, 10% had completed doctorate courses, 47% master's courses, and 43% undergraduate courses.

(3) Problems in the Current System

There are a number of problems inherent in the current system for fostering researchers.

First, the graduate course system introduced in Japan following World War II is now fully operational in the science and engineering areas. From the viewpoint of fostering researchers, however, problems still remain in the engineering area. Whereas in 1992, 89% of doctoral course quotas are filled in science programs, in contrast only 67% are filled in engineering programs. The dissertation doctoral system does,

however, complement the formal course system in the engineering area by allowing scientists who leave the course before obtaining their Ph.D. to continue their doctoral research.

Second, offering tenure to research associates upon entry into university positions does give them a stable base of employment upon which to perform ongoing research activities. On its negative side, however, the tenure system tends to obligate research associates to the requirements of professors and other superiors, impeding their ability to freely conduct their own work. This tenure system also poses problems in the cultivation of highly qualified scientists: Because research associates are hired early in their careers, they tend not to have had a sufficient research record to evaluate their potential during hiring, which tends to promote an element of inbreeding in universities.

Third, the aggregate number of posts in national universities is strictly limited, and there is a tendency when reorganizing research departments to increase the number of professorships and other higher positions by decreasing the number of research associate positions allotted. This has the effect of narrowing the employment opportunities available to young researchers.

2. System for Supporting Young Researches in Japan

(1) Current Supporting System

It is important to ensure that young researchers with outstanding potential have the opportunity to continue their research work until which time they are employed in a permanent

research post. To this end, the following support systems are provided for young researchers in Japan.

JSPS Research Fellowships for Young Researchers

This is the centerpiece of the government-subsidized program for supporting young researchers, and is administered by the Japan Society for the Promotion of Science (JSPS). JSPS awards these 2-to-3 year fellowships to promising young researchers who are enrolled in or who have completed a doctorate course so as to allow them to concentrate on their research activities.

In 1993, 1,700 young researchers were awarded these fellowships. Plans are to increase the number of awardees in the future. In recent years, about 60% of these research fellows have gone on to position in universities, while 19% of them have obtained employment in other research institutions. The remainder have for the most part accepted part-time instructor positions or overseas postdoctoral fellowships.

STA Fellowships for young researchers

To provide young researchers with chances to study in national research institutes, the Research Development Corporation of Japan (JRDC) provides one to three year fellowships to researchers who have completed a doctorate course. (In 1993 140 fellowship were awarded.) The Institute of Physical and Chemical Research (RIKEN) also offers a similar fellowship program, through which it granted 75 postdoctoral fellowships in FY 1993.

Support Program for graduate students

This support system is administered principally with loans provided by the Japan Scholarship Foundation. Presently, 53% of all students enrolled in doctoral courses and 24% of all in master's courses receive these loans. Under the program, the amount of the monthly loan made to doctorate students is ¥109,000 and to master's students, ¥78,000. These loans are interest-free; and in cases where the recipient goes on to enter a university teaching or research position in certain specified institutes, they do not have to be paid back.

In addition to these made by the Japan scholarship Foundation, other graduate student-support programs are conducted by universities, private foundations, and companies. All totaled, the number of these awardees in 1991 equals about 27% of those receiving support from the Foundation. The total amount of funding they provide comes up to about 15% of that loaned by the Foundation.

(2) Problems in the Current System

With regard to the current support system for young researchers, two salient problems can be pointed out.

First, in Japan there is a general expectation that employers will provide new hires with lifetime employment. If, therefore, a clear offer of tenured employment is not made by a university, the young researcher may well seek employment in other sectors. In particular, it feared that promising young researchers will be lured away from the university by companies that offer better employment and research conditions. The above-described support systems have, therefore, been put in place to

retain promising researchers in the academic sector. At present, they are not, unfortunately, provided in adequate scale to fully achieve this purpose.

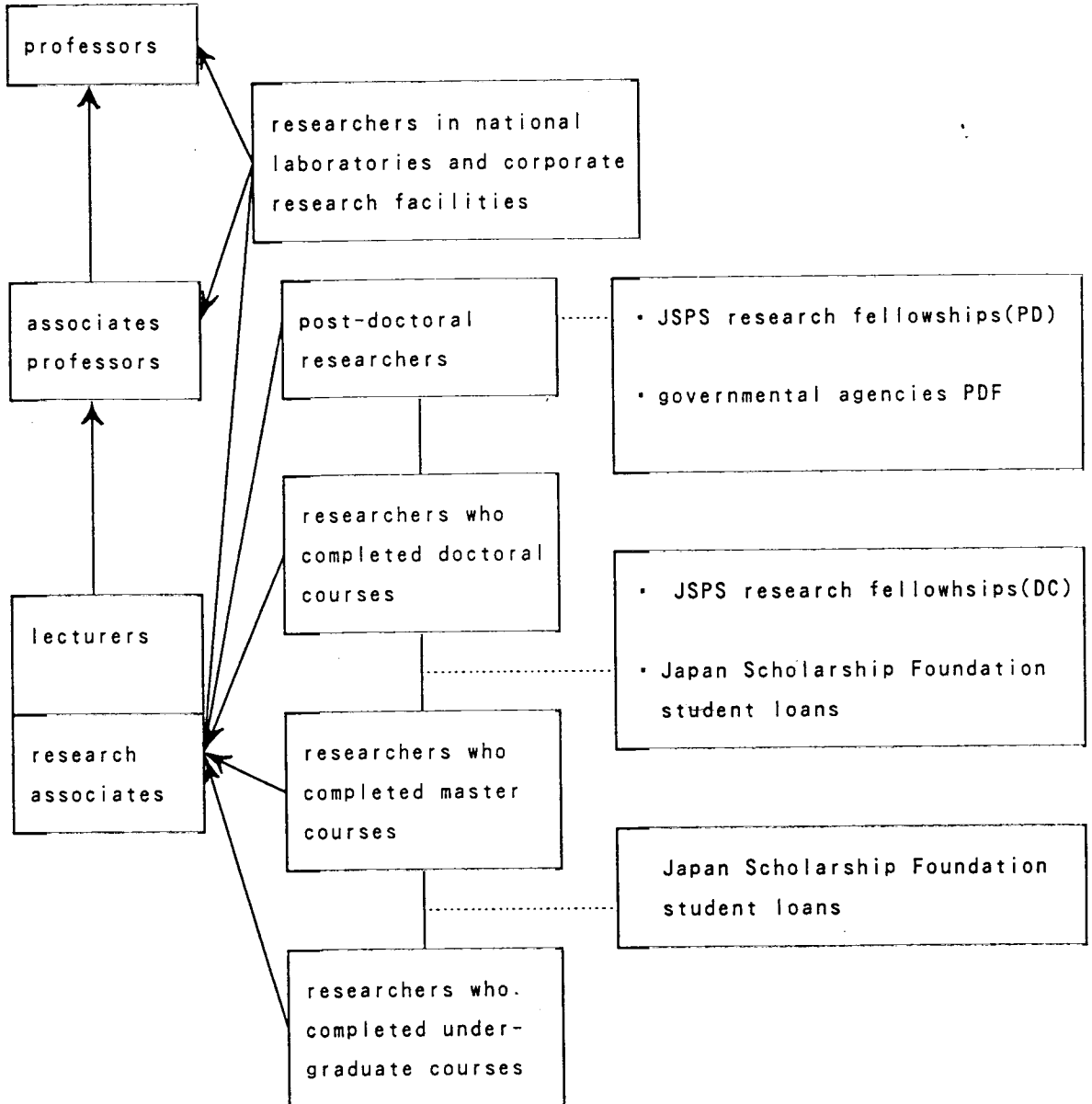
Second, due also to the custom of lifetime employment in Japan, it would be difficult to introduce a short-term postdoctoral employment system supported by research funds such as the one implemented in American universities. Furthermore, sufficient research funds are not currently available in Japan to support such a system.

In conclusion, the crucial issue will be how to go about providing a more flexible system that will give young researchers increased mobility and more diversified opportunities to pursue their work.

Career-paths for university scientists

Careers

Supporting Systems



CONTINUING ENGINEERING EDUCATION IN THE US AND JAPAN:

EXPLORING BEST PRACTICES

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ABSTRACT

This paper explores the subject of continuing engineering education as it is perceived and practiced in the United States and in Japan. It offers an imaginary profile of an American engineer at the start of his career, and, by comparison, an imaginary profile of a Japanese engineer at the same point in time; it outlines the prevalent continuing engineering education philosophy of large companies in the U.S. & Japan, ¹ gives a few examples of successful corporate models, and invites a discussion of what each country might learn from the successful practices of the other that might inspire ideas for their own continuous improvement.

Additionally, it raises as a subject for further study the question that both American and Japanese engineers are asking themselves of late:

" How does one maintain health, energy, good relationships and harmonious family life in the high-pressure, work-driven environment that is the central core of today's modern technical company - and country - and world? "

¹ Small companies in both nations are extremely varied and most of the research in this field is limited to large companies for that reason.

Introduction

Rapid advances in modern technology have focused attention on the leading-edge industries in Japan and in the United States and made new demands on the engineers of both nations to improve the quality and production of their goods and services.

The younger bench engineers and project managers of today are poised to be the star technical professionals of tomorrow, and their work is already cut out for them, because they will need the wisdom of Solomon, the patience of Job, the creative vision of Kurosawa and the enthusiasm of Walt Disney as they assume the multifaceted roles of manager, motivator, mentor, coach, teacher, trainer and supervisor of the people who work for them and with them.

Continuing Engineering Education is a Career Imperative

Because the changing demands of a technological world require more and more proficiency from professional engineers, it makes good sense for the American and Japanese engineering communities - and that includes the institutions of higher learning in both nations - to accept responsibility for improving the knowledge base, competencies and levels of expertise needed by today's professional engineer, along all the steps and stages of a career path. Why? Because the magnitude of the problem of maintaining professional currency demands that it be done, and it is for companies own best good that they have a hand in guiding the process.

Corporate Training in Japan: A Unified Philosophy

In Japan, companies promote a sense of community and connectedness to the company. Employees are encouraged to want what is best for the company rather than best for themselves. The guiding philosophy of Japanese corporate training is to make each and every employee an effective team player, and the execution of that philosophy begins the first day of employment. For example, in Japanese companies, performance on the job is always seen as a team effort, and it is the team that is rewarded, not the individual.

Everything in the gradual indoctrination of a new engineer into the company encourages him to feel a sense of family, community, personal connectedness to the company, and a sincere pride and pleasure in the company's success. The engineer is grouped with other new-hires and encouraged to feel part of that "group." He is put into the care and training of one person for a time, and that person is conscientious about his responsibility to bring the engineer up to speed in one area. After a month or two, when he has learned everything he possibly can about a particular skill, he is given another tutor/mentor to guide him through the learning curve of another skill. (Honda 1992) (Suvanto 1993)

On-the-job learning, (apprenticeship) and job rotation play primary roles in the education and training of an engineer and are viewed as essential in preparing the engineer to advance in his career. One teaching technique is that those who are in positions of managerial authority believe it is important to develop their people "by example" The department manager might

be the one to sweep the floor before the workday begins (additionally, his group would respect him for it and hold him in high esteem.)

Education on the job is designed to create a "generalist" engineer who is eventually knowledgeable about all segments of the company, It helps the engineer develop transferable, flexible skills, rather than the skills of a specialist, and this prepares him the best for the future. (Dertouzoa, Lester & Solow, 1989) (Honda, 1992)

Career-planning is carefully constructed and designed for the long term, because the retention of good people is crucial to the success of the company. As Morita Akio of Sony puts it:

"In the long run, your business and its future are in the hands of the people you hire" (Dertouzoa, p. 40)

Each year engineers in Japan routinely put in three times the number of educational hours that American engineers spend on technical education, and in a variety of forms:

- engineers learn about innovative practices utilized by other, smaller, companies; often their suppliers by visiting them and/or bringing their best people to teach in-house;
- engineers are sent to work at smaller companies in which *their company* hold stock, to learn their innovative technologies and work to improve them;
- companies regularly utilize intensive in-house seminars relying on the talents of in-house experts and/or external ones, from universities and other companies;
- job rotation and on-the-job training utilized regularly in the training of newly-hired engineers;
- self-study is also emphasized;

Coporate Training in Japan: The Nurturing of Human Resources

The Japanese word "Jinzai" means, in the abstract, the nuturing of human relationships. In reality, it is the day-to-day behavior where each individual treats those they work with with courtesy and respect. "Jinzai" is at the heart and soul of the relationship between a Japanese engineer and the company for whom he/she works. It exists as the foundation of a rich cultural tradition that values education and harmonious relationships in all aspects of life.

Best Practices of Japanese Companies

Although Japanese companies are currently exploring a number of personnel policy changes as they move into the nineties, these are the policies and practices they are known for:

- lifetime employment whenever possible (only since about 1955)
- management at all levels consistently plans for the long-term;

- democratic opinion-sharing is a valued part of the decision-making process;
- rewards are based in part on a seniority system; the person there the longest earns the most money;
- often practices whole-life care of the employee, such a making loans, etc.
- company is perceived as a "family"; that perception is strengthened through engineer's participation in many after-work company activities
- teamwork is emphasized, along with small-group activities, such as the TQC circles
- job rotation through all units of the company, starting with the shop floor
- teamwork approach to work; this minimizes conflict with peers
- key personnel are retained, guided with an emphasis on career-planning
- teaches engineer how to identify with the overall interest and goals of the company
- workforce and management both utilize a "vertical hierarchy" they are connected to the customer AND connected to their suppliers
- has a relatively flat hierarchy (when compared to western companies, which reduces paperwork and allows quick decision to be made and then implemented.
- teaches techniques of consensus-building; this helps to create feelings of "ownership" in the engineer of what the company is doing and its larger mission
- nurturing is comprehensive and consistent
- advancement is more determined by an engineer's *personality* than by their job performance;
- the question management asks is "how well does he develop and train his people?"

Profile of a Japanese Engineer

The primary school education that all engineers share in Japan teaches all children to assume personal responsibility at a very early age. Good social habits such as keeping the classroom clean and tidy, and keeping the bathrooms clean, were part of every students' grammar school experience. This social behavior is reinforced by an upbringing at home that emphasized diligence, personal responsibility and genuine respect for others expressed through good manners and common courtesies, and all this eases the transition the engineer is about to make from being a full-time student to a working professional; it builds on what the engineer has known all his life.

A Japanese engineer is patient, self-disciplined and highly self-motivated. He is a hard worker who goes directly to the company from college and who learns from hands-on training at the job. He is rarely absent and never late, has a high work ethic, a strong faith in authority, and is loyal to his employer. He believes that the success of the company comes first; if the company is successful then he too is successful. He does not see himself first as an "individual", he sees himself first and foremost as a "Sony" or "Fujitsu" engineer and a valued member of group "x" at the company.

The following is an imaginary profile of a young professional engineer in Japan drawn heavily from Lu (pp 29 -31):²

Minoru Endo, 22 years old, just received his engineering degree from the University of Tokyo. His test scores place him at the top of his class, and he was personally recommended to the vice president of Mihata Corporation * by his senior research professor.

Minoru interviews with Mihata Electronics for the job of manager trainee in their wireless data communications division, and after successfully passing their rigorous entrance exam and impressing four senior managers and the vice president favorably in successive interviews, he looks forward to his first day on the job.

The company gives a reception to welcome Minuru and the other new-hires, during which many speeches are made; even the company president comes by to shake their hands and offers his welcome!

This emphasis on relationships permeates every facet of the personal and professional life of an engineer and, in fact, begins even before the job is secured. Where an engineer in the U.S. will send out many unsolicited resumes for a job after graduation, the engineer in Japan is likely to require a personal introduction from one of his professors or a senior technical professional already employed by the company, just to be eligible to take the entrance exam and, if he passes that, to get an interview.

After the reception, Minoru and the others are sent to a Zen temple where they eat supper together, spend the night in the same dormitory, and, in the morning, perform ritual tasks of ablution, such as sweeping the garden, working in the kitchen and cleaning the bathrooms.

The day he leaves the temple, he receives his assignment; he is to begin his employment in Section A, one of the many corporate sections that are the mainstay building blocks of a Japanese company.

Although he is the only one from his Zen-temple "training group" that appears to be there, he is greeted warmly by the Section A engineers and immediately made to feel

² This imaginary profile of engineer Minoru Endo's professional career path at the fictitious Mihata Corporation owes its life to the profile captured by David Lu in *Inside Corporate Japan: the Art of Fumble-Free Management* (pp. 29-31)

welcome. A fifteen-minute pep talk by the section chief is the first order of this (and every day, he soon finds out.) It includes a briefing on current company events and discussion of the section's target goals for the day. Then he is put under the supervision of an experienced engineer, who will begin Minoru's one-to-one job training.

After a month or so when Minoru masters everything taught by that senior engineer, another is assigned to continue his training. As he continues to learn his profession on the job, and as he grows in confidence as well as competence, he may be asked to assist the senior engineers with their tasks.

After a year in this section of about 15 members, Minoru has learned a skill function from everyone and can say he knows everyone's work thoroughly. He is becoming a "generalist", a highly skilled engineer, and a well-regarded one, in Section A.

Because Japanese companies have traditionally boasted a "lifelong employment" policy, the advancement of an individual is very slow. Minoru's progress up through the technical/managerial ranks is long and drawn out, compared to his counterpart in the U.S. His first promotion does not come at the end of his first year, or even his second but rather at the end of his 7th or 8th year. At that point he becomes a "*kakaricho* or a subsection chief.

Excerpting from David Lu's profile: " After two or three years, (Minoru) may be moved laterally to another subsection either within his own section or in another. Job rotation (into other sections) begins at this point and takes place every two or three years. It is intended to train (Minoru) to know all aspects of the activities in his division....

"If everything goes well, in his late thirties, Minoru will be appointed to the position of *kacho*, or section chief. *

""He may remain there for a number of years or receive another round of job rotation to make him more conversant with the companies varied activities.

""The title of *bucho*, or division manager, comes when Minoru is in his late forties. At the age of fifty-two or fifty-three, Minoru begins to fret over his own job performance. No matter how well he may have done, he knows that he must retire at age fifty-five (sixty in some companies), unless he is appointed a company director. Once he becomes a director, mandatory retirement no longer applies and he can remain with the company. If he is lucky, he may even become the company president."

One Example of Best Practices Stands Out

² Not every skilled engineer will become a section chief and continue to progress into higher management positions, of course. In Japan, as in the U.S., there are only a few high-placed rungs at the top of the ladder.

David Lu in his book *Inside Corporate Japan: The Art of Fumble-Free Management* (p. 41-43) identifies Fujitsu as one of the best users of on-the-job training:

- (Fujitsu) recruits engineering graduates from top universities and immediately places them in the design division to design large mainframe computers.
- After two or three years in the design division, these young engineers are transferred to the manufacturing division to produce the computers they themselves have designed.
- Then, after three or more years in manufacturing, these engineer are sent out as systems engineers or (are) engaged in technical sales to operate, service and sell the computers they designed and manufactured.

This system gives the company several advantages. After five years, most engineers reach the point of burnout and require new training.

• It is at this juncture that they are sent to become closer to customers. They can be the best technical sales people and systems engineers because they know the computers inside out customers helps the design engineers do a better job of creating new computers." (Lu, p. 41) (Emphasis my own.)

Corporate Leadership is Serious

The leadership of major Japanese companies believes strongly in education and this belief fuels the company's support of the education and training mission. According to David Lu, one of the favorite mottos of Matsushita company is this:

"Matsushita Electric Company is a place to nurture people.
Incidentally, it also makes electric appliances."

Corporate Training in the United States: an Overview

Engineering continuing education as it exists today in the U.S. is generally a non-coordinated effort of those who need educational programs and those who provide them trying to find each other. All users and all providers are independent of each other and considerable costs are incurred on both sides as educational need is assessed, the product to meet the need is defined, designed and produced, and engineers are encouraged to be retrained, reeducated, and "retro-fitted" to meet the company's expectations of what constitutes technical currency. Although Japanese on-the-job training and education is preported to give talented engineers the flexibility, requisite skill and new knowledge that they need to adapt to new technologies that haven't been invented yet, there is no system in place in the U.S. now that systematically attempts to train engineers to move into new technologies that do not exist yet. (Although one is

in the making; see comments about the SEED project at Stanford Research International on page 10.) Everything that is out there is an attempt to meet current needs; a band-aid approach, if you will.

Additionally, continuing education and training has been historically viewed as a "perk" for staff and not essential to the company's mission.³

Hierarchical divisions of labor and responsibility tend to create calcification of personnel in a number of divisions/departments. Each division/department has its own budget for education and training; that budget is neither fixed nor guaranteed. Sometimes, however, education is a line-item in the corporate budget and funded accordingly. Justification of why someone needs education or training activity to increase their skills can be difficult when a company's primary concern is not to spend money but to save it; anything that looks like a perk is the first thing to go in a recession year. (For an illustration of this corporate mentality in action, see author's note, page 14.)

A major obstacle to the maintenance of educational continuity is the need felt by corporate managers to respond to stockholder concerns for a less than positive *profit and loss* statement every three months.⁴

Profile of an American Engineer

If you are an engineer with a baccalaureate degree and are working in an industry that requires continuous career-long education of its technical workforce, your professional profile at the early stages of your career may look something like this:

Your awareness of yourself is of an individual who has worked very hard to get where he is. Your educational background provided instruction in the fundamental principles of basic science and mathematics and included core courses in one or more engineering disciplines. Laboratory courses offered hands-on experience, and you learned to apply scientific principles to a number of engineering problems using various systems, materials, processes and devices.

You learned how to analyze, synthesize, evaluate, test, quantify, assess and interpret data. You learned how to integrate your knowledge of fundamental principles with your ability to ask the right questions. What you learned about good design through experimentation, trial and error, added to your knowledge and gave you the skill to practice competently as a creative, thoroughly professional engineer. Or so you thought.

³ Although this attitude still exists in some companies it no longer obtains in others. Motorola, for example, invests millions of dollars in education and training, and ties that training to corporate goals, as does Corning Glass and Texas Instruments.

⁴ Stockholder concerns influencing management decisions does not occur in Japanese companies because of the way the Japanese stock market is managed and regulated.

Your first job is a rude awakening. You discover that you have no credibility or status in the organization that hired you, despite your hard-won degree and excellent grades. Your work assignments are generally of a routine nature and are part of a larger project or activity. You have very little autonomy and work under the direct supervision of a senior professional, who is not always available when you need him. You are often frustrated and impatient when your suggestions are ignored or dismissed summarily. You realize that as well-educated as you are, there is still much that you have to learn. You find you are asking a lot of questions.

The learning process continues. You are expected to perform well under pressure and usually do, but you find it difficult to meet deadlines and budget constraints when working on parts of special design projects, having little or no experience with such matters. You sometimes feel overwhelmed with the magnitude of all you need to learn to do the task you've been given, and you begin to realize that engineering judgement develops through experience. You persevere and mature on the job.

After five years on the job: If you are with a large company, after two to five years of experience on the job you are in the 50% of your original group of new-hires that are still employed; the other 50% have left the company for a variety of reasons. (NAE, 1988)

At this stage of your career you are able to take a project from start to finish with very little supervision. You have learned the protocols of being part of a team but as energizing as you find the team approach is to problem-solving, you don't think it has any importance as a predictor or determinant of your future. Still, you believe that you make a valuable contribution as a member of the team and you have a voice in project-related decisions.

Of most value to you at this stage of your career is the mentor relationship you've established with a senior engineer. You have avoided numerous frustrations and potential obstacles as you learned your way through - and around - the company and its internal political system with the help of your mentor. Your mentor has also provided an example of professionalism, and you have benefited by observing his/her technical competence, teaching ability, emotional maturity, skilled engineering judgement and influence with decision-makers. Your mentor is also a skilled communicator and a good listener, and you realize how necessary these skills are if one is to realize one's highest career goals.

Because you have taken advantage of various educational opportunities, on your own or through your company's education and training programs, you are well on your way to earning a Master of Science degree in an engineering or engineering-related field or its equivalent in work experience. Although your primary reason for earning this degree is to make yourself more attractive to other companies and to be a good candidate for promotion, you have been rewarded with more challenging job assignments and increased project responsibility because of it. Various other career opportunities are open to you, and the interdisciplinary aspects of your professional

development give you greater flexibility and recommend you for promotion and advancement within your own speciality or laterally into field-related activities.

At this point you assess your career goals, your talents, your priorities and responsibilities, and think seriously about what you want your future to be and whether or not you want to stay in a technical track or move into a management track. And whether or not you even want to stay with the company that now employs you.

Best Practices in American Companies

Education programs are retained and valued by management when in-house statistical analysis proves year after year that significant bottom-line results obtain when education programs are linked to company goals. Motorola is a company that believes - and can prove - that goal-specific education and training programs have saved them billions of dollars.

There have been a number of innovative thinkers in the field of continuing engineer education but not enough doers. "To do" takes money, time, commitment and patience, and lately, except for those few visionary practitioners in our midst who are doing their own thing, we have become too interested in quick results and immediate success to commit ourselves to something where results are anticipated to be a few years down the road. As a culture, we have forgotten how to delay or postpone the gratification we seek. But there is one notable exception:

One Best Practice Stands Out: The National Technological University

In 1985 Lionel Baldwin, then Dean of Engineering at Colorado State University, envisioned a national university of the air - a television satellite education system that would bring the best courses from major engineering schools to working engineering professionals in industry. His vision is now a reality. From a core consortium of approximately 20 schools, NTU member schools have grown to 45, and now include UC Berkeley, UC Davis, Purdue, Cornell, Illinois, Urbana-Champaign, and the Universities of Michigan, Minnesota and Washington. Its member companies number 339; the top five companies (in numbers of sites) are Hewlett-Packard (48), AT&T/NCR Corporation (32), Motorola, Inc. (28), IBM (23) and Digital Equipment Corporation (23). In 1992, NTU upgraded its equipment; it is now boasts a compressed digital video network.

Additionally, in 1992 the NTU Master of Science degree programs were expanded from nine to eleven: Engineering professionals across the United States can now earn a master of science degree in computer engineering, computer science, electrical engineering, engineering management, hazardous waste management, health physics, management of technology, manufacturing systems engineering, materials science and engineering, software engineering and the "special majors" program.

Six Canadian and Mexican sites are in NTU's satellite network. It has awarded 255 Master's degrees and expects to award 150 next year alone. Four hundred and forty six courses were broadcast to 4,576 credit students throughout the United States.

Baldwin does not rest on his laurels; he continues to look to the future:

"Communication and information technology continue to advance at a tremendous rate and are becoming increasingly cost-effective. Perhaps NTU can develop entirely new methods for training and helping technical people to learn, based on innovative ways of exploring this technology."

Some Good Things are Happening

New and vital approaches to some of these age-old problems continue to surface in the U.S., and they are noteworthy in their vision and scope:

- At the university level, the State University of New York at Binghamton has proposed a model for inculcating career-long engineering education objectives and determinants in individuals by building a program that incorporates these objectives within a series of established courses.⁵ The student, at the end of the program, acquires not only the knowledge defined by the course syllabus, but also the skills and assessment strategies needed to take responsibility for his/her own professional development at all the steps and stages of a career.
- A number of states in the U.S. (Florida and Michigan, to name just two) have redoubled their efforts to coordinate continuing engineering education with economic development. At the present time, the process of bringing politicians, educators and industry representatives to consensus is long and arduous. But the vision that "*the future won't wait*" is strong among those who are leaders in these dynamic interactions, and so their efforts continue to push the connection further.
- Individual companies are profiting by realigning educational objectives with corporate goals. Not only is quality improved and productivity increased when education is needs-based, but cutting courses that are not essential toward meeting the goals of the company can reduce expenses. TEKTRONIX, INC., in Beaverton, Oregon, for example, reduced its educational costs by 60% during 1986-1989, even though program participation had increased by 50 percent.⁶

A U.S. Model for the Future? Perhaps ...

At the present time, a number of high-tech firms are supporting the design and implementation of a continuing education model (SEED) to be designed and managed by a team at SRI International. This model is to be forward-looking in nature and readily adaptable to meet the in house-needs of all the various companies that are members of the SEED project. One of its most exciting components is that it will be constantly assessed and re-assessed to see how well it meets the training needs of the companies that buy it, personalize it and put it into practice. The model's success - and its future - will be determined by how well it works. Needless to say, the

⁵ *Preparing Engineering Undergraduates for Career-Long Education*; Proposal submitted to NSF by Richard Culver, The Watson School of Engineering, Binghamton, NY, February, 1989.

⁶ MICROWAVES & RF; Ron Schneiderman, March 1988, P. 36

most important part of this model will be the assessment tool itself. Still in its formulative stage, the SEED project goals are ambitious and its potential promising.

Some Questions That Might be Explored

As continuing education specialists in academe and industry continue to try to solve the numerous and continuous problems of availability, cost, quality and just-in-time delivery of education and training courses and programs, a number of questions constantly surface and invite discussion:

Could better undergraduate counseling help prepare engineers to take control of their own career-long education from the beginning of their careers?

Is there a need for a practice-oriented advanced degree? What might it look like?

Where might the natural linkages of educators and practitioners occur and how can they be further developed and enhanced?

What is the best approach for U.S. companies to take to move away from relying on "short-term vision" towards a more rational use of a "long-term vision".

Conclusion

There are many who believe that industry collaboration over non-proprietary issues, the sharing of resources, and the use of new and improved communication technologies to keep engineers and technical professionals up-to-date is one way the U.S. can maintain a successful competitive position in the global marketplace.

If today's engineers are to be the technical leaders of tomorrow, they will need more knowledge and talent, more creativity and leadership than they have needed heretofore. Additionally, they will need better communication and language skills than their professional experience and college engineering education has given them.

Maintaining the productivity of engineering personnel is not only good for company morale, it is a smart business decision. The sustained value of any resource, whether it is machinery, money or people, comes from investing in its development, maintaining its reliability, managing it wisely and letting it do what it was created to do.

The financial investment that industry has already made in its technical staff is considerable. It can capitalize on that investment if it understands that continued education and training of people is not a gratuitous expense but a cost-effective way of enhancing and acknowledging the value of people to the company that employs them, and in a larger sense, to the community at large.

Large American companies need to link education to company goals as done by Motorola, Honeywell, EXXON and others. But - there is a problem. It's difficult to link company goals, *national* goals - and the personal goals of each engineer together because all that input confounds

the basic goal of what they are trying to do, which is to visualize the future and then systematically plan for it. They are not all of one mind.⁷

The variations in problem definition, the order of priorities, the institutional resistance to change, the individual levels of commitment and personal involvement, and the levels of financial commitment from the top, all seem to distance groups and individuals from one another, and this distancing takes its toll on engineers who enroll in programs, the companies who pay for it, and the educational institutions that provide them.

The number of engineering professionals that can benefit from retraining and new learning is a significant resource that the U.S. needs to take more seriously. For the last few years we have been concerned about a demographic shift in our population. Statistics show that the number of babies born in the 1960's and early 70's is too few to seed the engineering talent pool that we believe will be needed for the late 1990's and beyond. A few years ago, engineering faculty were beginning to see a decline in their schools' enrollments, and like the good engineers they are, they went to work to identify the problem. Demographics are tangible, comfortable for engineers to take hold of, and the logical conclusion from reading the numbers was that as a nation, we needed to increase our efforts in recruitment and retention so that no talented student would fall through the cracks.

It is obvious to us now that we should have also concerned ourselves with the thousands of engineers that were soon to be displaced by the end of the Cold War and the gearing down of our defense industries. Fixing a problem is easier if you are ready to meet it with the solution in hand. Talking about re-training programs now is shutting the barn door after all the horses have left (or ... as our Japanese friends might say,

Doroboo wo Mitekara nawa wo yoru!

English translation: "Weaving a rope after seeing a burglar is not very smart!"

out of work underscores anew the importance of maintaining the productivity and expertise of the engineering workforce during their work-life, which would have the effect of preparing them ahead of time for other work in a new arena.

A Question for Open Discussion

How DOES an American engineer reschedule time in an already time-compressed day to accommodate the additional hours of study and hands-on training that he needs each year in order to remain technically proficient in his field? And how DOES a Japanese engineer, with a work week that is appreciably longer than the American engineers week, do the same thing?⁸

However many hours that engineers spend now learning new information in a given year, it is probably not enough, because someone, somewhere is learning more.

⁷ In a Japanese company, they *are* of one mind: everyone's focus is centered on doing what is best for the company.

⁸ I think "used to be" is now more appropriate. American engineers now routinely spend 10 -

Author's note:

While finishing this paper, I received word⁹ that the Office of the President of Digital Equipment Corporation, a Fortune 500 company and a considerable investor in the continuing education of their technical staff, as of January 1, 1994 through June 31, of the same year, will be freezing tuition reimbursement to all employees enrolled in credit courses and/or audit programs. In the past, university providers of continuing engineering education have learned through experience that audit courses and seminars could abruptly be canceled by companies during economic downturns, but credit programs were not touched. This action is a surprise to quite a few people, (I include myself) but none are as surprised as the DEC engineers will be who are enrolled in hundreds of M.S. degree programs.

The reason for DEC's decision to freeze tuition was not told me, but considering the state of the economy in our high-tech industries, and the current state of DEC's corporate affairs, it seems all too obvious that this decision was made out of concern for the bottom line. Unfortunately, it is a short term decision that may have long-term consequences.

12 hours a day at work and, on a fairly regular basis, frequently give up one day of a 2-day weekend to do work at the office. Of course for Japanese engineers this has always been just a normal week, nothing out of the ordinary. The future may look different ...

An engineer at a Fortune 500 company recently said: "We are on call 24 hours a day. And the day we complain about it is the day we get a bad review..." (Personal conversation. Jan 10, 1994.)

⁹ November 1, 1993; personal communication.

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