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Abstract and Summary:

Japan has been worried for many years about the paucity of doctorates in science and engineering it has been producting with respect to the Unite States. This report investigates actual differences in the structures of graduate programs between japan and the United States. A comparison was made between both countries of top and middle-level universities. Various graduate programs in science and engineering of 14 U.S. universities were compared with those of 10 Japanese universities. The main differences were as follows:

Administration:

The Japanese graduate system is obviously much more centralized thant he American one. The form of what a graduate program varies extremely little from university to university. Funding is also extremely centralized and constricted, which present diffeiculties for professor in assuring funding for potential graduate studetns.

Whereas most of the top graduate schools in Japan are connected to the ex-Impersial colleges, the top graduate schools in the U.S. are a mixture of public and private universities. Public universities emulate the private universities as far as possible, while in Japan up to now it has been the reverse.

Financial Aid:

Japan falls way behind the U.S. in terms of financial aid. Graduate students are still considered, for the most part, to be responsible for their own financial support. A certain amount of money is provided by companies to individual researchers, but the employment obligations that this places on the recipients are found to be onerous by many. This funding pattern is in direct contrast to the U.S., where if money used by graduate students has been provided by companies, it is a direct donation with no obligation entailed. Most U.S. graduate students are funded through a combination of Teaching Assistantships and Research Assistantships.

Departments and Interdisciplinary Programs:

Individual Japanese graduate departments offer a relatively narrow range of courses in comparison to U.S. graduate departments; on the other hand, there are more of them. Japanese graduate departments also almost totally lack interdisciplinary (cross-registered) courses, while U.S. research university departments can have up to a third of their courses joint courses with other departments. U.S. mid-level universities do not have interdisciplinary courses, basically because of their emphasis on practice as opposed to theory. U.S. universities

are likely to handle a new dub-dsicipline as an interdisciplinary subject partaking of two or more departments (biophysics partaking of biology and physics, for example.) Japan, by constrast, will split a sub-disciplinary area off as a new, separate department.

Difference in Programs and Courses:

Japanese graduate programs depend heavily on seminary and lectures, with the rest of the time ideally being taken up by research. Little homework is required, most of it in the form of reports. By contrast, U.S. graduate programs require an assortment of courses, often with two minor specialities in addition to the student's major speciality. Laboratory courses are often required. Courses in the U.S. are highly structured, with problem sets requiring sizeable amounts of time, mid-term and final exams. In doctoral programs, the student is often required to teach one or two terms as well.

Whereas the difficulties in advancement through a Japanese graduate school stem more from financial problems and lack of equipment and/or time, U.S. graduate schools are quire competititve, with a series of exams the graduate student must pass before being admitted to condidacy. These exams are not trivial; one-third to one-half of the students do not pass.

Certain courses are found in Japanese graduate departments that re not found in U.S. graduate departments: courses dealing with secondary equipment and data. In the U.S., it is taken for granted that the student will learn this on his own if necessary. Other courses that are more often found in Japanese graduate departments than in U.S. ones are courses of applications tailored to a speciality (Matrix Algebra for Engineers, for example.) The U.S. is more likely to offer these as joint courses or simply tell the student to take a praticular course in another department.

Differences in how the Economic Structure views graduate students:

Whereas in the United States M.S. and Ph.D. recipients have a definite value in the employment market of industry above and beyond that of someone who has stopped at a bachelor's, in Japan the main arena of employment for graduate students is still considered to be academia. Companies may find use for Master's recipients, but the reputation of a doctorate is of an over-specialized intellectual who cannot adapt to a company environment. In the U.S., M.S. and Ph.D. recipients hold positions higher in salary and responsibility than people of similar age with only B.S. degrees. In the case of doctorates, this is particularly so. In Japan, little or no distinction is made between the job responsibilities of a P.S. graduate and someone with a higher degree. Comparing salaries, it is in fact financially disadvantagous to continue for a higher degree.

Conclusions:

In regards to possible actions Japan can take to increase the number of graduate degree recipients, the simplest and most obvious is to increase the financial support of graduate students and to improve the level of facilities and equipment in Japanese graduate departments. This simply requires money.

However, it is questionable as to how effective this will be until Japan has some form of market demand for people with higher degrees. It is a circular problem: Japanese companies will not place a premium on the possession of a higher degree unless the people holding such are demonstratively superior in research capabilities. However, until the possession of a higher degree becomes obviously highly valued, people with skills and ambition might as well work their way up through the company ladder, rather than go to graduate school.

Since Japanese companies do not value higher-degree holders, they must consider that they are not superior in research capabilities. Either graduate training is bad, or companies do not need researchers superior in research capabilities. No matter how the Japanese graduate education is evaluated, it is obvious that it is not producing a product (researchers) which is valued by the industrial market. Any attempt to reform Japanese graduate programs should address this mismatch between what the Japanese educational system produces and what Japanese business wishes.

Chapter I: Introduction and Basis of Graduate Education:

Problems and Possibilities:

Recently Japan has become more and more worried about how it is to maintain its technological forte in the next century. The phrase that continually crops up with incessant regularity is Japan's description of itself as "an island country with few or nor natural resources." Modern Japan has attempted to overcome this by focusing on the creation of high-value-added products whereby a small amount of natural resources (either native or imported) can be worked on and transformed into high-technology products which command a good price in the world market.

Up to now, Japan has been able to compete in the world economy mainly by taking ideas for technology from the rest of the world, improving them, applying them, and refining them into useful products quicker, cheaper, and easier than anyone else. Historically Japan has obtained its knowledge from China and Korea, importing the Chinese character system for writing, Chinese art and science, and pottery techniques from Korea. Western technology trickled in here and there--much of the Tokugawa period wrestled with the finely tuned problem of how to allow Western technology in while keeping any disturbing powers out. At the beginning of the Meiji Restoration, the doors were thrown open in a great drive to "catch up" with the West. The question now is--where next? Japan has rapidly advanced on and now rivals the West in many technological areas such as electronics, high-speed trains, and so forth. With the rapidly increasing speed of change in technological fields, the power associated with a particular technology has started to shift to not who does it best, but who does it first [1].

Japan now finds itself at the crossroads. Although Japanese science and engineering has never been as "uncreative" as its detractors claim, it is true that industry and academia have been formally far more separate in Japan than in places like Europe or the United States. In the "catch-up" mode, Japanese companies preferred good team workers who were technically skilled to individualistic geniuses. On the whole, it was felt that in-house training and/or education of researchers on top of the already high level of education a college student possessed was preferrable to bringing in people with higher degrees. This was reinforced by two facts: first, with the Japanese lifetime system of employment, a company could be more or less certain that investment in training would result in a long period of useful payback. Second, although the tradition of Japanese graduate programs--as is the US--is based firmly on the German graduate system (See Appendix), Japanese graduate programs have never quite moved away from the ivory-tower/apprenticeship system.

In the U.S. , the education provided by graduate programs is considered an essential contribution ot any researcher's training, and in particular is necessary for learning how to carry out indepenent and original research. By the time a graduate student has obtained a doctorate, he will have a broad basic background, experience in usually two specialities, and experience in designing and carrying out at at least one major piece of research. He will also in many cases have experience in teaching undergraduates or spent a summer as an intern in a company, and has often experience writing his own research proposals. In short, the possession of a doctorate is considered in the American system to be proof of the individual's ability to conduct independent and original research, and is treated as such by U.S. corporations, who will pay a Ph.D a higher salary and place him in a position with more responsibility than someone entering with a M.S. or a B.S.

The Japanese graduate system used to be handled almost as an afterthought to the university system until relatively recently. Most of the doctorate recipients ended up working in academia. Much of the system was structured towards an apprenticeship style system, where a professor would train one of his graduate students to succeed him when he retired. At present, there seems to be a growing mis-match between the education Japanese graduate programs provide and what is considered suitable for researchers in governmental and corporate laboratories.

This report investigates actual differences in the structure of graduate programs between Japan and the United States. A comparison was made between both countries of top and middle-level universities. Various graduate programs in science and engineering of 14 U.S. universisites were compared with those of 10 Japanese universities. Aside from my own experience of both Japanese and U.S. graduate programs to call upon, in addition, in-depth interviews were conducted with roughly 15 people, both Japanese and non-Japanese, who had experience with both Japanese and the U.S. graduate educational systems. Finally, also used for reference were comments from several surveys carried out by various organizations investigating the experience of foreign scientists, researchers, and graduate students in Japan.

<u>Breakdown by Chapters:</u>

Questions this research attempts to ask are as follows: First of all, what are the differences between the U.S. graduate system and Japan's? Where do the problems lie--in the structure of the graduate programs, or is it a larger problem? Chapter II starts off with an explanation of the structure of graduate programs both in Japan and in the U.S. It then goes into an analysis of differences in the administrational structure in an attempt to answer whether the administrational structure in Japan presents additional problems. Since research is considered an important part of any graduate student's education, I also investigate two related areas which have often been raised by foreign researchers in Japanese universities: problems in carrying out research due to the regulations and lack of facilities/equipment/computer networks. I then move to the actual required graduate courses and look at the difference between Japan and the U.S., as well as the contents of the courses themselves and how they are taught.

Chapter II also investigates issues relating to graduate student funding. Two main complaints have been made about the Japanese graduate system: teaching is inadequate and the financial support system for graduate students is poor. U.S. graduate students in science and engineering are for the most part supported at a level of roughly 1000$ a month either by acting as Teaching Assistants or as Research Assistrants. (Fellowships are provided at a much higher level, but are much rarer.) In addition, U.S. graduate students usually do not pay turition and are not charged for exams. Because of this, U.S graduate students are able to concentrate on their research and studies without having to worry about how to support themselves. This is completely opposite from Japan. I provide a detailed comparison of financial support and comment on recent changes in the funding system. I continue with a section investigating problems in the U.S. graduate system, and finish the chapter with a few comments on how the increasing weight of Japanese government labs in research may be influencing matters.

Chapter III investigates Japanese and U.S. graduate programs from the point of how interdisciplinary they are, one major point that I feel is quite relevant and often ignored by researchers. One complaint sometimes made about doctorates from particular countries (England, Australia, and Japan) by comparison to U.S. or other European doctorates is the narrowness of the doctoral speciality. In Chapter III I have tried to compare the level of interdisciplinary education available, with examples as to why it is an important part of education.

Finally, Chapter IV looks at the reception M.S.s and Ph.D.s receive in the marketplace. In the U.S., a higher degree is in some ways a "portable reputation" which can be carried with a researcher when he changes jobs. In addition, by comparing salaries and job positions of the same age and different educational backgerounds, one can readily show that obtaining a M.S. or a Ph.D. is very much a "value-adding" activity, rewarded through higher salaries and more responsibility. Indeed, in the U.S., simply having a doctorate in any scientific field is taken as proof one can carry out independent research in any other scientific field, and in fact increases the potential mobility and employment flexibility of a researcher. By contrast, in Japan due mainly to the life-time employment system, having a higher degree does not help one's salary and may in fact penalize a researcher. Companies often complain that Ph.D.s are too specialized and often cannot work well in teams. In addition, the presence of the "paper doctorate" system allows any researcher to obtain a Ph.D. later on in life if it is felt useful.

Finally, this report closes with a short section detailing my conclusions and an overview of my recommendations for improving the system.

Reference:

[1]: Kash, D.E. Perpetual Innovation--the New world of competition
Basic Books, co. 1989

Chapter 2: Comparison of Programs:

Let us now turn to the basics. What exactly are the similarities and differences in the programs between the countries? As in when trying to translate literature from one country to another, this is a question which, on the surface simple, presents twists and turns when gone into deeply.

From the viewpoint of institutions performing the same function in society, the Japanese analog of the American graduate education is, from one viewpoint, not the Japanese graduate schools but the vocational programs offered in-house at the large Japanese corporations. To this should be added the heavy use of American universities by Japanese corporations. Due to the twin effects of the lifetime employment system and the practice, still common, of one's salary being determined by the years one has spent at a company, it is more intelligent for a bright Japanese student to enter employment after taking the bachelor's degree. After two or three years of work, if higher education is felt by the corporation to be in its best interests, chances are that the employee will be sent to the US for a Master's or Doctorate degree. This thread is not a negligible one. One report [1] claims that Japanese companies fund at least as many employees to study in the United States as the number of students industry provide funds for at the Japanese university level.

Even so, this chapter focuses in on Japanese graduate schools, partly because they are the obvious would-be counterparts to the American graduate schools, partly because the problems that afflict them are similar to those afflicting industry education, and finally, because they are held to be the one place where people capable of conducting basic research--something Japan is extremely worried about--are educated.

<u>Structure of Japanese graduate programs--an overview:</u> [2]

The forms of Japanese graduate programs are simple by comparison to those of the U.S. graduate programs. Japanese programs are divided into a standard master's program and a standard doctorate program. A Master's program requires 30 units and takes two years to complete., while a Doctorate requires only research and takes 3 years to complete. About the only courses for the MS which are absolutely required are the graduate "seminars" which talk about up-to-date research. Most of the course work demanded of the students simply involves reading books and papers, writing reports, or some experiments, followed by more reports.

The percentage of students which continued on from undergraduate to Master's level courses in 1989 was 23.6% and 46% for the sciences and engineering, respectively. The percentage of master's students in 1989 which were then continuing on to the doctorate level was 31% and 8% for the sciences and engineering, respectively. Most of the doctoral work consists of research and a few presentations of the student's research results, with no lectures. (Keio University and several of the other private universities seem to be exceptions to this.)

Structure of U.S. graduate programs: [3]

The archetypical graduate program in the US falls into two parts, that for the Master of Science (and other Master's level degrees), and the Doctorate, either a Doctor of Philosophy (Ph. D) or a Doctor of Science (Sc.D.) Among the degrees listed at the Master's level one finds Master of Science, Master of Science in Aeronautics and Astronautics, Master of Science in Computer Teaching, Master of Science in Mechanical Engineering, and so forth. Aside from term "Master of Science", little standardization of the names of the Master's degrees exists. In general, appending a distinctive names of a field to the M.S. indicates that the undergraduate degree was also in the same discipline. For the schools / disciplines which practice this, a simple "Master of Science" is a flag showing the student has jumped disciplines. Usually the programs corresponding to the two degrees (M.S., M.S. <discipline>) are slightly different, with the requirements for the latter program being slightly more restrictive.

For the two doctorates Doctorate of Philosophy (Ph.D) and Doctorate of Science (Sc.D)., little difference exists between the two. This is contrary to the English system (see Chapter I), where the Sc.D. is considered a higher degree, necessitating the achievement of the Ph.D. beforehand. (In the US, only one department at one university I investigated (Texas A&M) held to this tradition.)

In some cases, the Sc.D. is awarded after completing a slightly more interdisciplinary and pragmatic program. Although a thesis is still required for completion, the emphasis is not quite quite so much on research and it is expected that recipients of this degree will enter industry rather than academia.

Some universities in the U.S. (Texas A & M and Stanford among the schools I investigated) also offer what is known as an "Engineering degree", which can be considered to fall part-way between the M.S. and the Ph.D. Supposedly the Engineering Degree used to be far more prevalent, but at present the M.S. and the Ph.D. are the two main spokes of the graduate system.

Another comment should be made about the relative numbers of M.S. and Ph.D.s. in science vs. engineering. In engineering, partly due to the fact that the bulk of employment of degree recipients is industry, exiting one's scholastic career with an M.S. is a perfectly honorable and standard action. The feeling of industry still parallels that of Japan to a large extent: whereas the recipient of an M.S. is a specialist, he is still enough of a generalist to be able to turn his hands to many areas. A Ph.D., on the other hand, is often considered to be overspecialized and not worth the bother.

By contrast, in the sciences, the Ph.D. is the only degree worth having. Quite often, an M.S. ends up being awarded as a consolation prize to someone who failed to pass the qualification exams for the doctorate program. (Another reason may be due to the student's wish. While visiting Purdue University I met a graduate student in physics who, although doing extremely well scholastically, had decided to quit at the Master's level due to acute boredom.)

Graduate programs in the different disciplines reflect these different targets. Programs in the sciences are usually a combined M.S.-Ph.D. program with the Ph.D as the main focus. The M.S. is awarded along the way after a certain number of courses are completed, with no thesis or final exam required. Programs in Engineering place more focus on the MS programs, since that is where the bulk of students lie. MS programs contain courses, lab or research, and (often) a thesis. For those who wish to continue on, the doctorate is usually treated as a separate program, with more courses and more research. Most places try to provide some form of a "streamlined" track, which more or less mimics the doctorate programs found in the sciences, either truncating the requirements for the M.S. or consolidating the requirements of both (using the final exam of the M.S. as the entrance exam for the Ph.D. program, for example.) In many cases, even trying for the doctorate program is off-limits unless one has entered a master's program requiring a thesis. In other words, often if one chooses the option of master's program without thesis, it is considered that the M.S. will be one's terminal degree. Figure 2.1 shows a range of the different M.S. and Ph.D. programs available

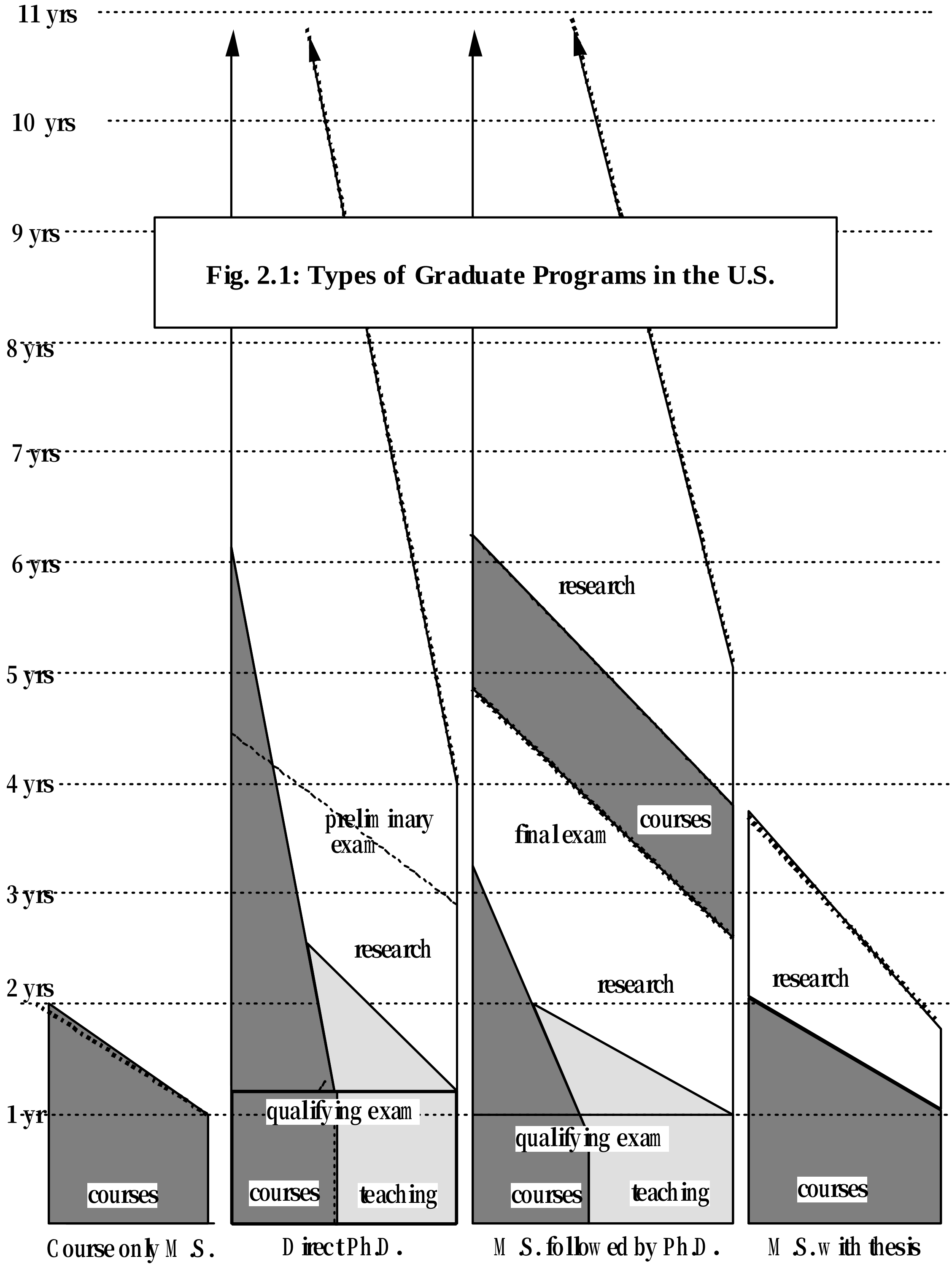


Fig. 2.1: Types of Graduate Programs in the U.S.

The structures of master's programs seem to fall into two categories, depending on the school and the discipline. On one hand are the extremely structured programs. Here the usual mold is a) a set of core courses widely spanning the disciplines, courses for specialization, and lab courses. On the other hand are the "everything goes" programs. Aside from requiring a certain number of courses to be taken within the department and maybe a math course, the student has absolute freedom. I have noticed that this form of requirements seems to occur more in wildly interdisciplinary disciplines (Aeronautics and Astronautics) where at the same time a relatively limited number of courses is offered. Probably the sheer number of courses required forces the student to diversify, while it is expected that pure self-interest in future employment prospects will nudge the student to take some form of laboratory and research courses. In fields with a large number of disciplines and a large number of courses (Electrical Engineering, for example), it is far more likely for the programs to be structured with lists of required courses.

The emphasis of the master's programs can be said to be providing the student a solid grounding in not only his discipline, but other specialities as well. Many programs require "minors", which are blocks of two to three courses, in addition to "majors", which correspond to one's specialization and require three to four courses. Some places and departments insist that two minors be taken, one outside the department. Given the breadth of U.S. departments by comparison with those of Japanese departments (see Chapter 3), one can see that this is setting a broad base indeed.

The record is mixed on research and seminars. A so-called graduate seminar is often required in engineering programs, although this is probably more in order to provide a respectably-sized audience for visiting speakers than out of a belief in any intrinsic use of the custom. Science departments rarely require this, probably because the breadth of the fields are narrow enough that most practitioners are interested in each other's research and can understand a lecture on another topic without it needing to be simplified beyond reason. Seminars are usually held in the mid-afternoon, often with coffee being provided by the department. It provides a relaxing break from work.

Research and/ or laboratory work is required by almost all master's programs. Usually the problem seems to be to keep students from taking too many of these courses, as is witnessed by the number of programs with restrictions on the upper limit of research units to be taken.

Although most graduate students depend some way or another on financial support, either through the form of Fellowships, or Research Assistant or Teaching Assistant positions, no master's program of those I investigated required teaching experience.

Finally, one should not neglect the large number of variants on master's programs which can be found. The number of master's programs which contain internships is large. Double-major or interdisciplinary programs are also common. Finally, one can note a certain number of programs which have been set up allowing people who have been in industry for a while to capitalize on their experience when getting a Master's. Sometimes the courses are offered at night, allowing for someone while employed to also gain a Master's. (akin in a rough way to the "paper Ph.D." of Japan) It should be noted, however, that in all cases investigated, such industry-university programs were only at the Master's level and assumed it was the terminal degree.

Comparison of Administrational Structures:

(This and following sections are partly based on the detailed results from detailed interviews of an hour or more, opinions and experiences solicited over the Internet from certain discussion groups, and several published surveys covering the experiences of the MIT/Japan program interns, and those of foreign scientists and engineers in Japan. Comments from the last set of sources had to be interpreted judiciously, since the emphasis of the surveys was on research, rather than on the contents of the educational programs.)

Whether it is due to the overriding influence of the Mombusho, or whether it is simply a mirroring of the rigid hierarchical structure found in Japanese companies, the structure of a Japanese university and its laboratories is considered by outside observers to be much more rigid and isolating than those found in the US, with very little fluidity either in structure or in the nature of programs.

The main unit of the Japanese university is a "chair", comprising a full professor, one or two assistant professors, a few "lab assistants", and graduate students. Different chairs do not interact, and in fact the administration seems to be set up assuming their acting in almost complete isolation. [4]

As an MIT report commented, covering the experiences of students on the MIT/Japan program,:

> In Japan, graduate research groups are an academic version of the rigid corporate hierarchy. At the apex of the pyramid is the senior professor, by whose name the lab is referred to (e.g. "Saitama Lab", not "Electromagnetics Lab") Below him are several assistants, full professor in their own right, but nevertheless subservient to the wishes of their superior. These parties form a committee which generates ideas for new research projects and parcels out work among the students. Going down the totem pole (in order) are junior professors, post-doctoral researchers, graduate students, and undergraduate students. Even within groups there are sub-hierarchies based on "years of service" (i.e., second-year grad students being higher than first-year graduate students.) (MIT report) [5]

The system seems to be set up to replicate the vertical structures found in Japanese society as a whole. As one person commented on his experiences as a researcher:

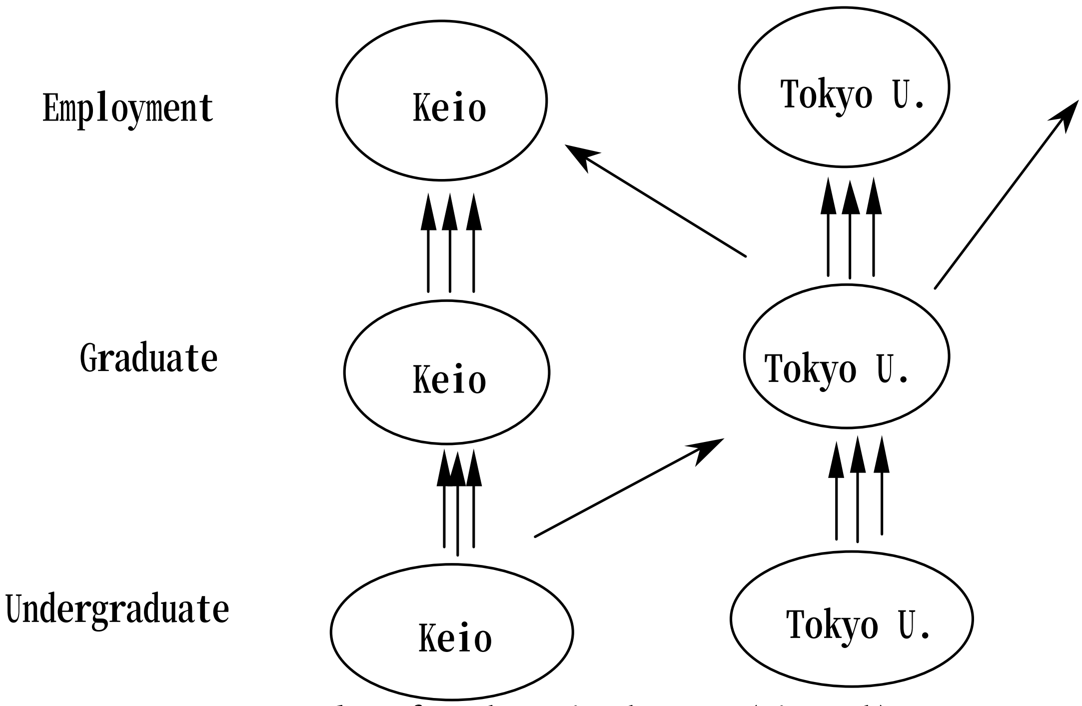
> "In my lab there are 23 students, the most senior of which sits beside the window and the most junior of which sits besides the door. At the start of the new year, or when someone new arrives, the students shift desks in accordance with their status. As a visiting post-doc, despite being younger than some of the students, I was seated beside the window and all the students changed desks to accommodate me." (GaiSci survey) [6]

This rigidity can be found as well in the structure of the graduate programs themselves. The Japanese MS course, as mentioned above, consists of two years of courses and seminars, the end of at which a thesis is written. Whereas a wide range of variations of master's courses are found in the US (see Figure

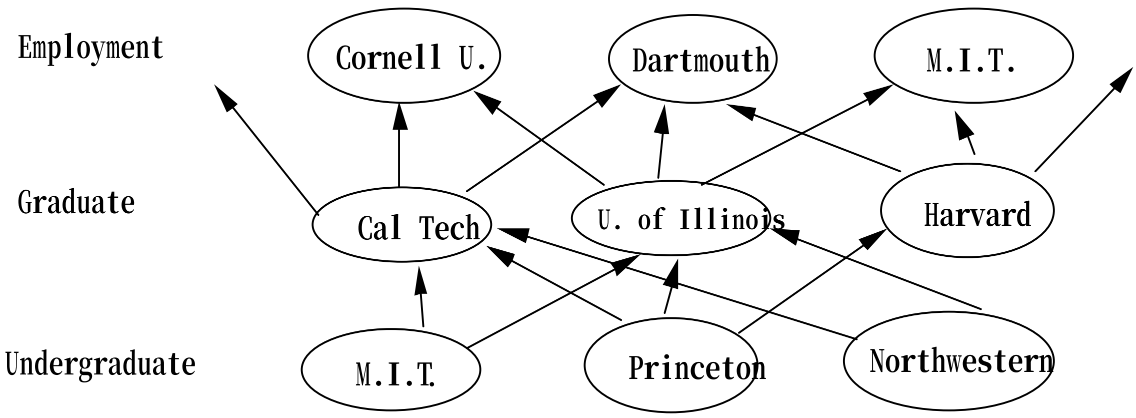
2.1), Japan is extremely fixed. For the few students that continue on to a doctorate program, this consist of another three years of research and seminars, the required time being extremely fixed, leading towards a doctoral thesis. The student writies his thesis (usually in English for the science and engineering disciplines [7]) and gives a presentation to the rest of department. The ideal track continues then on in academia--several years as a "lab assistant", corresponding closer to a post-doc, after which he will, if lucky, advance to becoming an assistant professor and finally, a full professor. [5] Although movement between universities occurs, it is often where the lesser-rated undergraduates of a particular caliber of university end up accepting graduate posts at lower caliber universities. Similar behavior occurs for the transition between the graduate and faculty levels.

This "inbreeding" is in direct contrast to top research universities in the US (and elsewhere) like MIT and Stanford, where the structure is much more free-flowing and chaotic. Not only are the structures of graduate programs far less determined, but also the path of an academician is far more like that of a ping-pong-ball and far less linear. (See Figs 2.2a,b)

Flow of Students in Japan (Fig. 2.2a)



Flow of Students in the U.S. (Fig.2.2b)



The rigidity of the Japanese system is not helped by its extremely vertical structure. Whereas the university laboratory system in the U.S. can be seen as a huge series of webs and cross-links, the Japanese system is an upside-down tree, with little communication between the branches.
Nor is there feedback from the bottom back to the top:

Such a stratification may not seem remarkable, except for the fact that it is strictly top-down. In a fair number of cases, senior professors acted as petty dictators, and their junior professors as "wardens" of the grad students, always with a wary eye on them. (One professor was so petty as to forbid a certain convenient matrix notation from being used in articles from his lab, for reasons unknown.) Graduate students and even junior faculty were assigned research projects to perform, and had little discretion in choosing their work. This prevented the "bubbling up" of good ideas or even feedback on the work from those lower in the hierarchy. Burdened with administrative responsibilities, the senior professor had little time for casual interaction with his students.(MIT report)[5]

But it is the lack of communications even between different laboratory groups in the same department that many people find the most discouraging and stressful:

> "I am doing theoretical work and although theoreticians usually work alone everywhere, here you have to read journals to find out what is happening in the next office." [6]

While encouraging communication within groups, the rigidity of the organizational hierarchy can inhibit the exchange of information between groups. Most university interns were struck with the lack of interaction between academic departments, or even between groups within the same department. Groups working on the same area of research in the same field interacted sparingly. Even when making presentations at technical conferences, Japanese presenters held back research results "proprietary" to their organization, while gathering as much information as possible from others. [5]

> "Outside of my own research group, I have no idea about the other research activities of the department. This is caused by each research group being totally insular. There is no "common room" where people from different groups can mix

and chat to each other."[8]

Every laboratory is isolated. It's not designed this way and there are ways around it, but there's much less interaction between laboratories (than in the US), even those that are doing the same kind of research. Or even in the same department. There's another foreign student in our lab. He's doing some work on the Roppongi campus, at Fujita, who's very famous in the micro area. He has some better equipment. so he can do things we can't. So this guy has to use some of this equipment. ....there's really not a lot of difficulty. You can walk into a professor's office, go talk to them, people are very friendly, the great majority are very helpful, very willing to help. It's just that in general, it's not done that way. It's separate. People who are in the same lab as undergraduates, and then continue onto the Master's program, but get get separated into different labs, they don't see each other any more inside the labs even though they're great friends. They're almost afraid. There's almost this protocol where you don't go into the other person's lab. I guess it's unproductive. [9]

Many people commented on the duplication of effort that such isolation engendered, as well as some of the other attendant problems:

"Be prepared to work in a team. Expect to lose a certain amount of time in largely unproductive meetings but stop going to some if it gets really excessive." [6]

In making micromachines, huge part of the problem is simple actual fabrication. There's all kinds of things. Learning how to make things, learning how to etch things., sticky films, thin films, which ones work, which one's don't work, which ones have residuals. There's all kinds of things. Very "artful" techniques. It's not a well-documented area. There are sorts of documents, but....there's a good deal of repetition.

--Would you also say because of the isolation between labs?

A little of isolation between labs, .a little due to isolation between master's and Ph.D students....the lack of last year's master's students because they've graduated and left....a lot of this.[10]

The lack of interaction between labs is only reinforced by any existing tendencies to "hoard" one's collection of information:

> In spite of the academic atmosphere, there was little cross-pollination between groups, both inside and outside the university. "Knowledge is power," Anders observed, "and the Japanese realize it." As a result, research "secrets" are not given out at conferences. Graduate students had a propensity to hang out in their lab and identify with it.
>
> Even when making presentations at technical conferences, Japanese presenters held back research results "proprietary" to their organization, while gathering as much information as possible from others. [5]
>
> My own experience of the unconscious barriers that are set up was when someone in my department (Solid-State Engineering) asked me whether I knew where he could find some energy-band diagrams of Gallium Arsenide. I suggested the Physics Library, at which he simply stared at me. The concept would have never occured to him. [11]

The problem with these forms of isolation is that it hinders the transmission of information from one generation of researchers to the next. How is information transmitted? This depends on the form in which it is encoded, as is shown in Figure 2.3. It may be written down in books and other such documents ("Formal" Information) which can be stored on a shelf and read much later by other researchers which have no spatial nor temporal connectivity to the first group. The second type of information is that which cannot be transmitted this way, but requires the intermediary of a person ("Informal" information.) This occurs with tacit information ("here, I'll show you how to kneed bread"), or with meta-information, ("why don't you talk to Tom Rice about this problem? I think that's his speciality.") The use of informal information is particularly true in fields that are highly applied, depending on a large number of techniques which, although not directly connected with the research area, are essential to its manipulation (preparation of surfaces for crystal growth through solvents, etc.) or which require intermediatary instruments for investigation (the use of Atomic Force Microscopes or Scanning Electron Microscopes.) Quite often, the instrument in question is the only one in existence (a friend of mine tearing down and rebuilding a quarter-million dollar machine so that it worked ten times better than the specifications, for example) and has obviously not been documented.

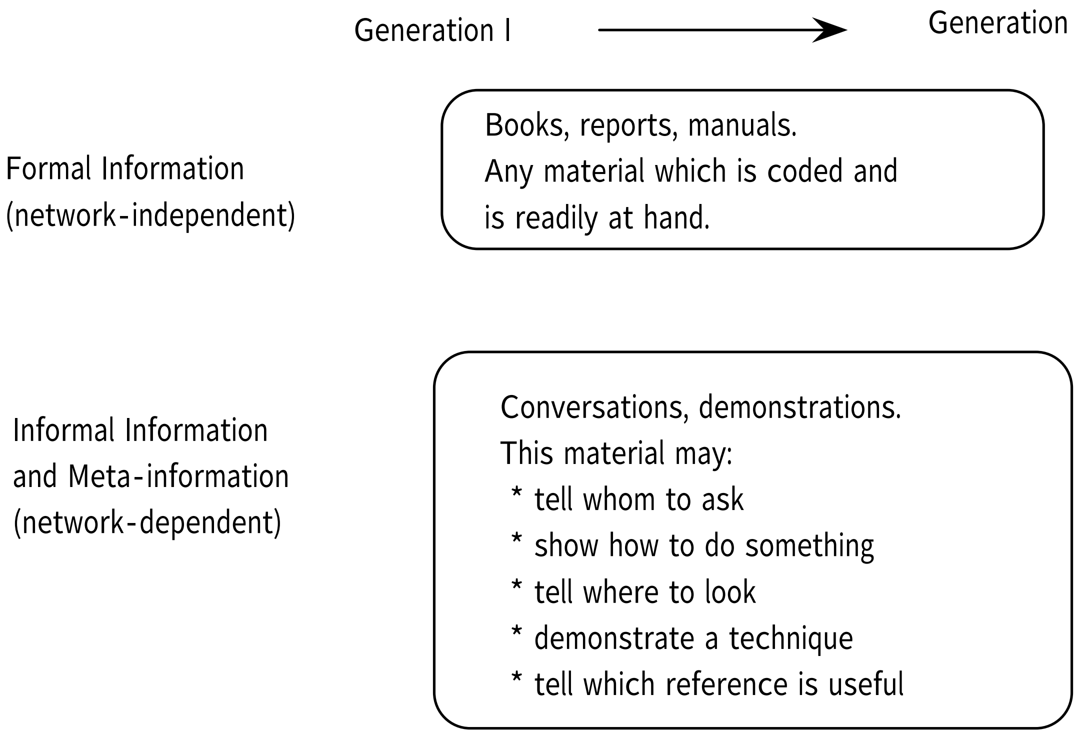


Figure 2.3 Informal Information vs. Formal Information

With formal information, the medium of communication can be considered to be the book itself. With informal information, the medium is the actions of people. The more people around who do use a device or program developed by a certain researcher, the greater the chance that the information on how to use it will not be lost when the inventor/developer leaves and will be transmitted onto the next generation. (In parenthesis, I should mention here the oft-encountered problem of scientists failing to comment their computer code, which means that several years later, even they don't remember how the program worked.) This is a point where the isolation of Japanese laboratories, which already suffer from a lack of graduate students "below critical mass." actively presents barriers and causes the loss of information from the system. This was directly pointed out by an NHK television special, "Nihon no Kenkyuusya no Gensho", which investigated how the lack of graduate students was affecting research. [12] Figure 2.4 demonstrates schematically how such knowledge is lost. a), b), and c) represent successive time steps in the history of a department, composed of groups A, A', and B. In the left half of the figure, which corresponds to what one would expect to see in an American-style university, the loss of group A in step b) does not result in the loss of group A's knowledge from the overall system, because the knowledge has already been shared with group B. Later on, in step c), the knowledge is transmitted back to the new group A', which can now carry on its predecessor's work even though there was no temporal overlap between group A and group A'. The right hand side mimics the vertical, laterally isolated structure found in Japanese universities. Here the lack of a network structure inhibits the transfer of information and does not allow group B to be used as a "emergency knowledge bank", resulting in the loss of group A's knowledge.

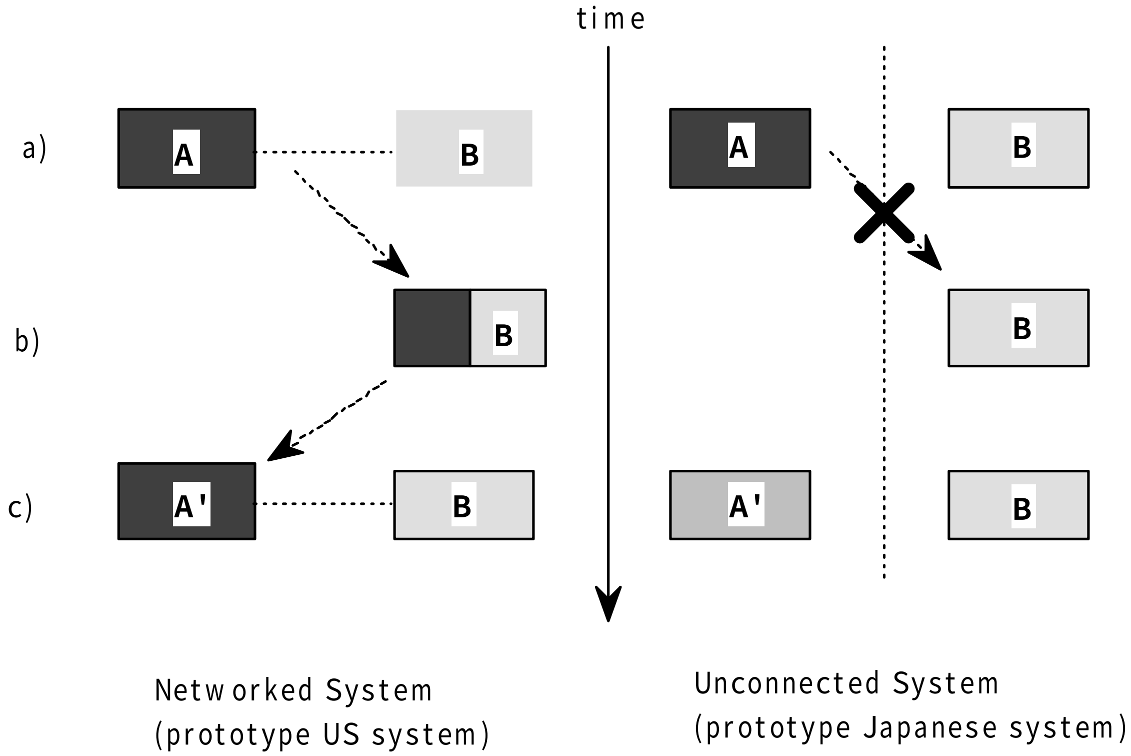


Figure 2.4 Networked system vs. Unlinked system

An equivalent to this "failure of the links of the temporal network" can sometimes happen to students in US departments who suffer from "the ABD (All but Dissertation) problem." (see the section "Problems with U.S. Graduate Education"). Students who have completed all the requirements for their doctorates except for part of the research and writing up of the dissertation sometimes fall into this category, where they take more and more time and get less and less done, effectively never completing their doctorates. Most of the delays seem to occur, not so much because of problems with experiments--although that occurs as well--as because of problems engendered by dropping out of their support network. Links between the student and the professor, the student and other researchers, and between the student and other graduate students break down. This means that there are less roads along which helpful information flows, and less places for the student to turn to for solutions when his research runs up against the inevitable stumbling blocks. (See Fig. 2.5)

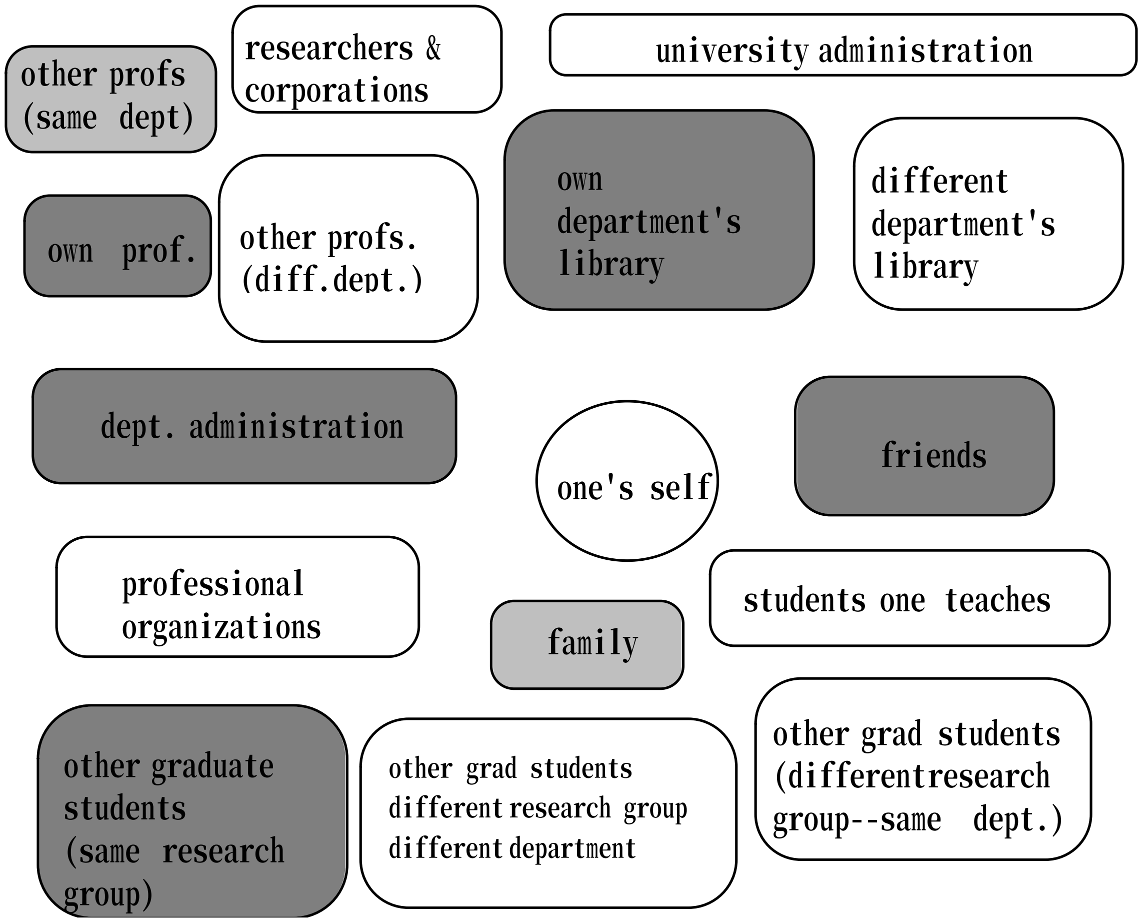


Fig. 2.5 Network around student. Dark grey areas indicate parts of network which also exist in Japan.

A large amount of what is learned in a "good" graduate school in the United States seems not so much to be direct, straight information as it is simply learning where to look for needed information. In many disciplines, knowledge seems to be encoded, not so much in articles and books, as it is in free-floating information that everyone in the field "knows", but no one has bothered to write down. Conversely, useful information is written down, but the question is where to find it. (I myself remember being advised to go look at an appendix in a particularly obscure book for an precise derivation of how in general the terms in a Lagrangian turned into the corresponding Feynman rules--something which I had seen done for a large number of particular examples, but had never understood the justifications for.)

Aside from where to find more understandable explanations, another type of information that seems to float around this way is information which could be called "supporting information", i.e., nothing that could be considered belonging to a particular discipline, but certainly information important in doing research. For example, in at least two physics departments I know of, graduate students have written and compiled a collection of macros used with a certain computer typesetting program used in writing papers and theses. The macros allow extremely specific and complicated tasks to be completed quite easily. One of these sets of macros allows a switch to be set which automatically formats one's paper to the different guidelines required by different (well-known) physics journals. Formatting for a different journal simply requires changing a switch. Here, although certainly not physics by themselves, the information in these computer files is useful in carrying out--in this case publishing--research.

When a graduate student "drops out of the network", it is this level of information that he is cut off from. While in most of the cases of ABD the dropping out is done individually, with one student removing himself from the net, it is also possible for chunks of the network to fail. This happens when the number of knowledgeable researchers in a field drops below a certain number in the department. A well-known saying holds that putting two researchers together results usually far more than in twice the productivity.

Being able to "bounce ideas" off other researchers and take advantage of the tacit information in the network is extremely important and an area I think not enough attention paid to [13].

Atmosphere of Department:

This was an area that many of the observers commented on, feeling that the Japanese universities did not have "enthusiastic" atmospheres, nor were there places to interact with other researchers. Several commented on how the aura of a bureaucracy seemed to take precedence:

> "The important thing seems to be "the being there" with regard to the work environment, not " what do you do while you are there." [8]

> There's surprisingly little motivation [for people] to dwelve into their own studies. There's very little excitement. People are interested. People are serious, they're interested--but there's very little excitement about what they are doing, that they're going to make a difference. It's "do it in order to graduate."
>
> I'm not the typical nurd who spends all his time in the lab. I have outside interests. But at the same time, you have to have a little more enthusiasm, more motivation, not simply to graduate on time. [9]

As several interns remarked, the Japanese graduate students did not seem genuinely enthusiastic about their research. Graduate school was more a matter of marking time for them, until they went to work in industry, which most of them did. Rather than pursue risky new research, they tended to pursue "safe" projects which would allow them to graduate on time. This tendency echoes that of Japanese industry to pursue medium-term "bang for the buck" research. Their studies consisted mostly of scanning the literature, assimilating a massive amount of knowledge in a short period of time. Groundbreaking research was almost non-existent and practically discouraged. This may be due in no small part to the poverty of most Japanese graduate research departments. [5]

(Of course, such lack of enthusiasm is often a complaint made by researchers in the U.S. as well. I myself experienced the "death of a department" during my own years at the University of Illinois, when it became more and more obvious that supersymmetry and superstring theory did not lead to any definite conclusions. At the same time, although the discovery of high-temperature superconductivity in certain rare element ceramics sparked great enthusiasm through solid-state physics, as the experimental results remained stubbornly incommensurate with any theory, this quickly dwindled away, leaving more and more physicists looking for areas in which to conduct "meaningful" research.)

Many people who have had experience of both MIT and Japanese graduate departments were quite frustrated with what they experienced:

> In a way there was a real lack of enthusiasm. Even in the seminars we attended, people were simply summarizing the research that other people had done, and I feel that there was a real lack of enthusiasm or interest. Which was sad. Coming from MIT, where there is so much enthusiasm, people crawling over each other to have quick conversations. [14]

Quite a few researchers have commented on the difficulty of brainstorming with colleagues for whom the idea seemed foreign.[14], [10], [15]

<u>Regulations:</u>

Foreign scientists seem to feel that many of the problems in the Japanese system stem from the over-regulation and lack of mixing between groups. Partly this is due to the dominance of the national universities within the overall system. Whereas in the US, the intent of all state universities seems to become as much like the private universities as possible, in Japan it seems to be the opposite. The bureaucratic system affects laboratory funding, program structure, and funding for students.

Financial support to a (national university) laboratory is available in three ways:

(1) Funds provided by the Mombusho directly automatically. The amount of funds provided are determined by whether the university in question has graduate programs or not, the specialty, and whether it is classified as a "research" area, a "non-research area", or a "clinical area." The variation can be quite great, a factor of 8 between the lowest (non-research, undergraduates-only chair) to the highest (clinical, medical graduate program chair.) The funds are modified also according to the numbers of people involved. These

funds, after reaching the university, have a certain percentage withdrawn by the top administration to handle general administration, a process which is repeated at each department. What is left can be used to buy equipment, books, and hire part-time secretaries. Whereas such funds used to be the main source of research funds, their failure to be upgraded along with cost-of-living increases has made them less important. These funds are also available to some of the private universities, but are granted at far lower levels and less systematically. [16]

(2) competitive funds awarded by the Mombusho after peer review of the proposals. These are closer to what the U.S. National Science Foundation grants.

(3) other funds granted, again competitively, by other foundations and organizations..

Finally, there are research funds granted to a particular laboratory for a set period of time, usually 3 to 5 years.

Universities in Japan seem to be afflicted with a much more obvious (and over-whelming) bureaucracy than places found in the US. Even though there are locations in the US and and in Europe that are notorious for the paperwork (government procurement, for example), most researchers feel that research centers/ universities should be set up to be free of this. By contrast, Japanese universities seem to be set up to have as much red tape as possible. People (not just foreign researchers) have complained about the ludicrousness of having funds to buy a multi-million dollar piece of equipment, but not being able to spend a small fraction of such funds to maintain the building and power supplies that it needs.

> Red tape and bureaucracy in arrangement of experiments. It takes months to achieve any administrative decision. Nobody can consider the problems as one piece, but each item is discussed separately. As a result, some expensive equipment was purchased but cannot be used because some cheap essential parts have not been bought. [15]

What is perhaps interesting is the ways in which the Japanese system is "gotten around." In more than one case, funding for graduate students (not covered under the standard terms of the grant) was enabled through an elaborate scheme of "hiring" them as researchers doing work for the top professor personally and the money shifting through several layers before finally landing in the graduate students' pockets. [8], [10] While one is lost in admiration of some of the schemes developed, one also wonders whether it wouldn't be more sensible to provide funds in one lump sum, to be used at the discretion of the researcher as needed. Here, the centralization of the Japanese system is seen to hinder research directly. (This is a totally different issue from that of underfunding of graduate researchers, which I address later.)

Programs are affected. The structure of the programs at the national universities are determined by the Mombusho. The years required for a MS and for a Ph.D. are fixed. Supposedly bureaucratic inertia is the reason Japanese universities have a tendency to create new departments rather than expand the range of topics covered by already existing departments when confronted with interdisciplinary fields--it is easier to get permission to form a new department than to change the parameters of the old.

<u>Lack of equipment--how Japanese universities are viewed:</u>

Another main tendency of the Japanese university research labs, that of a severe lack of technicians, was also commented on by observers mainly negatively:

> --The other difficulty I referred to, and which I've experienced myself, is because due to the lack of technicians.you end up doing everything yourself. In some ways it's a dead waste of time, because you really don't need to have....
>
> Yes. I took circuits classes. It's not my major, but I took them, to learn how design circuits. To do anything I have to look at my old manuals, the old problems...I have no experience in designing things. Some times that's a good part of research, really, simple areas that should be supported by technicians or people with prior knowledge.(interview) [9]

Suggestions on Improving Japanese Universities:

> Universities are not sufficiently equipped for 1st rate science. University system definitely requires TECHNICIANS - somebody to look after valuable equipment [8]

> Difficult to do research by oneself! Severe lack of technical support. No lab technicians (as I was used to in Europe.) [6]

> ...The lack of professional technicians creates some problems for the maintenance. [6]

> Equipment and machinery would be adequate, provided technicians would be also available. Unfortunately, equipment and very sophisticated pieces of machinery are handled by virtually anybody, including people with no previous experience on them. The result is that very expensive equipment is usually out of order and cannot be used. [6]

> ....One noticeable difference between Japanese universities and their Western counterparts is the lack of technicians, the majority of the technical tasks being undertaken by students. This tends to give the students a very much hands-on approach but leads to a lack of efficiency as every year new students must be trained. It can also make for a very frustrating time when something breaks down. "First class facilities but now enough first class researchers and very little support-- the lab will spend freely on equipment but will not supply staff to maintain it."[6]

Computer access and Internet access unfortunately remain much different from that in the US and Europe. Computer networks still do not seem to be considered a tool when conducting research, particularly for departments outside Computer Science:

> Despite the fact that this is one of the foremost technical universities in Japan, I

believe the level of integration of computer systems is too low. It's not that there is not enough equipment, it's that there is no central authority. This means for example that majors outside of CS are at a big disadvantage in terms because they lack computer hackers. The problem is only compounded by the lack of exposure to facilities in these departments. On the other hand the school is getting a new Cray supercomputer in January which will be in the university's computer center. Unfortunately the computer center not only demands a lot of money for use, but they also seem fairly unconcerned about having the facilities open only during daylight hours Monday to Friday and even then shutting down the computers every fourth day for "Maintenance." Fortunately in our lab we have a solution to the problem which is to have a lot of hackers and a lot of computers. ..(comment) [17]

There's less access in this department among the students to email than there is in the US, for example. Certainly there are students here whom I've asked for their email address and they don't have one. This is mainly with newer students, because the older students seem to be all set up. There is a reasonable public computer room here, which is open basically 24 hours a day. [18]

"Be prepared to rough it in dealing with computer facilities. System administration of networks is completely ad-hoc and non-professional." [8]

I have quite a few colleagues in the humanities in Japanese universities that have yet to receive network access from their universities. This includes simple email! Ironically enough, these people are in media and communications fields.(comment from researcher) [19]

Comparison of Course Content and Teaching:

As for the contents of the individual graduate programs, there was disagreement as to whether the range of the courses offered was similar in extent to those offered in Japan. Of the three math researchers interviewed, all agreed that they felt the Japanese mathematics departments were very similar, both in structure and in graduate training, to mathematics departments in the U.S.

> From the people I've talked to in the sciences, they seem to find it much more different here than I have. The mathematics department here at TIT is very similar to a US department. Maybe that's because this university is fairly open, and it's always had a lot of foreign students compared to other universities in Japan....[20]

> I would like to note that I was actually very surprised at how SIMILAR the mathematical academic climate was in Japan and the US. [21]

The latter, when asked about whether he felt if the range of courses was much less than for US graduate programs), answered:

> I think that the range of COURSES is very small in the US too. I didn't know any laboratory scientists taken courses after the first year, and in math we only had 2 years of coursework. [21]

By contrast to the mathematicians, many of the scientists and engineers felt that the number of courses offered in Japanese universities was minimal. A direct comparison of the required courses in U.S. and Japanese departments seems to provide affirmative evidence. As has mentioned before and will be shown in the following chapter, any one U.S. department covers a range of fields that would be broken up into 3 or more departments in Japan.

Cal Tech MS AA

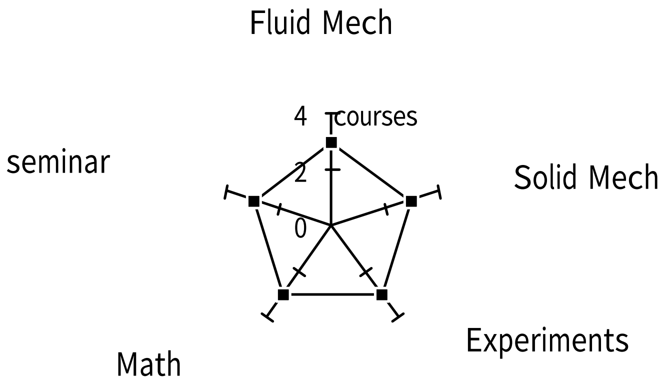


Figure 2.6

Of the seven Japanese universities investigated, only two of them required, among any of their departments, any directly indicated courses. This was in direct comparison to US departments, many of which required specified courses. For example, the requirements for the MS degree in Aeronautics and Astronautics at the California Institute of Technology are as pictured in Figure 2.6.

Stanford MS Mech. Eng.

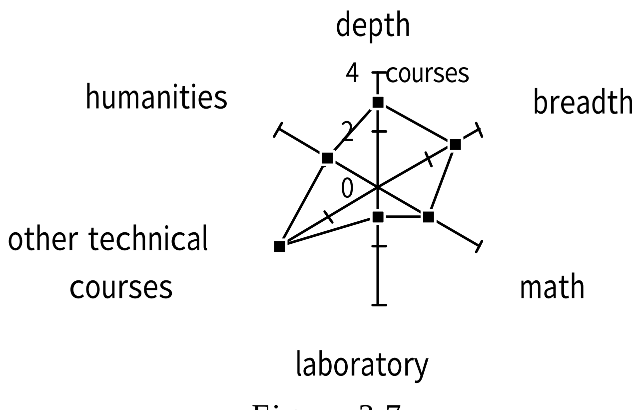


Figure 2.7a

Stanford's Mechanical Engineering, or Aeronautics and Astronautics course requirements (Figure 2.7a, b) can be considered typical of those required for the Master's degree. Here, the student is required to have a speciality (depth), several areas for a broadened background (breadth, math, humanities, other technical courses), and hands-on experience (laboratory).

Stanford MS AA

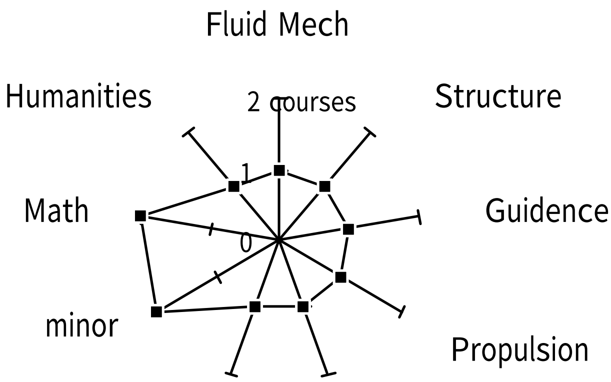


Figure 2.7b

By comparison, Keio's MS in Mechanical Engineering has few constraints (Figure 2.8). Aside from some research both 1st and 2nd year, the courses remain unrestricted within the department.

Keio U. MS Mech Eng.

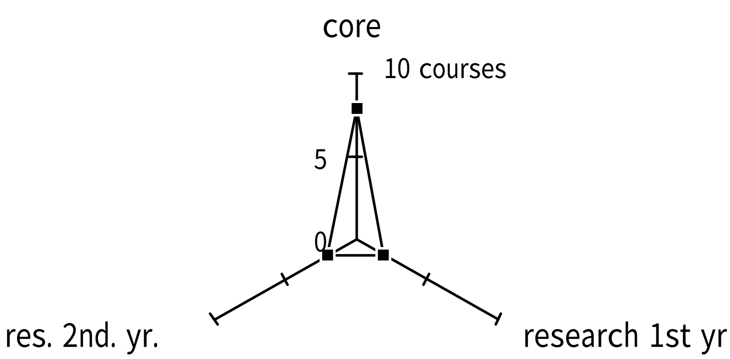


Figure 2.8

At the doctoral level, Stanford's Ph.D. program in Chemical Engineering (Figure 2.9a) can be considered more a less typical of a program starting from the B.S. level. The student is balanced between research experience (research), core courses (one's speciality), a broader background (other courses), and teaching experience (teaching) Of course, the writing of a thesis is also required.

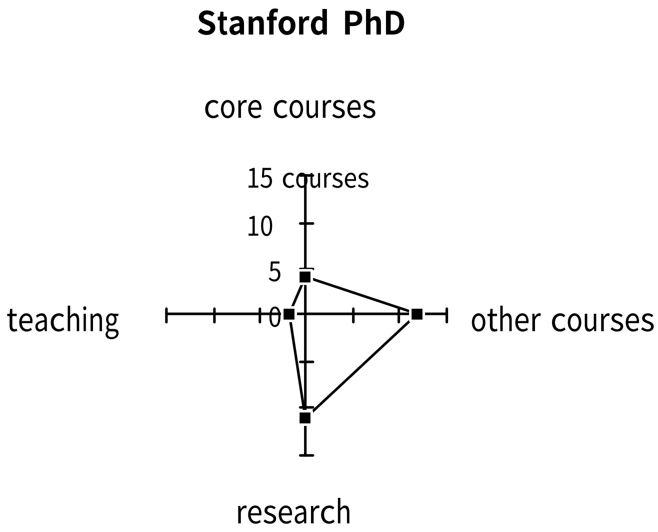


Figure 2.9a: Stanford Ph.D. in Chemical Engineering

Ohio State's Ph.D. program in Civil Engineering is an example of another standard form (Figure 2.9b), closer to an expanded Master's course. Again we have the balance of research, core courses, and other courses. Teaching is not required, but on the other hand one must complete a Master's thesis as well as a Ph.D. thesis.

Ohio State PhD

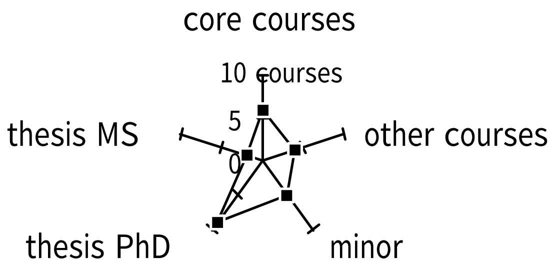


Figure 2.9b: Ohio State Ph.D. in Civil Engineering

By comparison, a Japanese Ph.D. requires no coursework whatsoever, only a rather light load of seminars and book-reports. The focus is completely on research, with the image of the scientist as bureaucrat.

While coursework does exist in Japanese graduate work, it does not seem to receive favorable reviews from outside researchers. In general, the comments are negative:

> Indeed, graduate school in Japan does not look very much like graduate school in America...Most university interns considered the teaching uninspired and even "downright boring." [5]

> [The courses] are a joke. They're absolutely worthless. So there's not really any "course" to share, no homework.... you don't have to do problem sets together, sharing notes. take a test. There's no tests. If there is a test, then most people aren't going to take that class.
> Almost always you have a report at the end. Two or three pages, on very simple stuff. It's not hard at all. The classes I worked hardest in and put forth the most and learned a lot--I got Bs in. The other classes.... Sometime your grade is based simply on attendance. [9]

The same person commented:

> We had one person, last year, who had 60 or 70 units to make up in his last year.

> 40 classes. And he managed to graduate. Even if classes only meet once a week, it's hard to fit in 20 classes. I take it that people take advantage of easy classes, not going--unless of course if there's attendance, they go---there was a girl in our lab who came the first day to one of the classes I was in. And then came the end of the class--she had never come again. She asked me whether there was a report in that class. "Oh yeah, there's a report." "Oh, can I see it?" I gave it to her....Professors know about this. They even joke about it. Professors speak derogatarily of it--"Classes are just a waste of time". They want to do research, they don't want to teach classes. The majority of professors are like that. I've had some of the worst lectures in my entire life here. [9]

Whereas complaints about teaching also occur in U.S. universities, it does not seem to reach the level of overall negativism that seems to occur in Japan. Partly this is due to the greater emphasis on teaching when determining tenure, but most likely is due to the courses being in most cases non-trivial to complete. American graduate courses are much more structured and competitive than Japanese courses, with problem sets (homework), mid-term and final examinations, and direct participation in class. Courses, if they are symposium courses, regularly demand 25-50 page reports. Due to this, students get very annoyed if the teaching does not reach a certain level of competence, and are liable to complain bitterly to the administration if they feel short-changed. [22]

One observer commented astutely that the structure of the Japanese graduate program, with its emphasis on hands-on research and lack of broad base, was (in his opinion) made up by the breadth of the undergraduate education:

> But to get into the graduate program, you've got to be very solid as an undergraduate. You've got to be able to handle courses that you hated., that no one liked. You had to do real serious problems on the qual, to get in. So you've already got a very high level. You may forget it, but you've gone through, had this slightly lower or not drastically lower level as an undergraduate. I think some of the courses are more advanced than at MIT, and I think if an English

> version of my test, given to everyone at my lab (at MIT), I think there would be very few people who could have passed it, even given a lower level of passing. I think everyone could have done some, but not a lot. I know that some of the math problems I couldn't solve necessarily. If people were studying thermodynamics, they could specifically solve that problem, because it's easy, but everyone at MIT hated it, and he forgot it when the class was over. I think the level of people who take this entrance exam is much higher than the level of students who graduated from MIT. [9]

It has also been suggested that the rather desultory graduate education is made up by the reception graduates get at a company. With Japan's life-time employment system, companies know that entering employees are not going to "jump ship", and thus they can afford to spend the first two or so years providing on-the-job training and education for their researchers if necessary. This is particularly true since the research for which these people have been hired is extremely specialized, in most cases, and would not have been covered in a university, anyway. It is felt that what is more important is that the student during his graduate career has had the experiences of conducting research, particularly as part of a team:

> It is not surprising that the graduate experience becomes a sort of bureaucrat-in-training process. Students are required to publish and present papers at conferences, whether they have anything new to say or not. It is the exercise that is important, not the content per se. While there are some truly promising researchers in Japanese graduate schools, the majority are industry apprentices. [5]

By comparison, the job mobility in the U.S. is such that companies would not feel obliged, in general, to provide on-the-job training for their researchers. This means that entering researchers have to have a wide range of skills and knowledge in hand already, so that they can rapidly learn the applications of such particulars of whatever the company is requesting. It is ironic that although the main employment path for Japanese doctoral recipients is academia, the atmosphere at the graduate level in Japan seems to be more that of a bureaucracy than a research organization, to many observers.

Of course, there were also several places which were praised as having a very positive atmosphere:

> "My professor encourages everyone - particularly the students - to be creative - consider experiments and results and think about alternative methods, implications, etc." [6]
> My experience here has been very positive. I will try to summarize it, but you must remember that it is just one slice of life here. There is great diversity here, with different professors taking approaches as different from each other';s as night and day. We study learning algorithms in general, with an emphasis on pattern recognition for such things as handwritten character recognition. My professor has a theoretical bent, and this is more or less reflected in the approach of his disciples' research. Apart from that requirement, which is one more of style than content, we have great freedom. [23]

Several people had comments to make about the level of research found:

> Overall, you can see that my impression of the research here is not very good. I tend to find that the papers published here do not contain substantial or interesting work. Nor is much of it original. Sometimes it is just a simple calculation redone to a different set of data. Some of the current Ph.D. theses written by middle-age researchers even contain work that was done 10 years ago! [24]

One great difference between US and Japanese programs, which does not seem to have been adequately documented before, is the lack of interdisciplinary activities in Japanese universities. Whereas U.S. universities are more or less casual about students taking classes from other departments--in fact, many of the graduate programs require classes from outside the department--none of this was seen among the Japanese universities studied. (This point will be addressed later, in Chapter 4.)

Details of individual programs in U.S. universities:

The following section provides an overview of the MS and Ph.D. programs in different fields. It should be pointed out that it is very difficult to calculate explicit data about the "average program", since the structure of programs differs according to university and department. Even such a seemingly simple question as "average number of courses required" presents problems, since some of the universities investigated are on a semester system, while others are on the quarter system. In what follows, I have tried to give as accurate a thumbnail sketch as possible of more prevalent departments.

Universities investigated:
Cornell University
UCLA
U. of Chicago
Ohio State
Michigan State U.
Oregon Graduate University
Massachusetts Institute of Technology
Stanford University
U. of Texas at Austin
Texas A&M
U. of Pittsburgh

Departments investigated (where appropriate)
Agricultural Engineering
Applied Physics
Aeronautics and Astronautics
Astronomy
Atmospheric Sciences
Biochemistry and Molecular Biology
Biology

Bioengineering
Cell and Structural Biology
Chemistry
Chemical Engineering
Chemical and Petroleum Engineering
Civil Engineering
Computer Science
Computer Science and Electrical Engineering
Electrical Engineering
Environmental Engineering
Engineering-Economic Systems
Industrial Engineering (and Engineering Management)
Materials Science and Engineering
Mathematics
Mechanical Engineering
Nuclear Engineering
Operations Research
Petroleum Engineering
Physics
Scientific Computing and Computational Mathematics
Statistics
Welding Engineering

Data for the programs of individual departments can be provided upon request.

<u>Aeronautics and Astronautics Depts:</u>

As is prevalent in engineering programs, the Master's programs are at least as structured as the Doctoral programs, with fully two-thirds of graduate students in AA stopping after the MS. Typical AA MS programs are as pictured above in Figs. 2.6, 2.7a. There is a tendency for explicit courses to be required, said courses covering a wide spectrum of fields. Programs seem to be split roughly half-and-half between those requiring a thesis and those not. The doctorates are usually "on top of" a Master's, although dovetailing of the MS thesis defense with the Ph.D. Qualifying exam is not uncommon.

Chemical Engineering Depts.:

Again, very structured MS programs. Usually the student is required to pick from among a selection of Chem Eng. courses, although in some cases a small set of required courses forms the core of the student's work. Programs again are roughly split between those requiring a thesis, and those not. Doctorates again usually follow an MS.

Industrial Engineering/ Operations Research

The universities which offer either or both of these departments seem to be very involved in "hands-on" experience, combining coursework with an internship or some sort of project. Figures 2.10. and 2.11 show the breakdown of the types of MS programs offered (with thesis, without thesis, with final exam, with project..) and the structure of the courses required.

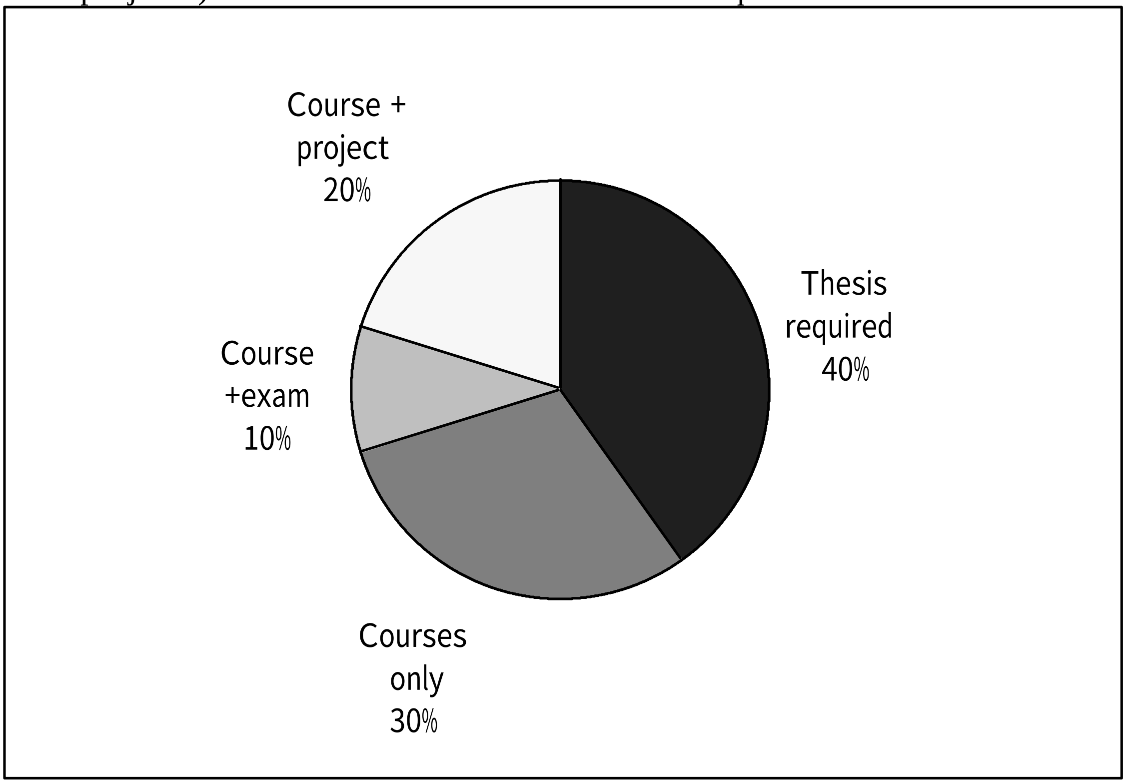


Figure 2.10 MS Program structure in Ind. Eng. and Operations Res. Depts. (10 cases)

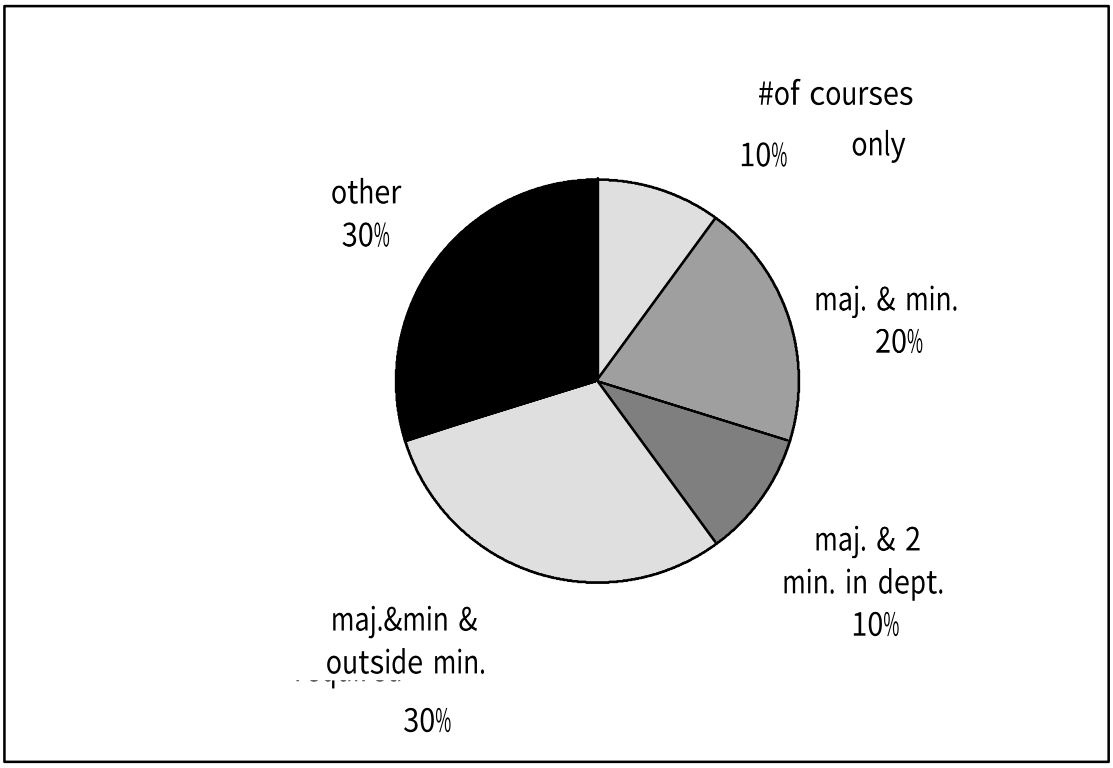


Figure 2.11 Detailed MS Course Structure in Ind. Eng.
and Operations Res. Programs (10 cases)

Computer Science/ Computer Science and Electrical Engineering / Electrical Engineering:

On the whole, the more "research-oriented" a university is, the more CS/EE is treated like a science rather than an engineering discipline. Thus, the CS/EE departments of such universities as MIT, Stanford, U. of I seem to push students towards the Ph.D. rather than the Master's. Quite a few have direct Ph.D. programs. The MS programs which do exist (at the research universities and elsewhere) are heavily dependant on a MS thesis (see Figure 2.12). There exists a wide distribution in the structure of the courses required (see Figure 2.13) Lab courses are not required in CS programs, probably because most computer courses end up requiring a lot of programming. Doctoral programs seem to be quite standard, with the only interesting aspect the wide number of specialities now existing inside CS. EE doctoral programs seem more likely to require courses from outside the department (physics, statistics.)

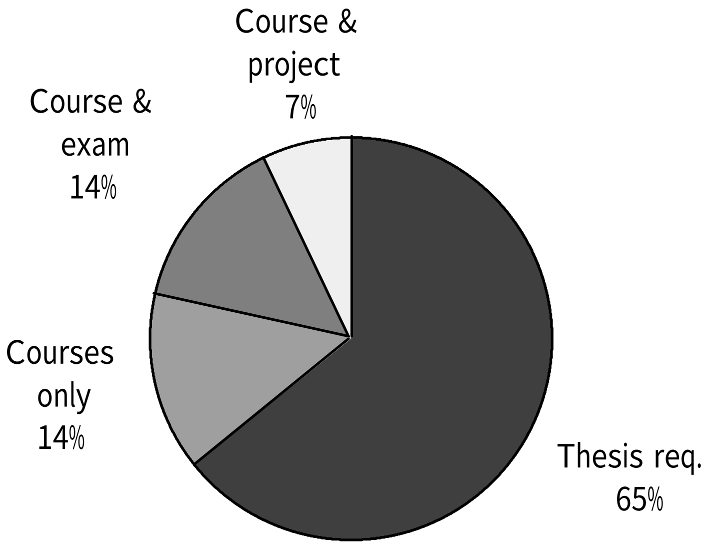


Figure 2.12 MS Program Structure in CS and EE Depts. (15 cases)

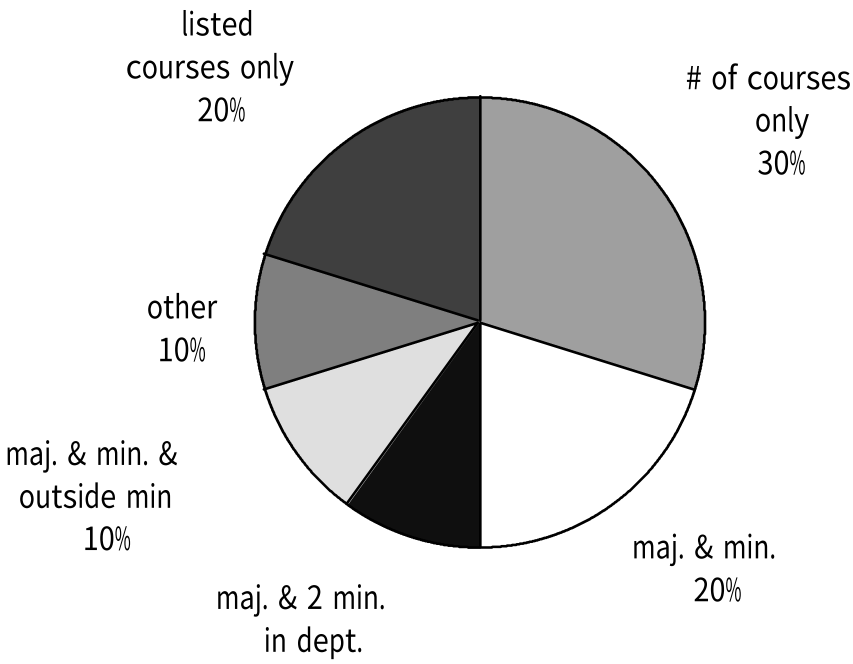


Figure 2.13 Detailed MS Course Structure in CS and EE Programs
(15 cases)

Mechanical Engineering:

Mechanical Engineering often shares courses with Materials Science or Ocean Engineering. It is considered a "practical" discipline, with a large number of its practitioners stopping at the MS level. Due to this, it is not surprising that the bulk of the MS programs require either a thesis or an exam (Figure 2.14). Program structure often requires a minor within the department (Figure 2.15)

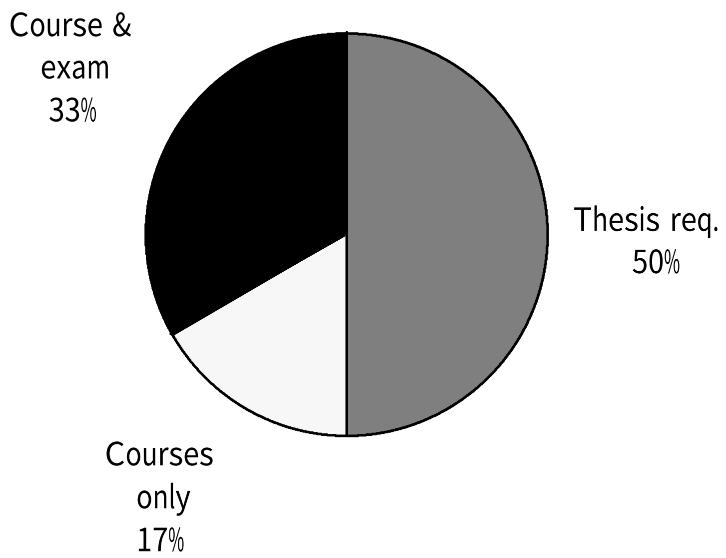


Figure 2.14 MS Program Structure in Mech. Eng. Depts. (6 cases)

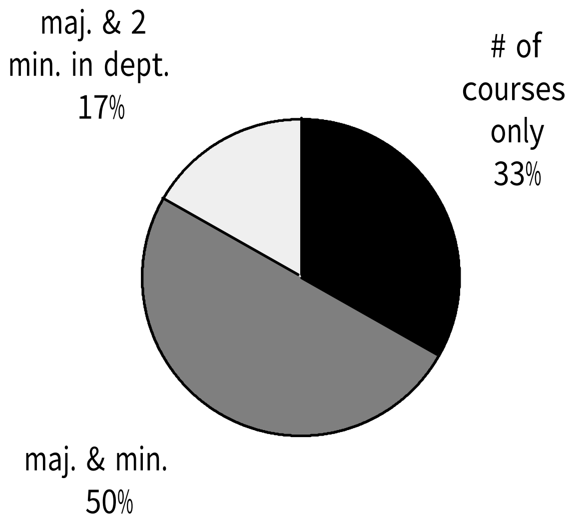


Figure 2.15 Detailed MS Structure of Mech. Eng. Programs (6 cases)

Sciences:

In the sciences, most people enter with the idea of obtaining a doctorate. Although separate MS programs do exist, it is deceptive to note their high level of "thesis required" programs (49%) and assume that this is typical of all the sciences. Quite often a master's without thesis is granted as a consolation prize for students who have failed to pass the Qualifying exam. The distribution of courses from the programs which provided enough information to include is given in Figure 2.16. A large number of programs were listed as "requirements determined after consultation with advisor."

A large number of the science Ph.D. programs I looked at required teaching, in one case a full year of actual teaching (grading not acceptable.) Laboratory courses were usually required in the biological fields.

All the mathematics Ph.D. programs investigated (4 cases) required a reading knowledge of one or two foreign languages (French, German, or Russian).

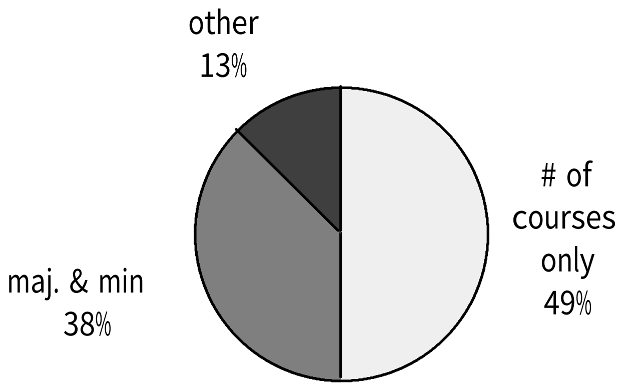


Figure 2.14 Detailed Structure of MS Science Programs (9 cases)

Comparison of Financial Support:

One of the most disconcerting aspects of graduate life in Japan is the extremely low level of financial support available. Many of the so-called "grants" should be more accurately called "student loans", since they oblige the student to pay them back after a certain number of years. The standard fellowship, offered by the Japanese Association for the Promotion of Technology, offers yearly grants of 156000 yen, but this is hardly enough to cover one's tuition, let alone the cost of living in a Japanese city. In addition, between 1988 and 1990 only 323 graduate students out of 5405 were covered, a rate of only 6%. [4]

American graduate schools cover graduate students through a combination of outright fellowships and teaching/research positions. In 1991, half of the primary support for graduate science and engineering students was provided by nonfederal sources (i.e., academic institutions and private industry); 20 percent was from the Federal Government; and 30 percent consisted of self-support. Fueled by growing university research funding, teaching assistantships and especially Research Assistantships have over the past 12 years, displaced fellowships and traineeships as the major graduate support mechanism. [25]

The forms of individual graduate funding differ according to school and department. Investigating 177 U.S. universities, most departments of 109 of them waived tuitions in all cases when providing funding, 39 of them required tuition to be paid in all cases, and the rest were mixed. (Fig. 2.17) [26] In many cases, tuition would be waived for Teaching Assistants and Research Assistants, but not for Fellowship awardees. In a fewer number of cases, tuition waivers were considered a side benefit for fellowship and similar awardees, but required of both TAs and RAs. In one university, all forms of TA, RA, and fellowship support carried tuition waivers, unless the fellowship was from a private foundation. George Mason University, Harvard, and Montana State University provided tuition waivers for all recipients except TAs, while the University of Nevada at Reno was just the opposite. It should be also pointed out that for some universities which required tuition, this extra cost would be factored into the amount of money provided by the fellowship.

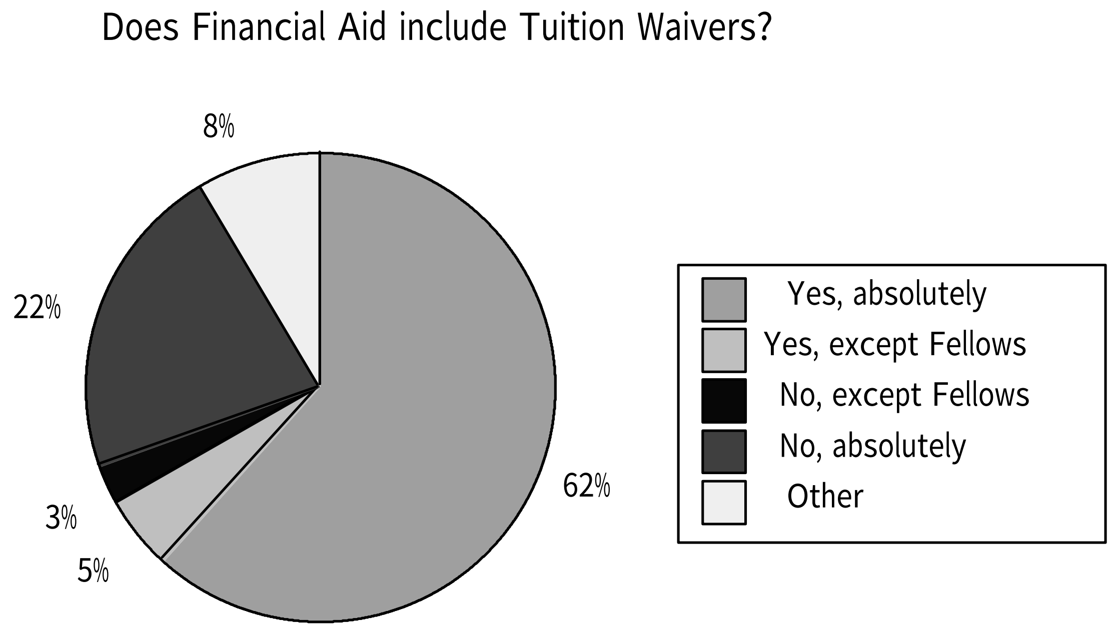


Figure 2.17: Breakdown of Tuition Waivers at U.S. graduate universities

In general, state universities charge less tuition than private universities, with even lower rates for in-state students in comparison to out-state students. In-state students typically pay anywhere from one-fourth to one-half the cost of out-state students. In all cases, graduate students taking over a certain number of courses (usually 1/3 full schedule) were eligible to pay tuition (if it were not waived altogether) at the in-state student rate.

In general, students applying to a graduate program in the US receive one of four types of offers: outright fellowships (often which must be applied for separately), a standard teaching or research assistant position at half-time (usually also with a tuition waiver), no extra financial support but a tuition waiver, or simply acceptance into the graduate school.

The picture is clouded by the fact that there exists, in addition, the possibility of the student being funded directly by his professor out of some research grant. Some universities (most departments in MIT, for example), seem to work in this manner. It is the student's responsibility (often after entering) to find a research position under some professor who has the funds to provide a stipend. [27]

By comparison, there seem to be two major sources of official funding for graduate students in Japan: Fellowships from the Japanese Society for the Promotion of Science and so-called "scholarships" from the Japanese Scholarship Foundation [28], [29] . The latter differ from scholarships as standardly defined in the US by being required to be paid back unless under certain circumstances (the graduate continuing on in academia, for example.) It would be more appropriate to call them interest-free loans, comparable to the student guaranteed loans in the US. (In fact, a certain sub-division of them are loans charging interest, pure and simply.) The numbers of graduate students who receive these are not insignificant--for 1995 the numbers were 24,834 and 17,416 for MS and Ph.D. students, respectively. This works out to 25.6% and 53.0 of the total MS and Ph.D. students, respectively. Selections are supposedly made "on the basis of academic achievement, financial support, character, and health of the applicants", but one of my contacts pointed out, that for a student who has already gone through the entrance exams and has been accepted by a graduate school, "anyone can get one." [9]

The stipends provided for are less than what these students could earn as salaries, obviously, but can be thought of as roughly half of what US graduate students get as TAs and RAs, assuming purchasing power parities. The stipends are at present 81,000 yen/month for MS course students and 112,000 yen/ month for Ph.D. course students.
(By comparison, a bachelor's-only student in 1991 with no experience entering as a technician received a average starting salary of 181,000 yen/month [30])

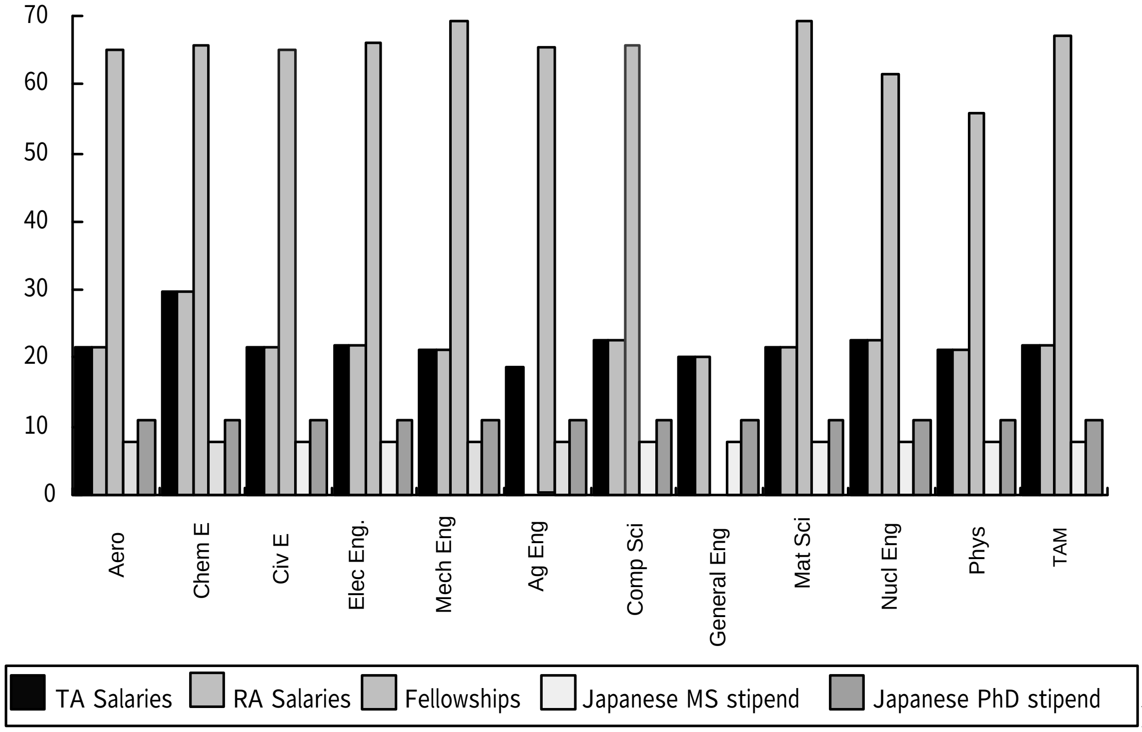


Figure 2.18a: U. of Illinois vs. Japanese graduate stipends (10,000 yen/month units)[1]

It should also be pointed out that in the Japanese system graduate students do not receive tuition waivers. At present, taking the entrance exam has a fee of around 30,000 yen (national universities), the entrance fee is around 300,000 yen, and tuition per year is around 450,000 yen. (Private universities are even more.) The tuition by itself swallows up one-third to one-half of the above MS and Ph.D. stipends, reducing the already small stipends to an amount impossible to live on.

[1] Data from 1994

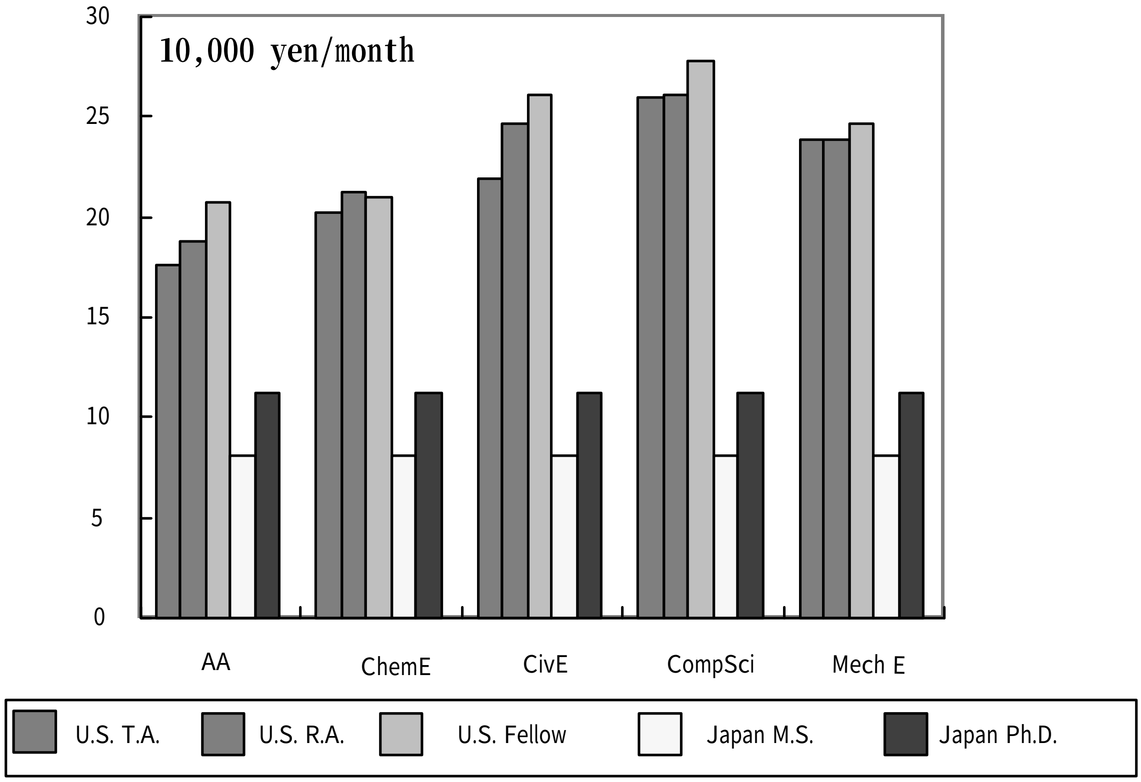


Figure 2.18b Average[*] * Stipends of Graduate Students in the US and Japan (10,000 yen/month units)[2]

The period of repayment can stretch up to 20 years, depending on the amount borrowed. For MS students this results in a repayment of 11,000 yen/month, while for Ph.D. students this is 16,000 yen/month. Repayment is waived if the grantee has been employed for a certain number of years at elementary schools and higher levels of educational institutions, or teaching/ research posts at laboratories, research institutes, and educational/cultural institutes designated by the Minister of Education. (For an interesting cultural comparison, note that in the US and many other countries such loans are forgiven if the recipient enters the military.) For a more accurate view of graduate stipends, which takes into account the presence or lack of tuition waivers, see Figure 2.19. Here it was assumed that U.S. fellowships did not

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[*] * Calculated from the stipends of 10 "typical" universities [40]

[2] Data from 1995

include tuition waivers.

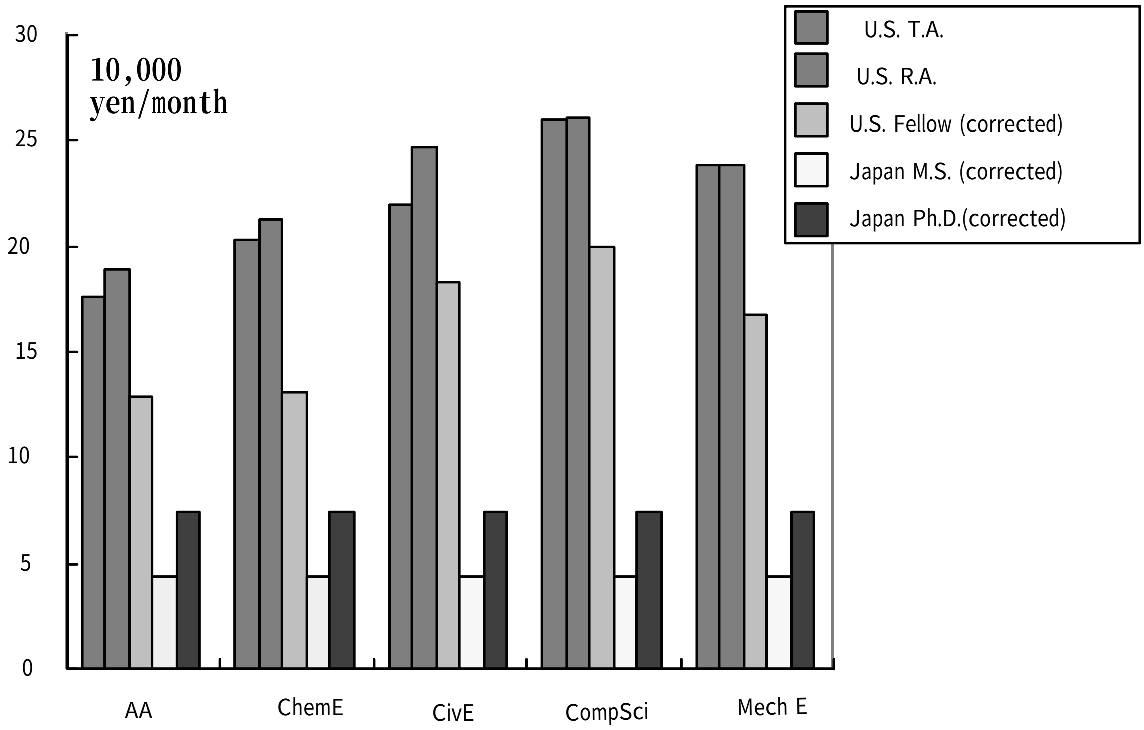

Figure 2.19 Average stipends among US and Japanese graduate recipients, corrected for tuition (10,000 yen/month units)[3]

By contrast, the JSPS Fellowships are far closer to the American form of scholarship: support paid during the student's Ph.D. program which provides a sensible amount of support and which does not have to be paid back. Interestingly enough, these fellowships seem to have been establish specifically to encourage students to continue on to the doctorate level--support is provided only for those as doctoral students and post-doctorates. Doctorates--and those in their last year of MS work who plan to advance onto the doctorate--can apply for the DC grants, which provide 174,000 yen/month Postdoctorates (and expected PDs) are eligible for the PD grants, which provide 271,000 yen/month.

[3] Data from 1995

The Foundation seems to be attempting to expand as rapidly as possible, with 1,700 post-docs and doctorates being funded this year, covering all fields. (As a comparative example, the U.S.'s National Science Foundation provides 1500-1800 Fellowships a year in the sciences and engineering.) [31]

In addition, there seem to exist several other forms of scholarships which provide support and which do not have to be paid back. Unfortunately, the numbers of each are usually rather low--the Mombusho Fellowship supports only 2 students each year in the entire engineering department of Tokyo University.

> Being at Todai, and being in Engineering, there are a lot of these sorts of scholarships for Japanese students. I don't know how they're advertised, but most everyone in the lab has one. They provide 7 to 10 man a month. Not enough money to live on in Tokyo, but it does provide you that amount of money. Almost everyone has one of these. That's about it. [9]

Other sources of private funding do exist. Unfortunately, the bulk of them seem to have been set up with the same flavor as those from the Scholarship Foundation--loans to be paid back, unless the student enters the company.

> We had a couple people in that situation funded by one of those big "Meikaa"s (manufacturers), as they call them. They decided to continue on at this company after getting Master's. The penalty being otherwise having to pay back the loans. [9]

The stress of feeling tied down by such obligations was cited as a major reason by graduate students as to why they did not want to obtain money from such sources. [32]

And then, of course, are the old stand-bys, teaching and relying for support on parents:

> Of course, there's parents...Parents, I think, are still important. There's part time jobs, which most people do some. Professors don't like it, but they accept it. From what I

hear it's mostly teaching--private teaching, teaching in jyuku. One of the guys had to quit his job. He advertised his job--way up in Omiya--so it's not in the middle of Tokyo. He was some kind of math teacher, and it was 5000 yen an hour. That's good for a Japanese arubeito.[9]

I found some people who do some teaching, but it's miserable, just on an hourly basis, not at all the same preference you have in the US, with a stipend. It's certainly not enough.to live on. They might do it (here) just for pocket money. I think that's a big problem. It must surely discourage people going onto graduate school here. [20]

Japan has just recently (since 1995) introduced a so-called "Teaching Assistant" stipend, but this is in no way comparable to the "Teaching Assistant" posts available in the U.S. Rather, it is an additional stipend on top of the standard "scholarship", to be paid per hour used in an attempt to compensate the students for some of their time used. Both graduate students in master's and doctorate programs can be participants. According to statistics from the Ministry of Education for 1995 [33], 246 universities now offer "teaching stipends" and the number of students receiving such was 23,688 students. "Teaching Assistant" responsibilities are different than in the U.S. Whereas in the U.S. TA responsibilities are a) teaching recitation sections and lab courses, and b) grading homework and exams, Japanese TA responsibilities are as follows: (listed in order of frequency) a) helping out and preparation for experiments, b) preparation of materials for seminars, c) helping with preparation of reports, and only at the last d) correction of tests/reports. It has been commented that this does not really change the university system, simply takes a section of work that used to be done by the graduate students anyway and dignify it with a separate name and some extra money. Supposedly the idea is to replace the part-time work done by many graduate students teaching at cram schools or preparation schools with some part-time work that at least lies within their own research fields. The monetary value is not high: ideally 40,000 to 50,000 yen a month. As the system now stands, however, each professor submits each year the number of requested "slots" he wants for TA. Each university collects all requests from its professors, then applies to the

Ministry of Education for funds. If the professor has underestimated the number of bright students he wishes to support, he may decide to “spread the wealth” he has received among all of them [33]

The above-mentioned difficulties about funding for graduate students in all forms, particularly when contrasted with the much higher salaries available in industry, should obviously be considered a hinderance in increasing the flow of students into graduate school. As confirmatory evidence, it has been definitely shown [34] that for U.S. graduate programs the main factor in increased time-to-degree and attrition rates has been a lack of funding. It should be pointed out that the contrast was between students who had some form of fellowships or on-going financial support provided in exchange for employment (R.A.s or T.A.s), and those who were supporting themselves through guaranteed student loans, part-time employment outside the university, and/or other sources. The so-called "scholarships" in Japan would thus fall in the latter category. Although the amount of money to be paid back each month is quite small, it is another extra burden to impose on a young employee. From a viewpoint of increasing the number of graduate students in general, Japan would do well to provide such "scholarships" as outright grants. Another useful step would be to encourage tuition waivers at the graduate level. A third would be to abolish the entrance fee completely. Although the burden imposed by each is small by itself, when added together they must cause a considerable barrier to any potential graduate student.

<u>Problems with the U.S. System:</u>

Two problems have been becoming prevalent in the American graduate system--first, the increasing number of graduate students who complete all the course requirements and pass all the necessary exams, but who get stuck interminably in the research and writing of their thesis and never officially complete the doctorate. This is what is known as the "All But Dissertation", or ABD problem.[35]

A second problem, intertwined with the first, is the striking increase in time required for a doctorate. In physics, for example, the average time taken has jumped from roughly four years to over seven years. [34] Some of this has been due to the rapid increase in the amount of knowledge and prior discoveries which must be assimilated before being able to do cutting-edge research, but it is due also, I think, to the fact that all of the simple and obvious projects which can be done with table-top equipment have already been done. The graduate student is thus forced to investigate ever-more inaccessible realms with ever-more complex equipment. Another reason, I feel, is that the advisors are demanding more and more complex problems to be solved. Among the society of professors, there is a bit of a competition going on, where he who allows a student to obtain a doctorate with what could be labeled disparagingly as "master's level research" has lost status. Thus the temptation to ask the student to complete more and more.

Another reason encouraging longer and longer sojourns is that as of now, there are no checks in the system which work against a professor keeping a student around. If the student is being provided for as a Teaching Assistant, then his support is being provided for by the university and the professor has no need to worry. If the student is a Research Student, then the professor has to provide the money from his own research grants, obtained through application to the National Science Foundation (NSF), Department of Defense (DOD), Department of Energy (DOE), and so forth. However, since a grant is usually written to provide money for a certain number of graduate stipends anyway, it is unproductive for a professor to replace a trained (older) graduate student who knows the equipment and how to conduct research with a entering student who will produce nothing for maybe a year. Thus the system as it is now set up discourages professors from replacing their graduate students.

Other countries, namely France and England, suffer less from the problem of the permanent graduate student. (Some would say the programs are truncated to the point of being useless, but that is a different problem.) The financial support system for the graduate students turns out to be different. One finds that although funding is provided, unlike the US there exist limits on the length of time each student can receive such. In France, the limits are three years after which the level of support drops to zero--a particular incentive for the professor to see that the student completes his project within that time. [36]

Another problem, which is not at the graduate level itself but has resulted in a trickle-down affect, is with the demand for doctorates. American industry has been cutting back on its basic research laboratories and many other government laboratories have frozen hiring in an attempt to control costs. Added to this is the fact that the number of jobs opening in academia have been dwindling, leading to a glut of doctorate-holders out on the market. Certain fields have been able to adapt; for instance the increased prevalence of needing to understand complex systems for mastering the present-day financial markets, plus the added computer power now available at low prices, has meant a large number of mathematicians and condensed matter physicists have found employment on Wall Street at quite high salaries. [37] But for those who wish to continue in their present fields, the job markets have been getting tighter and tighter. Because of this, it has become more and more common for a Ph.D. graduate to take one or more post-doctorate positions lasting a year to three years each. This is before even being able to find a "permanent" position--which, with the cyclic ups and downs of the American economy and the enthusiasm with which all employers seem to be shedding research-related positions, may mean no security at all. It is due to this increasingly competitive job market that companies are able to ask for increasingly specific qualifications from applicants for a particular job (Microbiologist. Must have experience with such-and-such equipment. Candidates with experience using such-and-such software will be at an advantage) and still get them filled. On the academic side, the squeeze on most universities' finances has meant a cutting of jobs and a great hesitation to add new faculty members, especially since the number of projected new students continues to decline as the "baby boom generation" gets older. Hence the necessity for one or more post-doctorates while waiting for a position to open up in a faculty track position. It used to be that faculty who had undertaken postdoctorates were few and far between., and a postdoctorate used to be only for those who were really interested in obtaining more research experience. But as of now, it has become the norm for those trying to enter academia--and even industry.

The traffic jam in the employment pipeline has backed up to the point where now people are remaining extra years in graduate school, waiting until post-doctorate positions open up. I would hesitate to claim, however--as many commentators have--that on the whole the amount of pure research in the U.S. is going down. With the extra years in graduate school and the extra number of years in postdoctorates, about the same amount of time seems to be spent on research. It is simply that it is being paid at a much less lucrative level. Salaries for graduate students hover, at best, at around the $12K a year (100,000 yen a month) while postdoctorate positions pay $17-24K a year (141,666 to 200,000 yen a month). By comparison, an Ph.D. graduate entering industry can expect $45-70K a year (375,000 to 583,333 yen a month) and a beginning academic faculty-track position usually pays $27-32K a year (225,000 to 266,666 yen a month.)[43]

Leaving aside the problems of future employment, certain tactics can be implemented towards keeping students on a even track and getting them out in as few years as possible while maintaining a high level of education. The one tactic American universities do not want to do is weaken their programs. Partly this is due to a sense of maintaining prestige, partly this has to do with the fact that., unlike the Japanese system, there is a well-defined market for the product the graduate system turns out: industry. U.S. companies will not be happy at all if the so-called Master's and Ph.D. recipients come out with a deficient education. And mainly, because after investigating, the increasing length of time has been found to have very little to do with the number of courses or number of qualification exams and preliminary exams. The increase in time occurs almost completely in the length of research time required for completion of the thesis. [38] I have already written above on the possible reasons for this. (It should be noted that of the people who fail to complete the doctorate program completely, the bulk of these drop out before entering on the thesis research stage).

As of yet, no changes have been officially implemented anywhere so as to change the professorial side of the equation; i.e., the professor's salary being dependant on the number of students he graduates in a certain time-frame, or cutting off the support for a student after a certain number of years. Some schools are talking vaguely about taking the number of students a professor has graduated into consideration when considering tenure or equivalent, but this does not help the cases where the advisor is already a full professor.

I have already mentioned some of the techniques used by universities and attempts to keep students continuing in graduate school. The main thrust of the techniques is to keep the student connected to the network of research and university life. Keeping the student's interest going, giving him places to interact with other people involved in the same research (conferences), all are useful. It could be said that the most successful research universities are involved in a constructive spiral: Enthusiastic atmosphere --> attracts many high caliber professors --> attracts many top-notch students who wish to do research-->many students do cutting-edge research-->Enthusiastic atmosphere.

All of this is, of course, in addition to the financial support that the university--grant structure provides. Although fellowships are relatively few, the feeling--at least in the sciences and engineering disciplines--is that no graduate student should be forced to drop out because of financial difficulty. Certain universities are worse than others in this respect--MIT is notorious for the irregularity of funding in certain fields--but in the large state schools due to their large demand for graduate students to teach undergraduates it is very unusual for a beginning graduate student not to find some form of financial support through a fellowship or Teaching Assistantship.

The number of Research Assistantships (held by upper-level graduate students) available each year is usually limited by comparison. As mentioned above, although officially used to test the abilities of the students, the Qualification Exams are really used to whittle the number of students leaving T.A. positions down to the number of available open R.A. positions. This is why some of the universities are noted for their "killer quals", and remain extremely stubborn on allowing NO exceptions to what is considered a passing mark and the "two failures and you're out" rule. The real test of a student's research abilities usually occurs with the Preliminary exam. [39]

<u>A deepening problem of Japanese universities--the shifts in the system:</u>

Recently an article came out in Research Policy [41] showing how, working from first principles, one could derive the present-day formulation of the university system if one assumed one was trying to maximize the production of "free" knowledge (i.e., useful information readily available as a common good.) The discovery of new (useful) knowledge would be rewarded by relatively large carrots: the approval and envy of peers, upgrades in salary and/or working conditions (getting tenure), with, of course, the highest award being (usually) some form of Nobel prize. At the same time, it would not do to discourage those who were going through a "dry spell" to the extent that they would leave the university system all together--hence the payment of a modest stipend for some relatively non-onerous duties such as teaching. Educating the next generation of scientists is obviously a common good although the pay-back may not be seen for some time. The standard professor-student relationship, which is based on the apprentice system of the guilds, contains both aspects. A professor would have "apprentices" that he would instruct in how to do research, while at the same time that they would carry out the simpler and more tedious tasks he did not want to bother himself with. Both teaching and research were combined, to the advantage of both.

Unfortunately for Japan, its universities are losing more and more of their role as research centers. Partly due to bureaucracy, but mainly due to financial poverty, universities have been gradually had their research aspects superceded by the large laboratories, both national and commercial. Certainly many of the highly publicized science projects in Japan seem to be located now at government laboratories or Centers of Excellence, rather than at universities [42] . This shift is illustrated schematically in Figure 2.20.

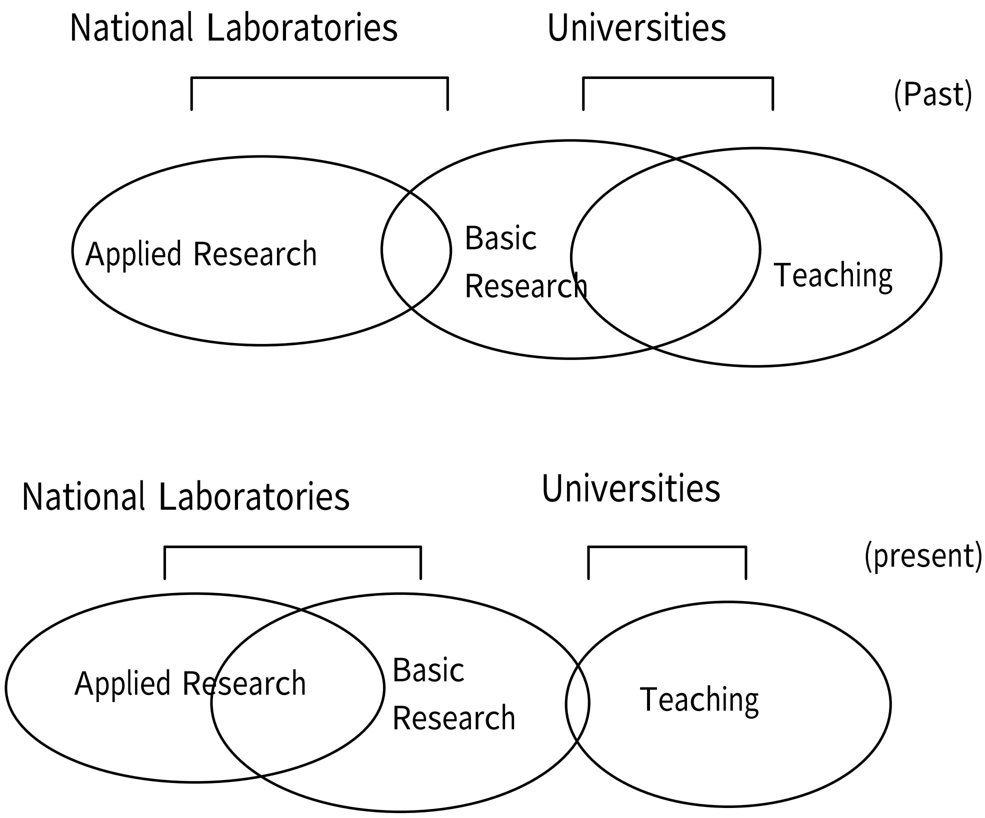

Fig. 2.20 Change in Areas covered by Japanese Universities and National Laboratories

Because of this, the attractive factors associated with a graduate program have been lessened. Unless the universities in Japan are restored to a position where the education associated with them is considered useful and necessary to learn how to do research, their isolation from the national-laboratory/ commercial enterprises structure will simply increase, with universities being considered irrelevant from all points of view.

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[10]: Interview with member of MIT-Japan program participant (M. H.)

[11]: Personal experience

[12]: NHK special, broadcast May 1st, 1994

[13]: One article which does touch on this is “The Invisible Key to Success” by

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[14]: Interview with member of MIT-Japan program participant

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[18]: Interview with US researcher in Japan

[19]: Comment received by email

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	AA TA	ChemE TA	CivE TA	Comp TA	MechE TA	AA RA	ChemE RA
UCLA	1335	1250	1337	1488	1335	1093	1250
UCBerkley		1555.56	3235	5153	4379		1555.6
U. of Illinois	1106	1208	1147	1181	1170	1106	1208
U. of Michigan	595	1200	745	1200	1156	1242	1200
U. of Miss-R	635	1195	1195	1195	732	777	1195
NorthWestern		1087	1087	1087	1087		1258
Ohio State	1000	1000	910	1125	1050	1000	1000
RPI	980	1011	922	1044	980	990	1011
Rutgers	1117	1117	1117	1117	1117	1117	1117
U. of SCal	1180	1180	1180	1180	1180	1180	1180
U.of T.at Aus	720	767	747	725	759	888	1098
Verg. Tech	1250	1176	1275	1119	1250	1250	1310
	992	1145.55	1241.4	1467.8	1349.58	1064.3	1198.55

	CivE RA	Comp RA	MechE RA	AA Fel	ChemE Fel	CivE Fel	Comp Fel	MechE Fel
UCLA	1115	1237	1093	1556	1250	2000	1444	1556
UCBerkley	4343	5102	3992		1555.6	3082	4513	4063
U. of Illinois	1147	1181	1170					
U. of Michigan	1200	1200	1200	724	1200	1300	1250	1200
U. of Miss-R	1195	1195	902	769	1195		1195	461
NorthWestern	1258	1258	1258		1052	1052	1052	1052

Ohio State	910	1125	1050		1000		1125	1050
RPI	1010	1044	990	1160	1011	1126	1333	1160
Rutgers	1117	1117	1117	1266	1388	1300	800	1266
U. of SCal	1180	1180	1180	1800	1800	1800	1800	1800
U.of T.at Aus	974	900	986	842	331	352	1224	444
Verg. Tech	1275	1144	1250	1250	1250	1275	1550	1250

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Chapter 3: Interdisciplinary aspects:

For anyone who has experienced the American graduate educational system, one of the most striking differences between it and the Japanese system is the differing breadth of specializations. On the surface one might think the two systems well-nigh the same; in both cases industry complains that while master's level students have received a more or less useful level of training, people with doctorates have overspecialized and are harder to place. Yet one of the advantages claimed for the U.S. graduate education is the breadth of knowledge the average graduate student attains, which supposedly contributes to a) the flexibility and resourcefulness of the future researcher, and b) his creativity. If this is true, where does it come from?

When comparing the structure of graduate departments / programs between the U.S. and Japan, two notable differences become apparent. First is the difference in breadth of material covered in an individual department. The second is the amount of "interlinking" between departments.

For purposes of comparison, first of all it is necessary to define what is meant by "department." Figure 3.1a shows the structure of a U.S. university, which usually contains one or more Colleges or Schools (College of Arts and Sciences, School of Engineering), each which in turn contain departments (Department of Astronomy, Department of Physics, etc.) Each department may offer further demarkation of its programs (Solid-state Engineering, Computer Architecture), but the "Department" is considered the smallest organizational building block in the U.S. university structure. On the Japanese side, Figure 3.1b shows an equivalent outline [1]. I have chosen to take as equivalent the Japanese "senkou" with the U.S. "department" since both seem to carry out the same position in the organizational structure for graduate students. An aspiring graduate student in the U.S. will apply to an individual department, not to a school. Graduate program requirements are outlined and decided upon (within university guidelines) by a department, not a College. Similarly in Japan, a graduate student will apply to a particular "senkou", will be dealing with program requirements outlined by that "senkou", and will be considered a graduate student of a particular "senkou".

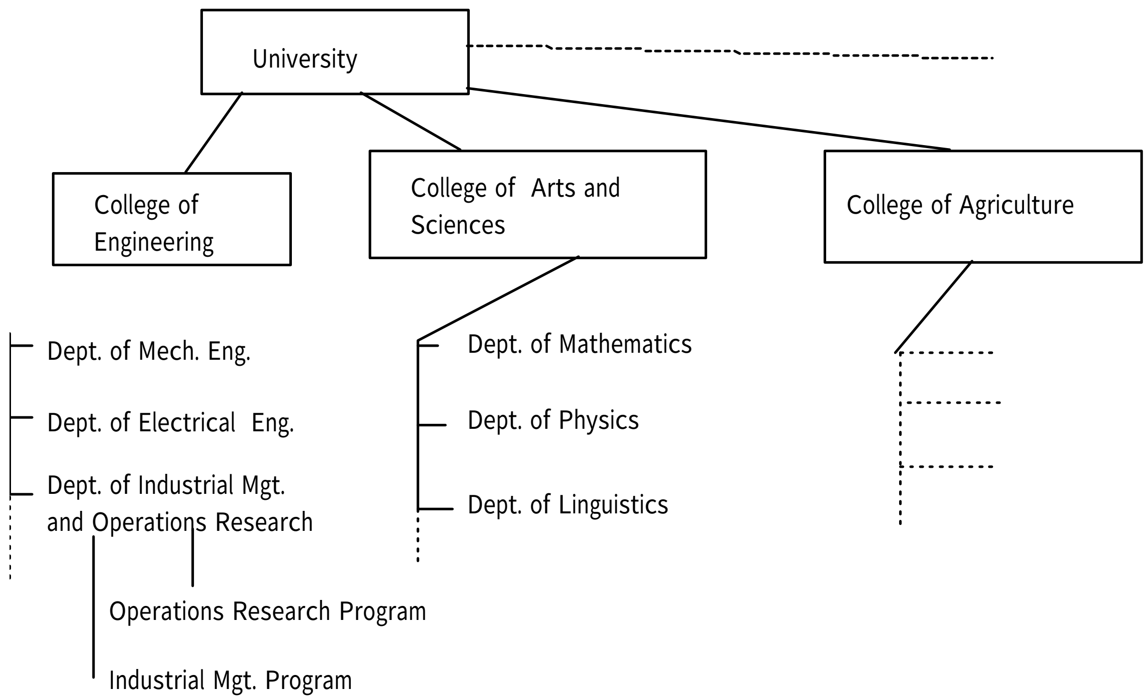

Figure 3.1a: Structure of a U.S. university

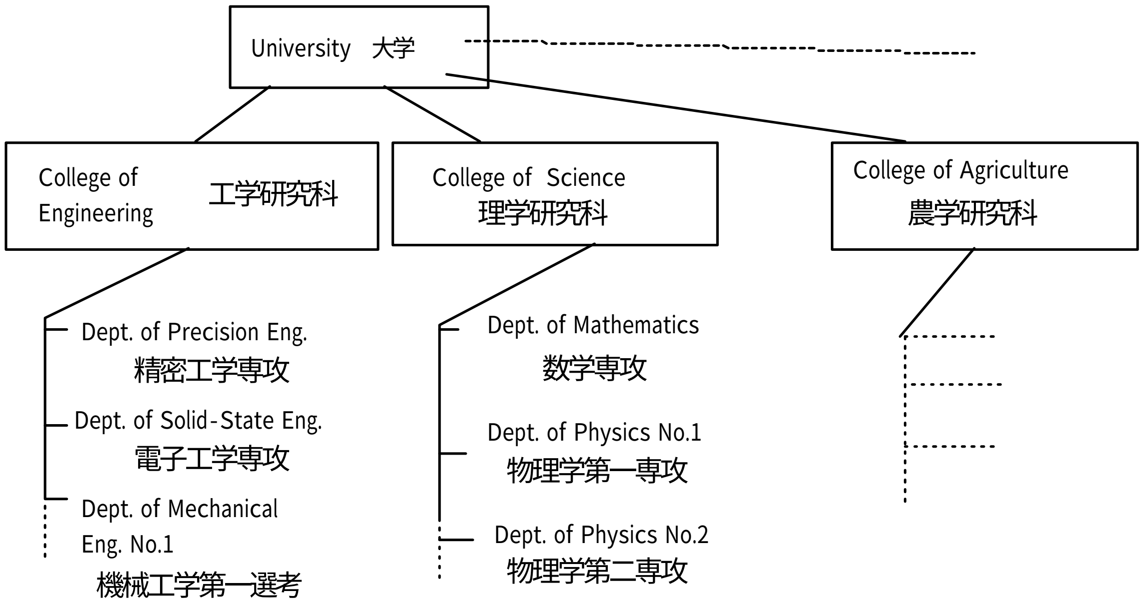

Figure 3.1b: Structure of a Japanese University

Comparing the range of courses offered in a Japanese "senkou" and the equivalent U.S. department, one immediately notices that the courses contained in one U.S. department will be parceled out into 4 or 5 "senkou"'s in Japan. For example, under what would be called "Civil Engineering" (and maybe Architecture) in the U.S. one finds in Japan such departments as "Civil Engineering", "Architectural Engineering", and "Sanitation Engineering" as separate departments in their own right, each of which is itself split up into 4 or 5 disciplines of its own. "Architectural Engineering" covers the specializations of "Construction Information Control Engineering", "Environment Formation Engineering", "Urban Management Engineering," and "Architectural Structure Production Engineering. " Figure 3.2 shows the differences in breadth between formal disciplines at M.I.T. and Tokyo Institute of Technology.

"Interdisciplinary" is another relevant word and occurs completely separately from the breadth of a department. Sometimes an overlap occurs between two disciplines, forming a new field. Some of the departments in Japan could be considered interdisciplinary departments in as much they partake of two different disciplines (Architectural Engineering, for example, could be considered to partake of both Civil Engineering and Architecture). The main difference between them and such departments in the US is that while the department itself could be considered to be the progeny of two older different disciplines, the width of the field is still quite narrow and there is no attempt to maintain overlap with the other departments. The overlapping subspecialities of the two older departments have been split off to form their own department and there is no attempt for the older departments to "hang on" to the subspecialities. In general, the Japanese structure is geared towards specialization, separation, and rigid demarcation.

By contrast, the US structure of departments is much more woolly-edged and casual in as to where their boundaries fall. Departments grow and expand. Disciplines are created within the department, more courses are added. If interest in an area overlaps with that of another department (Biology and Engineering in the area of Bioengineering, for example) a set of courses will be set up which will be considered "joint" courses, with students from both fields participating. If at some point the field grows large enough, it may be split off on its own, although this may take a long time. (As an interesting example, MIT still considers Electrical Engineering and Computer Science to be one department, albeit different disciplines ("6.1" and "6.3", in the jargon used), even though its continuing to do so has created a monster department that threatens to cannibalize the rest of the university . Several years ago over 40% of the entering students said they wanted to major in EE or CS, causing great strain in the size of introductory classes [2].)

Why are breadth and interdisciplinary aspects important? Because of the background they mandate. I leave the topic of creativity alone, but it is certainly true, in our modern world with its ever-increasing rapid change of technology, that "useful" areas of technology flicker in and out of vogue and links between fields that did not exist before may be the linch-pin of a new area of research. There are two forms of this. First, there may be the deliberate conjunction of two fields together in the hope that the cross-connections prove useful. Bioengineering is an example of this; so is the field of Computer Graphics. Second, we have the case where a phenomenon well-understood by practitioners of one field spontaneously occurs in a different speciality entirely.

High-temperature superconductors is an sterling example of this, where superconductivity (up to now only found in certain metals and alloys at extremely low temperatures) was discovered in a class of materials which, for all intents and purposes, can be considered to be ceramics. Here we have a phenomenon, up to now in the domain of the low-temperature solid-state physicist, occurring in the arena of materials science.

Having a wide background not only helps guard against obsolescence, but also allows one to make a greater number of contacts and to "pull knowledge" from a wider database. It allows one to turn one's hand to a different area much more easily than if one has a narrow speciality. Also, if it becomes necessary to learn new material, it is much more easily accomplished if one has a firm background to work with, rather than having to learn from scratch.

This is what I find remarkable about the Japanese educational system: up to college, the achievements of the system are obvious: students are grounded in a firm backing of math, sciences, language, and so forth to a far higher level than their U.S. counterparts. And yet, sometime during the college years, this starts to slip. The emphasis on breadth has been overtaken by specialization. Finally, for the few that do go on to graduate school, specialization is more and more the rule of the game, finally to the point where, as an unkind commentator has said about the products of the French system, "the expert knows more and more about less and less, until one reaches the point where he knows everything about nothing."

The lack of breadth in the Japanese graduate system can be seen, first of all by a comparison of the individual departments in the U.S. with their Japanese counterparts, and second, by the requirements of the M.S. and PhD. programs. I have covered the requirements in detail in Chapter 2 and will not repeat them here. As for the breadth of the individual departments, a schematic of how the Japanese departments fall in comparison to the U.S. ones is given in Figure 3.2.

Another interesting point lies in the lack of interdisciplinary connections between departments in Japan. The Japanese structure is extremely vertically oriented and extremely narrow. As mentioned before, each full professor acts with a separate research group under him, very rarely sharing experimental facilities or a research group with any other professor of the department. This is paralleled by the total isolation in which a department holds itself, usually keeping separate buildings, separate libraries, and separate facilities.

This isolation can be seen also in looking at the number of interdisciplinary graduate courses offered at each school. Most of the state universities have none. Tokyo University has a bare handful out of all of its courses--these are university-wide courses dealing with word processing, computer usage, and the like. Tokyo Institute of Technology has 9.4% of its courses cross-registered in 2 or more departments. Waseda, one of the private universities, is much lower with 1.4%. The university which seems to have gone the furthest in this direction is Keio University (again private) in a perhaps direct inspiration from MIT, but still only 15.7% of its courses are cross-registered, half of MIT's 30.7% It should also be noted that due to the narrow breadth of Japanese departments, courses may be listed as interdisciplinary, linking two departments which would be considered in the same department in the U.S.

While Japanese university departments act as isolated kingdoms, the motto of U.S. research universities seems to be "the more, the merrier." The universities devoted more to turning out engineers than to research (the "second tier", as it were), have departments with fewer interdepartmental links--the University of Pittsburgh, for example, among its departments of Chemical and Petroleum Engineering, Civil Engineering, Electrical Engineering, Industrial Engineering, Materials Science and Engineering, and Mechanical Engineering, only 8 graduate courses are cross-listed. At the same time, however, there also exist certain "interdisciplinary" programs (Bioengineering, Energy Resources) as well as the possibility of individually-designed programs. Another option which seems to be much encouraged in certain areas (Public Works Engineering and Administration, Electrical Engineering and Mathematics, is for a student to double-major, receiving two master's degrees after a slightly lengthened program. Finally, there exist programs (normally only at the MS level) which combine a standard master's program with an internship of a semester or a summer at a company. It also should be remembered that the breadth of the courses found in a department make the system extremely interdisciplinary to Japanese eyes.

Finally, one has the research universities. I have picked Stanford University and M.I.T. as being representative of this type. For both universities I went through the course catalogs and picked out all the courses in engineering and the sciences which were cross-listed in two or more departments. In the case of Stanford, I was limited to the courses cross-listed with the departments of engineering and science. For M.I.T., due to the level of cross-linkage, all departments except for Humanities (course 22) were inspected. For each school, the number of courses cross-linked between 2 or more departments and 3 or more departments are given in Figures 3.3, 3.4, 3.5,.and 3.6 at the end of this chapter. Figures 3.7 and 3.8 show the number of cross-linked courses at the Tokyo Institute of Technology.

Some of the cross-linkages are due to historical accidents; Stanford possessing a Physics Department and an Applied Physics (extremely cross-linked), for example. In other cases, the departments themselves seem to have dug themselves into a hole of overspecialization (Health Science Information, for example) and, rather than solving their problems by expanding the range of courses offered, have chosen to do so through hooking on to needed courses in another department. It is also quite possible in many cases that the department in question does not have the financial resources (or the number of students) to justify offering a particular course.

One would expect that where the overlaps in areas of interest between two or more departments is large, a greater percentage of the courses are interdisciplinary. Looking at the tables, one can see that this is so. Civil Engineering, Urban Design, and Architecture have a great deal in common, and correspondingly there exist a large number of courses cross-registered between them. Economics and Business also fall together as natural partners; so do Computer Science and Mathematics. (In fact, the upgrading of the Computer Science department undergraduate requirements at MIT has always lagged slightly what is going on in the industry--many of the more futuristic computer hackers couldn't stand the concept of their having to learn all about designing hardware circuits as well, and bailed out into Applied Mathematics, where they could concentrate on algorithms to their hearts' content. Considering the explosive growth of high-level math in certain areas of computer graphics, this has often turned out for the best.)

MIT is the interdisciplinary research school taken to an extreme--if one counts each time a course is listed in the catalog as one entry, then fully one-third of the graduate courses are interdisciplinary. In fact, there exist a handful of courses which M.I.T. considers to be completely interdisciplinary among almost all of the departments and which are officially listed as School of Engineering-Wide-Courses.(SWE).

MIT also does not confine itself to links between its different departments. Certain courses and certain graduate programs are offered jointly with other educational and research institutions such as the Harvard School of Design, the Harvard Medical School, and Woods Hole.

Another link, found both at Stanford and MIT, is the practice of mixing graduates and undergraduates together for certain courses. Usually in such a case the common area is the lectures, with the recitation sessions and tests being separate. The graduate students register for a "graduate level version of course XX" and are challenged with harder problems and more complex projects. In some cases a certain course will simply be considered an undergraduate level course for students of certain departments, and a graduate level course for others, although the work demanded is the same. This again should be considered "interdisciplinary", although I do not plan to go into it in detail.

Why the emphasis on interdisciplinary courses, and why do they seem more prevalent in the research universities than in the more standard universities?

The two points to focus in on are the backgrounds and the different emphasis on theory. Based on my own experience, I would say that research universities tend to be more hard-nosed about demanding a certain background level of knowledge. The attitude is "that's undergraduate level stuff. If you didn't learn it then, that's your problem. Go find a textbook and brush up on it." If the class seems to be totally bewildered, the professor may ask the recitation instructors to use their instruction period of give what amount to additional lectures, but on the whole the emphasis is on teaching to the level of the top student in the class, not the worst. On the whole, comparing research universities to non-research universities, one is left with the feeling that most graduate classes of the latter would be considered to be at most upper-undergraduate level at the former universities (In certain cases, even this is not true. There are several upper-undergraduate courses at MIT which were considered to be more advanced than their graduate-level counterparts--the upper-undergraduate Electricity and Magnetism course in the physics department, for example. Usually this occurred in departments where the number of undergraduates who remained on to do graduate work was low.)

The second point to consider is the emphasis on theory in the courses. If one looks over the courses that are considered interdisciplinary, one notices they fall into two classes--one, where the overlap is between one scientific or engineering discipline and one or more soft science aspects. Courses crossed with policy, management, economics, or history fall into this class.

The second class is where there exist an overlap between two or more hard sciences and/or engineering disciplines (Ocean Engineering, Mechanical Engineering, Aeronautics and Astronautics, and Nuclear Engineering all overlap in the area of Dynamics of Hard Shell Structures). Although the applications may be completely different, the underlying theory is the same. This is the core of why theory rather than practice usually provides the common link.

The non-research universities focus more on teaching the present realization of the theories in the field. In more blunt terms, this often comes down to plug and chug: memorize a handful of equations, memorize a list of physical parameters, and make sure you apply the right equation to the right situation. This is not to say that I think every university should be a research university--somebody has to design the present-day pipeline. Solitons may be a sublime possibility for sending compact, error-free signals but the gap between theory and practical usage when trying to send them over miles of copper wire is enormous.

It is easy to see why an emphasis on learning the specifics of present day systems cuts down on links between disciplines. There is nothing in common.

Perhaps the theory is the same for the two disciplines, but how the technology is applied is usually totally different. As an example, let us take two researchers occupied with keeping a flow going at the highest possible speed without stagnating. One is involved with coding a program to handle finance requests coming into a bank and the other is figuring out where to put traffic lights in a city and how to time them. The first researcher may not care about the theory; some theorist has already handed him the algorithm and he's trying to debug his computer program while the other researcher is more worried about the fact that the town doesn't have enough money to pay for more than 5 traffic lights even though the optimum result demands 14. These are the realities and problems most engineers are called upon to solve, not that of advancing theory in the field. There is an emphasis on learning what technology is in the present, rather than learning the tools with which to create the next generation technology. Expertise here lies in having experience with all the different machines/models/tests used in a particular area. For instance, a good CAD/CAM engineer is expected to know all the software packages on the market he may be called upon to work with, as well as all of the manufacturing processes he may encounter.

Research universities do not seem to worry about this as much. The attitude is that the student is expected to go into research, where if a knowledge of a particular system (software/ hardware) is necessary, the researcher will pick it up at that time. The machinery involved in the field will always advance, so why bother learning about it before you need to? I still remember the glee with which my computer science professor announced that we should expect all the specifics that we had learned about computer languages to be obsolete by the time we graduated. He then added, casually, that the specifics weren't the important part . More important were the underlying structures of the languages and which we would encounter again and again with every new language.

Finally, there is the question--are interdisciplinary aspects important to the level of future research, and if so, why? Why do I feel that one of the strengths of the US graduate education is this emphasis on interdisciplinary courses and that Japan, if it wants to reform its graduate education, should broaden the extent of engineering departments and discourage the specialization presently existent? First of all, possessing more than one speciality protects one against finding one's forte has become obsolete. It also encourages creativity because of providing experience with a wider range of problems and problem-solving techniques. This has become particularly useful recently in certain widely separated disciplines: finances and chaos theory, or graphics simulation and manifold theory, for instance. Another two areas which have been linked are topology theory and condensed-matter physics.

Another advantage of an interdisciplinary background, which mimics in part the advantages of working with a group of researchers, is of often being able to pull up multiple solutions for a problem. Rarely does there exist only one solution to a problem--usually the question is of choosing "the best" out from among a set. The broader the set to work with, the higher the chance that all factors have been taken into account and that the ideal solution lies within that set.

There is a question as to whether a much more broad and interdisciplinary graduate education could improve matters in Japan, since the tendency to work in teams within a company may already be providing many of the advantages outlined above. On the other hand, one of the complaints by Japanese industry about higher-degree recipients is their over-specialization and inability to jump tracks. Broadening the student's background can only help this, while a more interdisciplinary education would at least allow future researchers to explore various directions which may prove extremely useful in the future.

REFERENCES

[1]: Course catalogs from various Japanese and U.S. universities were used in determinining these structures.

[2] : M.I.T. course catalogs, various articles in The Tech (M.I.T.'s newspaper) starting from around 1980.

[3]: Nishigata, C. and Hirano, Y. Increasing the Number of Course PhDs in Science and Technology (in Japanese) NISTEP report #24, 1992

Tokyo Institute of Technology	M.I.T.
High Polymer Engineering Chemical Engineering Industrial Chemistry Synthetic Chemistry Reaction Chemistry	Chemical Engineering
Electrical and Electronic Engineering Electrophysical Engineering Information Engineering Physical Engineering Counting Engineering Control Engineering	Electrical Engineering and Computer Science
Metal Engineering Metallic Materials Inorganic Materials Organic Materials	Materials Science and Engineering
Mechanical Engineering Production Mechanical Engineering Precision Mechanical Engineering Marine Mechanical Engineering Industrial Mechanical Engineering Mechanical Physics Engineering	Mechanical Engineering
Resource Development Engineering Civil Engineering Architecture	Civil Engineering

Figure 3.2: Comparison of Departments at MIT and Tokyo Institute of Technology

Figure 3.3

MIT: Number of Interdisciplinary courses

Urban Studies has one course cross-ref'd with Harvard.

Earth & Planetary Sci. has 21 courses cross-ref'd with Woods Hole

	CIV ENG	MECH E	MAT SCI	ARCH	CHEM	ELEC ENG	COMP SCI	BIO	PHYS	COG SCI	CHEM E	URBAN	EARTH	OCEAN E	ECON	MGT	A&A	POLY SCI	MATH	NUCL ENG	HST
CIV E	98																				
MECH E	3	83																			
MAT SCI	5	8	65																		
ARCH				101																	
CHEM		2			38																
ELEC E.	2	6	3			83															
CS							27														
BIO					2			31													
PHYS						5			52												
COG SCI							2	2		33											
CHEM E		7	4		2	4		2	1		55										
URBAN	6			17		1						61									
EARTH	3					3			1				96								
OCEAN E	7	10	5			5					4	2	2	71							
ECON	2											1			47						
MGT				5		5		1			4	4		3	9	202					
A&A	4	9	2			6					4	1		5	1	1	69				
POLY SCI	2											2			1	2					
MATH						1	11									1			93		
HUM												1									
NUC E	3	7	6			5			2		3			3			1			58	
LING						1				3											
HST		9				9		1			2				1	1	3			4	70
MAS	1						1			1											
SP				1								2									
STS												1									
TOX																					
TPP	5	2	3		1	1					2	1				3	2			4	

	HST	MAS	SP	STS	TOX	TPP
HST	70					
MAS		40				
SP			13			
STS		1		43		
TOX					34	
TPP					1	23

	CIV ENG	MECH E	MAT SCI	ARCH	CHEM	ELEC ENG	COMP SCI	BIO	PHYS	COG SCI	CHEM E	URBAN	EARTH	OCEAN E	ECON	MGT	A&A	POLY SCI	MATH	NUCL ENG
CIV E	98																			
MECH E	3	83																		
MAT SCI	3	4	65																	
ARCH				101																
CHEM		2			38															
ELEC E.	2	4	3			83														
CS							27													
BIO								31												
PHYS						3			52											
COG SCI										33										
CHEM E	2	4	2		2	4		1	1		55									
URBAN	4					1						61								
EARTH						3			1				96							
OCEAN E	5	4	4			5					4	1	1	71						
ECON	1											1			47					
MGT			5			3		1			4	1		1	1	202				
A&A	4	8	2			6					4	1		5	1	1	69			
POLY SCI	1											2			1	1				
MATH																			93	
HUM												1								
NUC E	3	5	3		1	3			2		1			3			1			58
LING						1														
HST			9	2		7					1					1	3			1
MAS																				
SP																				
STS												1								
TOX																				
TPP	3	3	2		1	1					3			1		2	2			3

	HST	MAS	SP	STS	TOX	TPP
LING	1					
HST	70					
MAS		40				
SP			13			
STS				43		
TOX					34	
TPP						23

Figure 3.4

Number of Courses Cross-Registered in 3 or more Depts. at MIT

	AA	CHE	CIV E	CS	EE	EES	IEES	MSE	ME	OR	SCI CS	APP	ECON	MATH	PHYS	STAT
AA					2				18					1		
CHEM E		14						2								
CIV E			79													
CS				106	17	1			3	1	7			2		1
EE	2			17	143			7				9				2
EES				1		35			2							
IEES							25		3				1			
MSE		2			7			45	1							
ME	18			3		2	3	1	122					4		
OR				1						25			3	84		5
SCI CS				7							11			3		
APP					9							53			21	
ECON							1			3			143			
MATH	1			1					4	84	3			109		3
PHYS												21			71	
STAT				1	2					5				3		49
ENG	12				7		1		12					3		
OTHER	0	0	1	14	7	0	2	0	3	2	0	0	28	7	2	2

Figure 3.4: Number of cross-registered courses in two or more depts. at Stanford University

	AA	CHE	CIV E	CS	EE	EES	IEES	MSE	ME	OR	SCI CS	APP	ECON	MATH	PHYS	STAT
AA					1				18					1		
CHEM E		14														
CIV E			79													
CS				106												
EE	1				143											
EES						35										
IEES							25		2							
MSE								45								
ME	18						2		122					3		
OR										25			1			
SCI CS											11					
APP												53				
ECON										1			143			
MATH	1								3					109		
PHYS															71	
STAT																49
ENG	12						1		4							
OTHER	0	0	1	2	0	4	0	0	1	0	0	0	12	3	2	2

Figure 3.6 Number of courses cross-registered at Stanford in 3 or more departments

	Math	Physics	Chemistry	App. Phys	Info. Sci.	Metal. Eng.	Org. Mat. Eng.	Inorg. Mat. Eng.	Chem Eng.	Polymer Eng.	Mech. Eng.	Ind. Mech. Eng.	Control Eng.	Management Eng.	EE/CS/Info.Eng
Math															
Physics															
Chemistry				1											
App. Phys.		1													
Info. Sci.															
Metal. Eng.														1	
Org. Mat. Eng.														1	
Inorg. Mat. Eng.														1	
Chem. Eng.															
Polymer Meng.															
Mech. Eng.															
Ind. Mech. Eng.										1					
Mech. Phys. Eng.										2					
Control Eng.															
Mgt. Eng.										1	1	1	1		
EE/SS/Info Eng.													2		
Civ. Eng.															
Civ. Eng.															
Construction															
Social Eng.														1	
Nucl. Eng.				1								1			
Bioscience															
Biotech															
Phys. Info. Eng.															5
Electrochem.															
Prec. Mech. Sys.									2	5	1	1			
Soc. Devt. Eng.															
Mat. Sci.		1				3									
Elec. Sys.															6
Chem. Env. Eng.															
Knowledge Sci.													1		
Energy Sci.				1						3		2			2
System Sci.					2								5	3	
Env. Phys. Eng.															

Figure 3.7a: Number of Interdisp. Courses in Two or more Depts. at Tokyo Inst. of Tech.

	Civ. Eng.Math	Construction	Social Eng.	Nucl. Eng.	Biosciences	Biotech.	Phys. Info. Eng.	Electrochem	Precis Mech. Sys	Social Devt. Eng	Mat. Sci.	Elec. Sys	Chem. Env. Eng.	Knowledge Sci.	Energy Sci.	System Sci.	Env. Phys. Eng
Math																	
Physics											3						
Chemistry																	
App. Phys.				2											4		
Info. Sci.																	
Metal. Eng.											2						
Org. Mat. Eng.																	
Inorg. Mat. Eng.						1						1					
Chem. Eng.						1						1					
Polymer Meng.						1						1					
Mech. Eng.																	
Ind. Mech. Eng.									1								
Mech. Phys. Eng.															1		
Control Eng.																	
Mgt. Eng.																	
EE/SS/Info Eng.				2			5					5		3	4	1	
Civ. Eng.																	
Construction											1						
Social Eng.	2										1					1	
Nucl. Eng.										1					5		
Bioscience																	
Biotech																	
Phys. Info. Eng.				1				1	1			3		1			
Electrochem.							1						3				
Prec. Mech. Sys.							1					1			1		
Soc. Devt. Eng.	4	6	1														
Mat. Sci.																	
Elec. Sys.									1					1			
Chem. Env. Eng.															1		
Knowledge Sci.								3				3				2	
Energy Sci.					2												
System Sci.														5			
Env. Phys. Eng.																	

Figure 3.7b (Cont) Number of Interdisp. Courses in Two or More Depts. at Tokyo Inst. of Tech.

	Math	Physics	Chemistry	App. Phys	Info. Sci.	Metal. Eng.	Org. Mat. Eng.	Inorg. Mat. Eng.	Chem Eng.	Polymer Eng.	Mech. Eng.	Ind. Mech. Eng.	Control Eng.	Management Eng.	EE/CS/Info.Eng
Math															
Physics															
Chemistry				1											
App. Phys.		1													
Info. Sci.															
Metal. Eng.														1	
Org. Mat. Eng.														1	
Inorg. Mat. Eng.														1	
Chem. Eng.															
Polymer Meng.															
Mech. Eng.															
Ind. Mech. Eng.															
Mech. Phys. Eng.															
Control Eng.															
Mgt. Eng.								1	1	1					
EE/SS/Info Eng.															
Civ. Eng.															
Civ. Eng.															
Construction															
Social Eng.														1	
Nucl. Eng.												1			
Bioscience															
Biotech															
Phys. Info. Eng.															1
Electrochem.															
Prec. Mech. Sys.										1		1	1		
Soc. Devt. Eng.															
Mat. Sci.		1				3									
Elec. Sys.															
Chem. Env. Eng.															
Knowledge Sci.													1		
Energy Sci.				1						2		2			2
System Sci.													3	1	
Env. Phys. Eng.															

Figure 3.8a: Interdisc. courses in 3 or more depts in Tokyo Inst. of Tech.

Math																	
Physics																	
Chemis try																	
App. Phys.				2											2		
Inf o. Sci.																	
Metal. Eng.																	
Or g. Mat. Eng.																	
Inorg. Mat. Eng.						1						1					
Chem. Eng.						1						1					
Polym er Meng.						1						1					
Mech. Eng.																	
Ind. Mech. Eng.																	
Mech. Phys. Eng.																	
Cont rol Eng.																	
Mgt. Eng.																	
EE/ SS / Inf oEng.				1			1					1			1		
Civ. Eng.																	
Cons tr uction																	
Social Eng.																	
Nucl. Eng.															1		
Biosci ence																	
Biotech																	
Phys. Info. Eng.				1					1			2					
Electrochem.																	
Pr ec. Mech. Sys.							1					1					
Soc. Devt. Eng.	1	1	1														
Mat. Sci.																	
Elec. Sys.																	
Chem. Env. Eng.																	
Know ledge Sci.								1				1				1	
Ener gy Sci.					2												
Sys tem Sci.														2			
Env. Phys. Eng.																	

Figu re 3.8 b: (Cont) Inter disc. Cour ses i n Thr ee or M ore Dept s. at Toky o Ins t. of Tech.

Chapter 4: Rewards and Rejections:

And now, at long last, the graduate, master or doctorate in hand, is unleashed out on the world to find a position, a salary, and a place in society. How exactly does he fare?

Some research has been done comparing the careers and different prospectives of graduates of M.I.T. and the Tokyo Institute of Technology [1]. (It is interesting to note that the comparison did not use Tokyo University as its Japanese example.) Other data available compare salary levels among bachelor's, master's, and doctorate recipients of the top level universities in Japan. There also exists a large survey on the Japanese side which surveyed the experiences of present graduate students, graduate students now working for companies, and the people who hire them. We also have on the U.S. side all the data compiled on salary levels by NSF and other such organizations. Some data which would be useful to have for the Japanese side, such as the number of offers per student, do not seem to have been compiled at the M.S. and Ph.D. levels.

On the Japanese side, there seems little advantage either financially or from the viewpoint of increased responsibilities for a student to go on for a higher degree. Students who receive some form of graduate stipend from a particular company are obligated to repay the loans unless they enter employment at that particular company.* This, coupled with the Japanese lifetime employment system, means a student should be considered far more as someone who will enter a life-long committment with a partner rather than someone selling his services/knowledge on the market to the highest bidder. Although much fuss has been made in the Western press about so-called trends which indicate the breaking-up of the lifetime employment system, it should be noted that fully 80.8% of Tokyo Institute of Technology graduates (class 1970) have never changed their employer. (This should be compared to the 17.3% of M.I.T.'s class of the same year.) [1]

Of 35 Japanese companies questioned, fully 86% claimed that they did

* Only 22% of Ph.D students and 44% of M.S. students expressed willingness to receive such loans. [2]

not treat entrants at the Ph.D.level differently from those coming in at the M.S. level.[2] As to any comparison between those coming in at the M.S. level and those at the bachelor's level, it differs greatly according to location. I noticed, of my "class" of bureaucrats entering the Japanese government, that by comparison to the other ministries which were hiring mainly at the bachelor's level, the new entrants coming into the Science and Technology Agency were roughly 2/5 bachelor level, 3/5 at M.S. or Ph.D. level. Those of us with higher degrees were almost completely entering research positions at government laboratories.

The "standard" market for doctorates in Japan up to now has been the universities, with the overproduction spilling over into industry. The U.S. has a system which is a pale flavor of this--although in the sciences there has always existed a academic subculture which has despised "those out in industry", this has had more to do with the perceived morality of "pure research" complete with lofty ideals and images of Einstein with his violin as opposed to "applied research" with the distaste the English gentleman has always had for those "in trade".

By contrast to Japan, one of the main reasons in the U.S. for continuing one's education onto the doctorate level is because of the employment opportunities it opens up. While it is questionable--except for those in industry--for a doctorate to allow one a higher salary than that paid to other people of the same age--the assortment of positions available is completely different depending on the terminal degree. It has now become standard, when filling any research position with any level of independence and autonomy, to demand that the applicant hold a doctorate. This seems particularly true for government postions. This is not limited to straight "research" positions, either. There seems to be a growing trend in today's high technology world for companies to try to recruit their executive track employees and lower-level executives from people with backgrounds in engineering or science.

Another point is that with the incessant movement of people between companies as is standard in the U.S., someone who has a doctorate has a readily-understood credential which to carry to his next position. Although experience counts as well, having gotten a doctorate carries the message that one expects to work at an entirely different level, particularly the doctorate is from one of the top-class universities.

Europe is even more impressed by doctorates when it comes to employment. A friend of mine, who has worked as a consultant in scientific visualization for many years, says that he has given up even trying to find projects in Europe. Although a noted person in his field, his lack of doctorate continually hinders him.

Finally, there are the salaries. Japanese companies offer salaries which allow little or no benefit for having obtained a higher degree. Figures 4.1 and 4.2 show the Japanese salary levels for people of different educational levels, versus the year which they received their bachelor's degree.[3] (This allows comparison between people of the same age.). Since executive-level employees are employed at much higher salary levels than non-executive-level employees of the same age (see Figure 4.3), calculations were made to remove their contribution when comparing salary levels. The number of executives (at private companies) was known for each year, and a rough demarcation of them into bachelor's and master's recipients could be made based on the known distribution of bachelor's, master's, and doctorates in employees of private companies. It was assumed (based on information from conversations) that all doctorate recipients employed at private companies were in research-track positions.

The figures show that salaries for master's and bachelor's recipients are roughly equivalent, adjusting for age. Continuing on for a doctorate is definitely disadvantageous from the salary viewpoint.

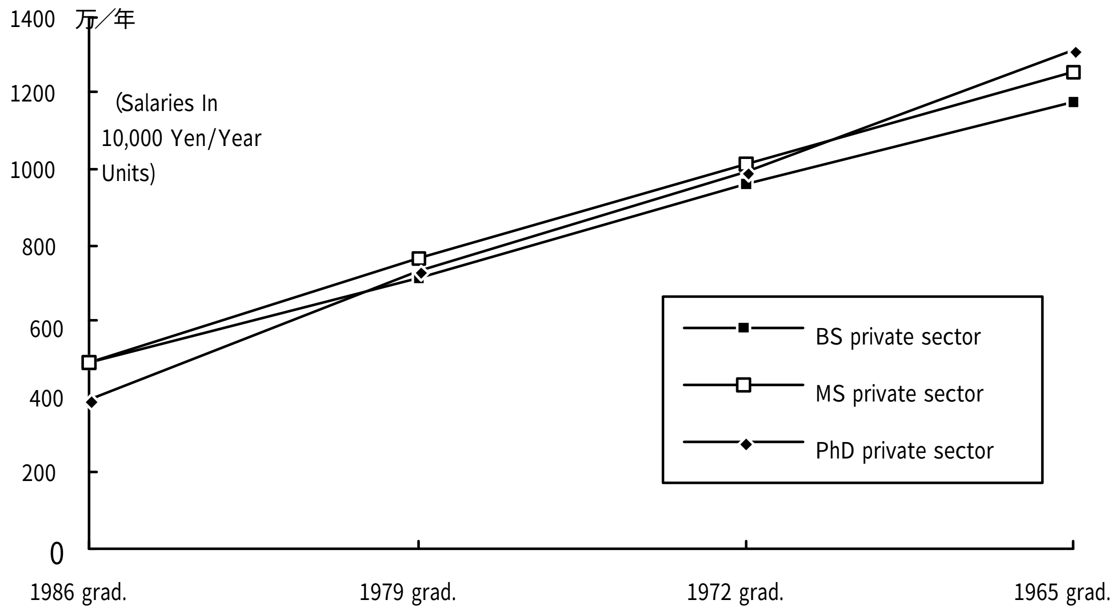

Figure 4:1: Comparison of Yearly Salaries in Private Sector (Japan), after correction

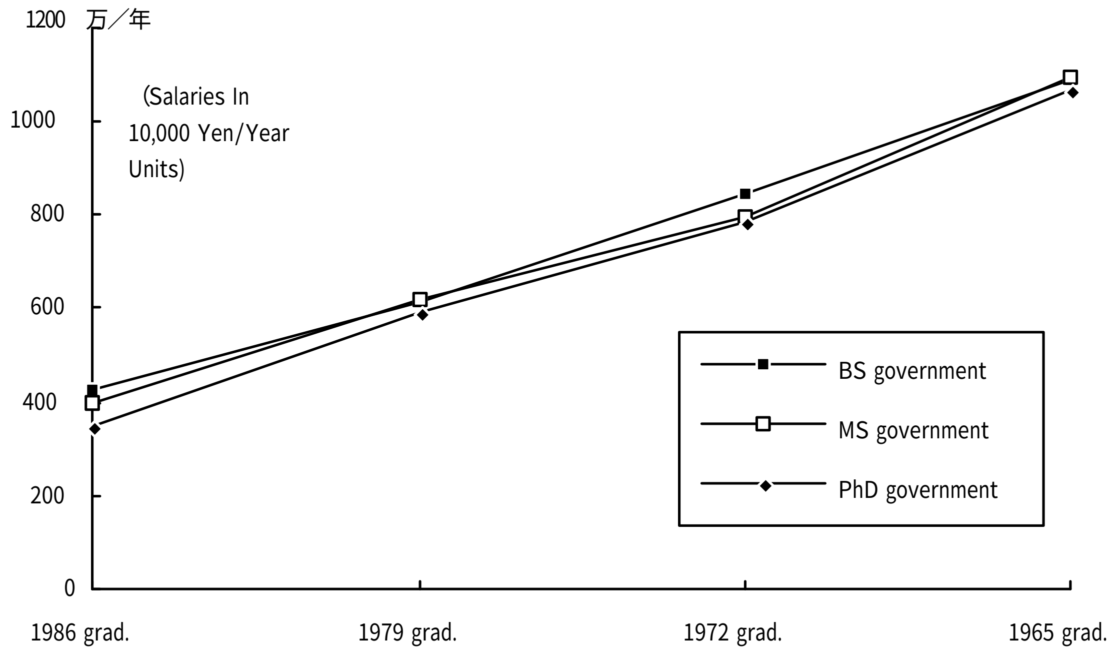

Figure 4.2: Comparison of Yearly Salaries (Japan) in Public Sector Positions

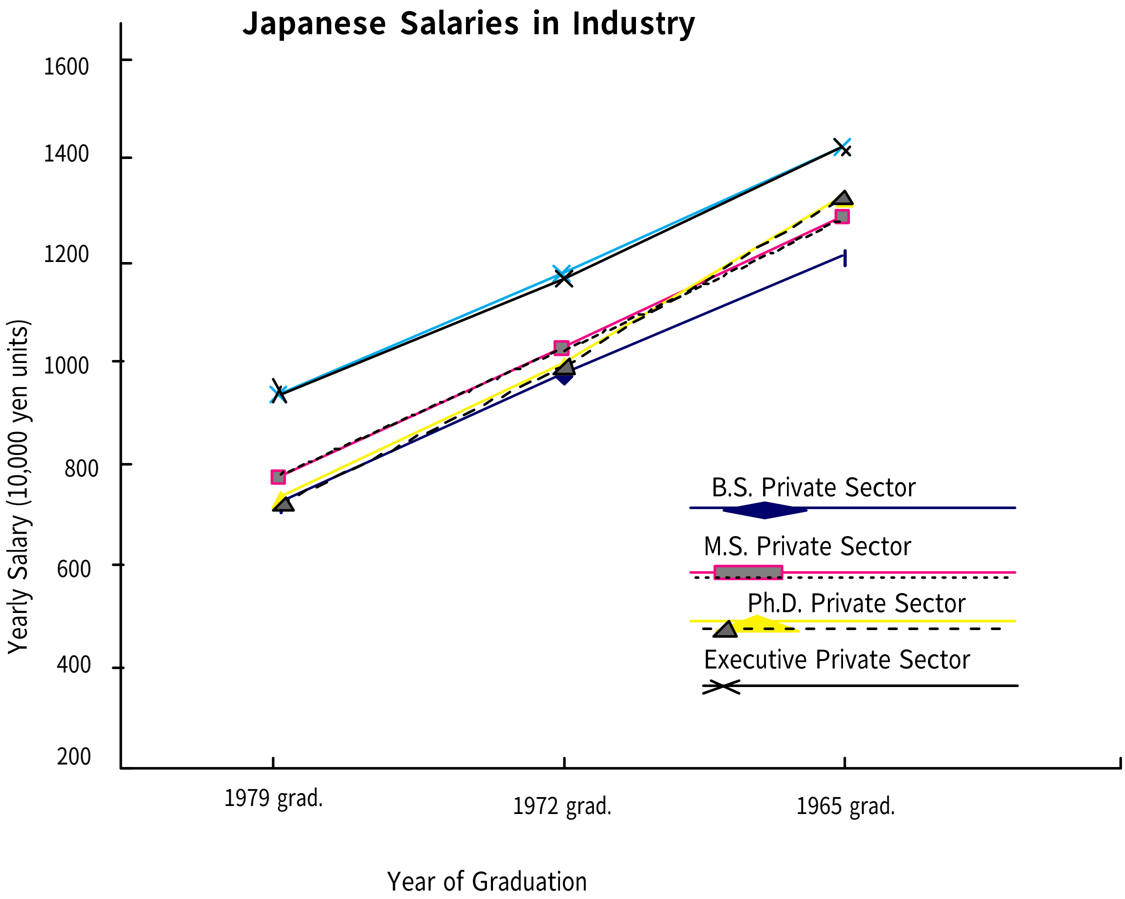

Figure 4.3: Comparison of Average Salaries in Japanese Industry (uncorrected)

By comparison, when looking at figures from the U.S. [4] we see either no difference or a definite advantage for higher degrees. (Figures 4.4, 4.5.,4.6, 4.7) A M.S. proves financially better than a B.S., while a Ph.D is usually about the level of a M.S. or slightly better. Interestingly enough, the real advantage with a doctorate lies not in government employment as several of us have thought, but in industry (Figure 4.4). Here someone entering with a doctorate starts with a salary up to one-third higher than someone of the same age who had entered with a master's. (It should be pointed out that all these data are of people in non-executive positions.)

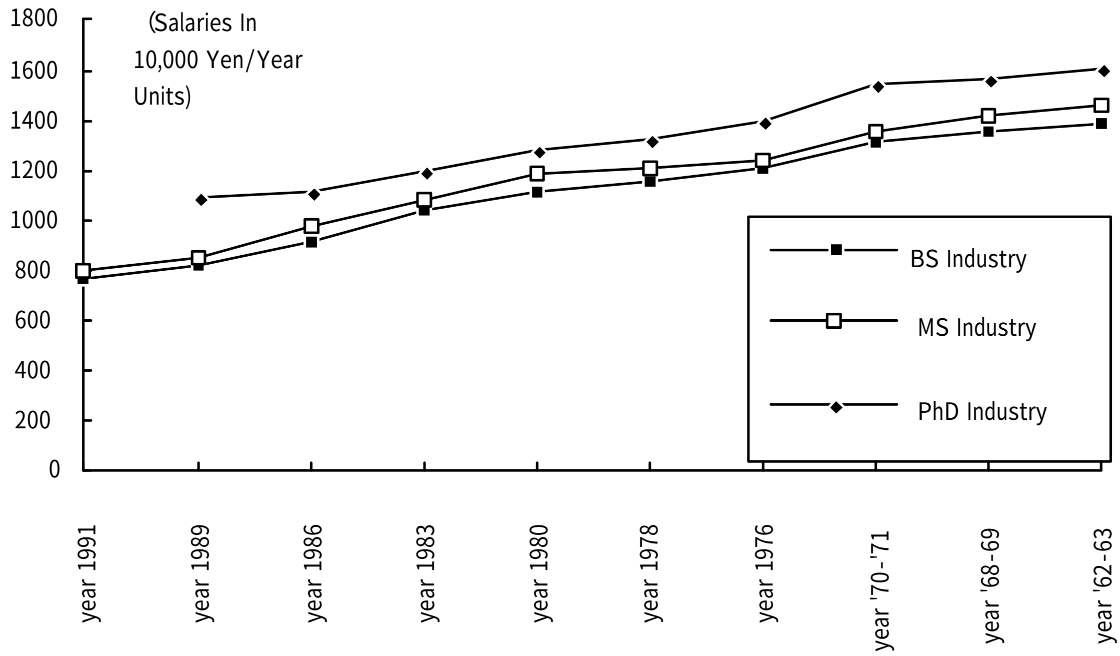

Figure 4.4: Yearly Salaries of B.S., M.S., and Ph.Ds in Industry (U.S.) by Year of B.S. Graduation

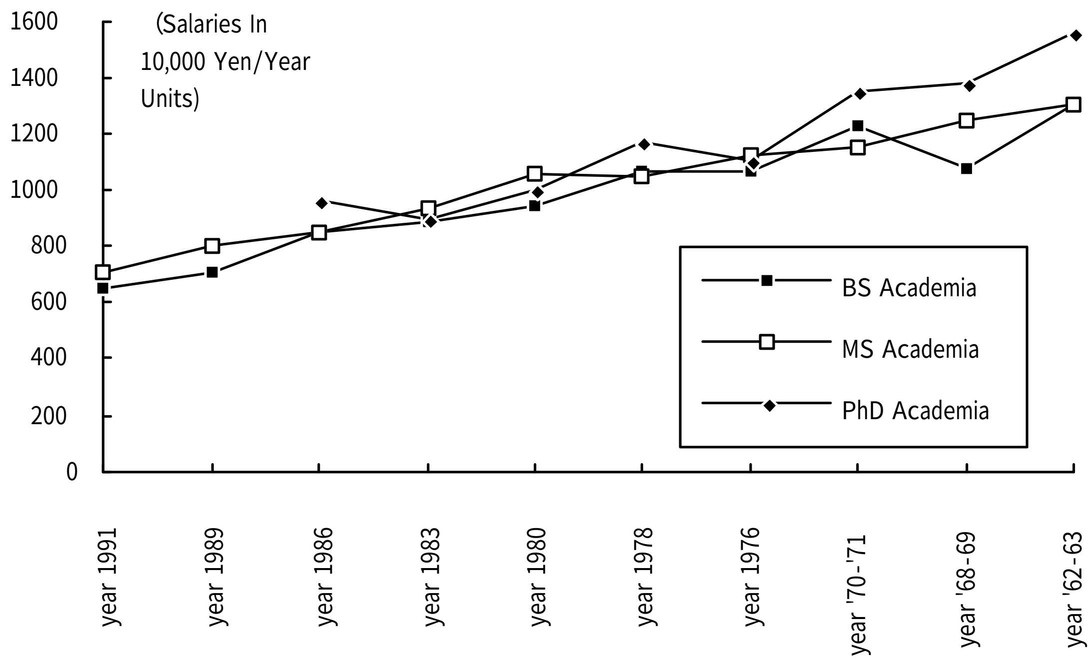

Figure 4.5: Yearly Salaries of B.S., M.S., and Ph.Ds in Academia (U.S.) by Year of B.S. Graduation

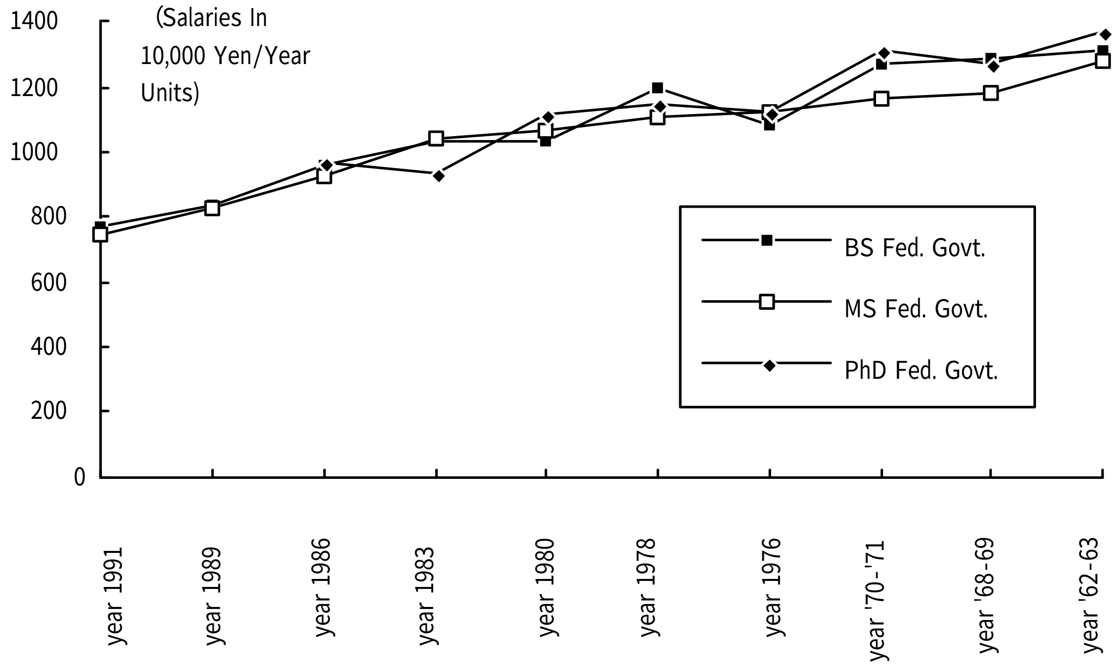

Figure 4.6: Yearly Salaries of B.S., M.S., and Ph.D.s in Government by Year of B.S. Graduation (U.S.)

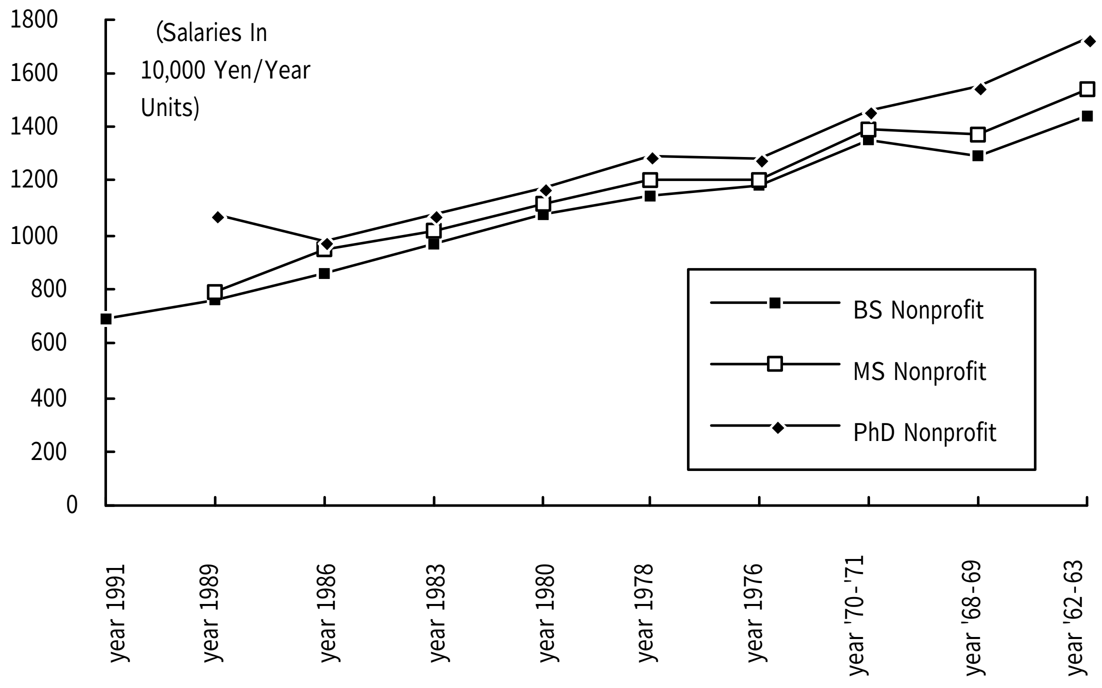

Figure 4.7: Yearly Salaries at Non-profit Organizations of B.S., M.S., and Ph.D.

recipients by Year of B.S. Graduation (U.S.)

Finally, one can carry out a comparison of Japanese and U.S. salaries. U.S. salaries were translated into their equivalents in yen, assuming a purchasing power parity of 195 yen/ dollar. Japanese salaries are much lower than U.S. ones, in some cases roughly half. Since what these graphs show is only a single snapshot in time, it is dangerous to conclude precisely what future salaries will be for different populations. However, there does seem to be a leveling off effect at the higher levels/graduation ages for the U.S. salaries. There is also a slightly larger slope for the Japanese salaries, leading to the two sets of salaries nearing equivalence for those graduating earlier than 1960.

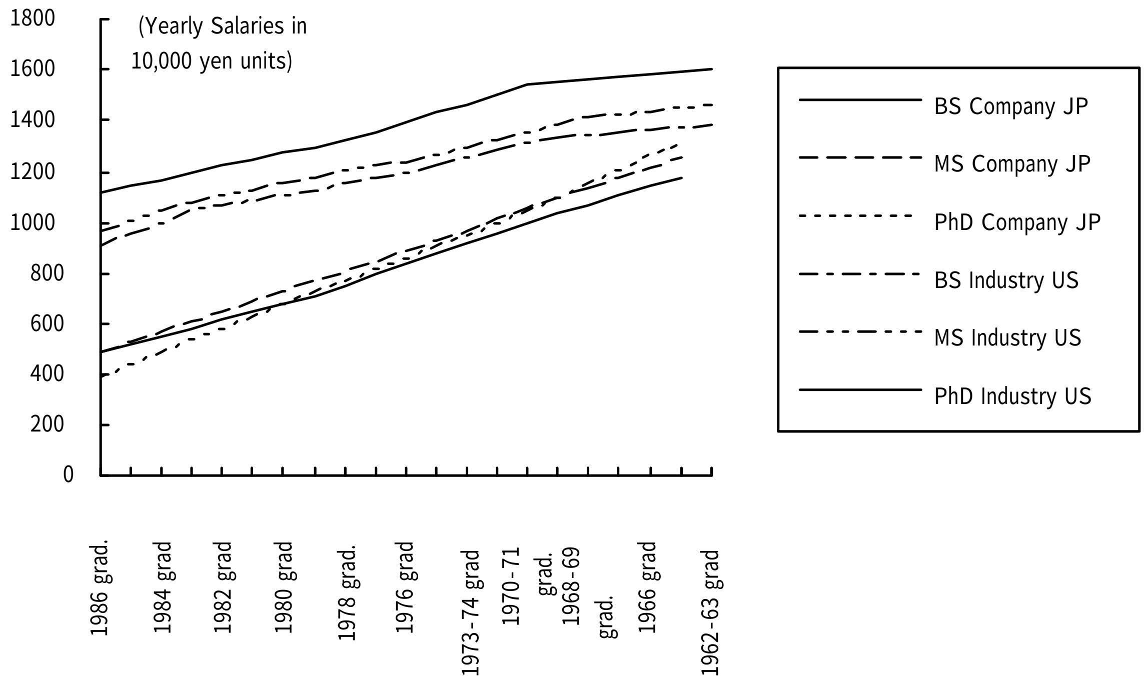

Figure 4.8: Comparison of Private Sector Salaries of B.S., M.S., and Ph.D. recipients in the US and Japan by Year of B.S. Graduation

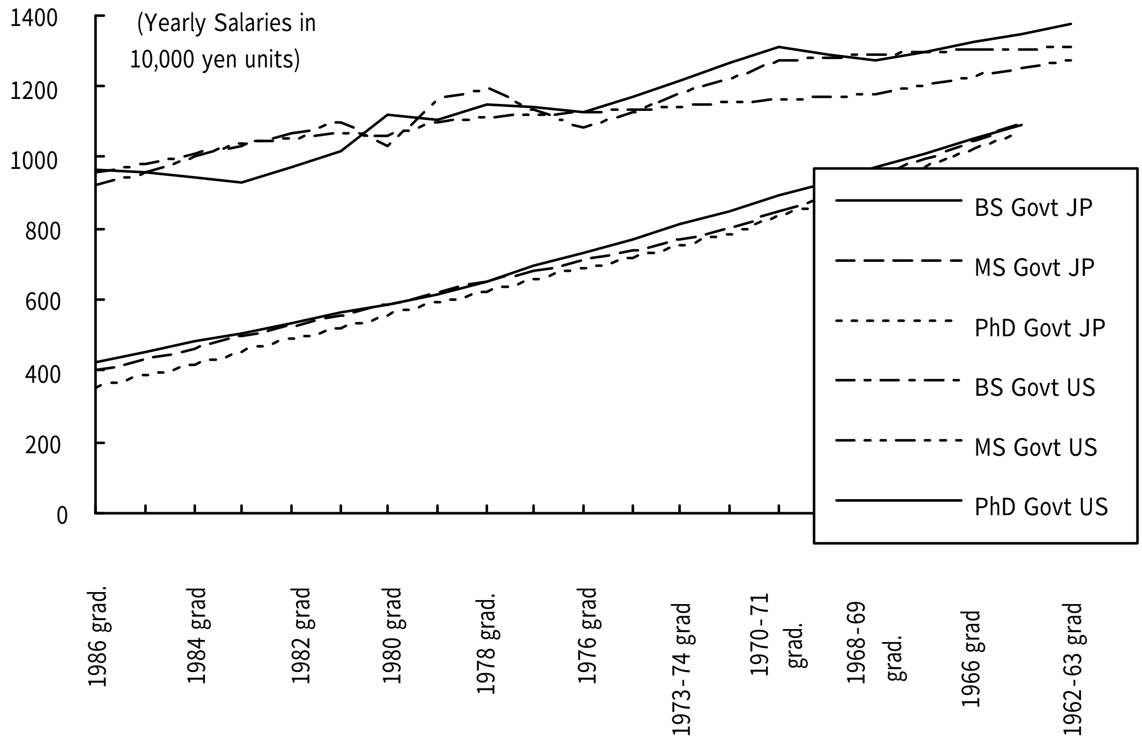

Figure 4.10: Comparison of Public Sector Salaries of B.S., M.S., and Ph.D. recipients in the U.S. and Japan by Year of B.S. Graduation

In conclusion, Japan differs highly from the U.S. in its reception of graduates with higher degrees. It is felt that Japanese companies do not offer such people employment responsibilities different from people entering with a B.S. When looking at salary levels among people of the same age, it turns out to be financially unrewarding to go on for a M.S. and is particularly disadvantagous if one goes on for a doctorate.

By comparison, salary levels in the U.S. reward those going on for higher degrees, although the level of increase differs by employment sector and level of degree. Rewards in the U.S. also come from the level of employment offered. Positions with autonomy and responsibility, in research and sometimes elsewhere, are reserved for people with higher degrees, particularly for those holding doctorates.

REFERENCES

[1]: " Comparative Study on Career Distribution and Job Conciousness of Engineering Graduates in Japan and the U.S. ", M. Ishii, Y. Yokoo, and Y. Hirano. NISTEP Report #28, 1993 (in English and Japanese)

[2]: "Increasing the Number of High Quality Science and Engineering Taught-Course Doctorates in Japan", C. Nishigata and Y. Hirano, NISTEP Report #24, 1992 (in Japanese)

[3]: "Survey on the Handling of Graduates in Science, Engineering, and Agriculture", Institute for Future Technology, 1993 (in Japanese)

[4]: "Salaries of Scientists, Engineers, and Technicians--1993". Commission on Professionals in Science and Technology, Washington, D.C. This is a summary of salary surveys done by different organizations and proved quite useful.

Data in above graphs. Units are 10,000 yen, values are for yearly salaries. Exchange rate was 195 yen/dollar calculated from equivalent purchasing power. Industry includes all private companies, Education means academia, CRC means Contract Research Centers, Fed. G. equals Federal Government, and Nonprof. means nonprofit centers.

Years	1991	1989	1986	1983	1980
BS Ind.	766.58	818.53	910.26	1042.00	1109.39
MS Ind.	797.71	850.82	971.59	1079.21	1179.59
PhD Ind.		1093.01	1115.95	1196.68	1282.79
BS Educ.	647.48	709.96	850.59	889.67	945.36
MS Educ.	713.232	800.05	851.76	940.21	1059.32
PhD Educ.			960.57	900.43	1001.52
BS CRCs	763.07	807.3	899.50	997.78	1075.00
MS CRCs	777.82	866.74	932.96	1021.88	1062.13
PhDs CRCs		1009.24	1086.46	1087.63	1172.34
BS Fed. G.	767.75	838.66	956.83	1035.68	1035.45

MS Fed. G.	743.18	823.45	923.13	1039.19	1062.83
PhD Fed. G.			969.23	932.96	1118.99
BS Nonprof	694.87	764.48	862.29	968.29	1077.34
MS Nonprof		787.41	946.30	1020.71	1116.18
PhD Nonpr.		1072.42	981.86	1077.10	1178.19

Years	1978	1976	1970-71	1968-69	1962-63
BS Ind.	1152.68	1200.42	1312.51	1349.95	1384.81
MS Ind.	1205.334	1237.63	1353.92	1411.72	1462.5
PhD Ind	1322.33	1395.81	1542.76	1564.76	1605.94
BS Educ.	1069.85	1069.38	1227.10	1081.31	1303.85
MS Educ.	1046.68	1127.88	1155.96	1254.47	1303.15
PhD Educ.	1174.68	1109.16	1357.2	1382.71	1560.31
BS CRCs	1069.15	1239.50	1275.77	1330.29	1328.18
MS CRCs	1146.37	1168.60	1254.47	1311.57	1407.04
PhD CRCs	1233.88	1298.23	1383.17	1424.59	1491.05
BS Fed. G	1194.34	1082.25	1272.02	1290.74	1311.10
MS Fed. Gov	1110.10	1124.14	1166.26	1179.59	1275.53
PhD Fed. G	1151.51	1125.77	1311.80	1270.39	1374.05
BS Nonprof	1145.66	1182.87	1356.26	1293.55	1440.04
MS Nonprof	1202.99	1204.16	1388.09	1368.43	1544.87
PhD Non.	1298.23	1279.28	1463.44	1553.99	1722.71

(This is the data without contribution from executive salaries)

Japanese Salaries: (corrected without executive salaries) Years are year of BS graduation.

Year	1986	1979	1972	1968
BS Private	487.36	709.97	958.56	1178.96
MS Private	488.84	764.57	1012.93	1254.49
PhD Private	389.06	728.57	991.67	1315.91

Year	1986	1979	1972	1968

BS Public Sector	426.61	613.46	849.14	1092.31
MS Public Sector	399.22	620.24	795.59	1096.74
PhD Public Sector	350.00	591.67	784.38	1070.45

Conclusions and Suggestions:

As the previous chapters have shown, Japanese graduate programs are weak and underutilized as a form of education in comparison to U.S. graduate programs. Chapter I provided an introduction. Chapter II looked at the structure of US graduate programs vs. Japanese graduate programs, and concluded that graduate schools' studies in Japan are specialized and extremely vertically structured, with a focus almost totally on research. The administrative and bureaucratic university structure presents problems for carrying out research, plus the extreme verticality of the laboratory system makes it difficult for tacit knowledge to be passed between graduate students in different laboratories. The emphasis on research instead of on courses encourages a narrowing of scope, while the lack of emphasis on teaching within Japanese universities results in courses which are said to be lacking in content and badly taught. In addition, little or no financial support has been provided for students stipends, although this is rapidly changing. Funding up to now has been extremely centralized through the Ministry of Education, which makes it very difficult for professors to guarantee graduate student support for promising undergraduates. The low level of funding means that graduate students have to either receive financial help from their parents, or must spend part of their time working. This is directly opposite the U.S. graduate funding system, where through working at Teaching Assistantships and Research Assistantships a graduate student (in science or engineering) provided with a sufficient level of support for daily life. Finally, the rapid growth of national laboratories in Japan and the shift of Japanese industrial laboratories towards more basic research means that it is less necessary for researchers with an interest in carrying out their own research to remain inside the academic system.

Chapter III looked at the structure of university departments and interdisciplinary research. A given Japanese university will have many more departments in science and engineering than a given U.S. university, but the width of the speciality of an individual Japanese department will be much narrower in comparison to that of a U.S. department. In addition, Japan has far fewer cases where courses will be cross-registered between two or more departments. Since most Japanese graduate students take courses only within their own departments, they end up with a much narrower education than US graduate students. Also, cross-department courses allow for a much wider range of disciplines in investigating a certain topic. Aside from broadening overall the base of knowledge of the participating students, it allows people of different disciplines to come in contact with each other and to expand their networks.

Chapter IV looks at after graduation, and shows how from the aspects of future employment there exists little incentive to go on to a higher degree, although a specialized niche market has been found for Masters recipients. Although the estimated length of time required in getting a MS or a Ph.D. is credited to one upon entering employment, this often does not cover the actual time taken. Neither salary grades nor responsibilities differ from those of employees without higher degrees, which is completely different from the U.S.

At present, there are two main problems with the Japanese graduate system: it is difficult for graduate students to get through the programs (mainly due to financial difficulties), and second, there is a large mis-match between the education/training provided in graduate school and what national laboratories and industry want. The first problem can be addressed with increased funding for graduate students as well as decentralization of the university system. The recent change in regulations allowing universities to accept directly funding from outside the Mombusho should help with this.

With regards to the overall position that graduate schools hold in respect to society and the employment structure, the difficulties are more complex and less amendable to correction within the present structure. Decentralization and deregulation of the university system is necessary to break down the vertical structure of the Japanese academic system, which has discouraged cross-fertilization between universities, or interactions between industry and academia. The lack of demand in industry for people with doctorates presents a chicken-and-egg problem: unless companies can claim they will hire doctorates at suitably improved salaries and responsibilities so as to encourage students towards higher degrees, industry will find it difficult to claim to have a reason to influence the university curriculuum. On the other hand, unless the universities upgrade their programs drastically, they will not produce graduates with the breadth and creativity now wished for by industry and government (and academia too, if they think about it.)

Japanese graduate education needs to be reformed. It has to become a part of education considered essential to every researcher, not just those in academia. In doing so, it must offer a different form of training than can be found within company training programs. When looking at the claims made for what one gets out of a top U.S. graduate program, one sees such words as vision , creativity , and learning how to learn. With the increasingly rapid changes in technology and development of new fields, what will become ever-increasingly important is the ability of a researcher to draw from different fields, to synthesize knowledge out of seemingly unrelated areas, and in particular, to learn quickly. This is what a graduate education should provide, and in my opinion, this should be Japan’s final goal.

Appendix: [History of Japanese and Western Graduate Education]

History of Western Graduate Education:[1,2,3]

During the second half of the twentieth century, the system of higher degrees has become quite complex, but basically the terms "masters" and "doctor" are still those most used to signify such attainments.

Originally, these titles had a very different meaning, since in the early medieval university the Master's degree was the only qualification awarded. It indicated the satisfactory completion of the student's 'apprenticeship' in the universitas (guild) and was equivalent to the title of teacher or professor. As such, its formal conferment by the university's chancellor would depend on the recommendation of the existing Masters. It signified the qualificant's entry into the teaching fraternity, equipping him with a licence to teach and thereby admitting him to membership of the university.

In the universities based on the system of Bologna rather than that of Paris, the term doctor was used instead. These medieval "Masters" and "Doctors" degrees were in some sense the same, were the only qualification conferred, and cannot be considered to be "higher" degrees.

Gradually some of these Doctors and Masters of Arts began to engage in further, more specialized studies which led to the evaluation of structured courses in theology, medicine, and law. These "superior" faculties were grafted onto what was now known as the "inferior" faculty of arts and led to doctorates in theology, Medicine, or Law. These degrees can be likened to the present day higher degrees which depend on higher-level specialized courses. The twentieth-century research degree had no equivalent in the medieval university, just as there was no recognized profession of research.

As the courses in the arts became more structured, the bachelorship began to be introduced to mark the achievement of the first step (gradus) towards the mastership, but for a long time this remained a semi-official qualification of no great significance. In England, Oxford University offered a bachelorship already by the 13th century. This was usually obtained at about the age of eighteen and signified no more than what would be considered today a high-school qualification.

As time went on, with the development of public schools in the fifteenth and sixteenth century, the universities were able to shift some of the lower level work over into the public schools. The university student would start his university at an older age and his time spent there was correspondingly reduced. In France and Germany this process ended up with the bachelorship shifting completely over into the school system, where the Baccalaureat and the Abiture, respectively, marked the end of a broad but extremely rigourous school education as well as the entrance qualification to a university. In England, the process reversed itself, with the bachelorship remaining in the university but the qualifications increasing until the 4-year core for the Bachelor of Arts at Oxford rose to an academic level not far removed from the original 7-year Master of Arts.

By the end of the 16th century, the 7-year qualification for the M.A. had become obsolete with the M.A. itself becoming a pure formality finishing off the Bachelor's degree. The M.A. was still the only route to membership in the university, carrying with it voting rights and other privileges. It also retained the essence of its former significance by conferring the rights to teach.

In England, a drastic drop in the number of students due to plagues, wars, and religious restriction affected methods of teaching, moving from the professorial lecture to the more personal method of tutorial teaching. Together with this there came a shift in the position of the professors and the "fellows", Masters of Arts who were continuing their studies. At the beginning, the university professors were held in great esteem and both taught and had time on the side to conduct personal studies in the fields of their choice. By the end, they ended up having little authority in the university or any connections with the students. At the same time, the tutors ended up teaching so much they had little time for anything but essential studies.

By the middle of the 19th century, English universities had been almost completely taken over by the "college" aspect as opposed to research or specialized education. Higher degrees, which would have required such, had degenerated into a series of cautions (dispensations) on payment of fees.

Germany evolved quite differently. During the 16th and 17th century most of the large number of individual German states instituted their own universities, unwilling to recognize qualifications awarded in another State. This tended to frustrate intellectual works but facilitated the breakthrough of new ideas.

Among the greatest of German education philosophers was Wilhelm von Humbolt, creator of the University of Berlin. He believed that the State should support the University financially but that it had no right on interfere in its internal affairs. Freedom of teaching, of learning, and of research were sacred, and knowledge was best extended when it was taught -- teachers made good researchers and good researchers made even better teachers.

Humbolt also introduced reforms to raise the level and broaden the spectrum of school education by founding the modern Gymnasium with the requisite school-leaving acting as the university entering examination. Students thus arrived at the university after a thorough nine-year course that terminated with the Abiture, which was practically equivalent to the English B.A. The nineteenth-century German university could therefore provide its students with courses of study that began at the point where the English student left off. The student was free to specialize in his particular field of interest, choose his courses, and even move from one university to another. So long as he could prove attendance at a number of courses and satisfy examiners by producing a thesis and defending it in front of the faculty, he would be awarded his degree.

In Germany, the role of and structure of the German university teaching profession became a model found nowhere else. The professor, recognized and esteemed both inside and outside the university, stood at the head of the university teaching profession. A specialist in his field, a teacher and a scholar, he had reached his position largely due to published research and, unencumbered by responsibilities in administration or the disciplining of students, his only formal duty was to give two public lectures a week. His salary was paid by the state, and while not over-generous, this could be supplemented by fees from private lectures held in the university. Finally, the principle of Lehrfreiheit assured him of freedom of expression, at least within the bounds of the university, thereby protecting him from any interference with the subject matter of his lectures.

The other end of the teaching ladder was held by the Privatdozent, which complemented the professoriate. These were academic tutors, who had themselves earned doctorates and further academic honours by "habitating" as a university teacher. The Privatdozent was in direct contact with the student, supervising his work and also teaching him in private lectures. His promotion to assistant professor and eventually full professorship depended on his being coming known in his own and other universities as an able scholar, through published work.

New methods of instruction also were introduced into German universities. The first seminars made their appearance before the end of the 18th century and during the 19th century spread into all fields of study, enabling students to become well acquainted with the meaning of scholarship and methods involved in research.

Certain fields, namely law, medicine, and theology, had already offered post-Masters work. It was now at this point that the "inferior" arts section of the German university became transformed into what was now known as the faculty of philosophy, and rose to take its place beside the other superior professional faculties. In addition, the Masters degree became incorporated into a new "doctorate of philosophy"

During the 19th century the philosophy faculty grew out of all proportion to the other faculties (For the academic year 1830-31 17.7% of all German university students were enrolled in the faculty of philosophy. By 1881-82 this had risen to 40.3%) and within this the proportion of students taking sciences almost trebled (in 1841, 13.6% of all students in the faculty of philosophy studies science or mathematics; by 1881 this had risen to 37.1%). In addition to this growing number of scientists at the universities who underwent training to a high degree of specialization one must add the large number of engineers and applied physicists studying in German technical institutions.

I have gone into much detail about the German universities because it can be said that they provided most of the impetus for the formation of graduate education in other countries. One commentator of the period, while not uncritical of the German methods of teaching, maintained that 'as establishments for the cultivation and encouragement of the highest learning, the German universities have left everything of the kind at this moment existing in Europe behind them...it is not as schools, but as centres of mental activity in science, that these institutions command the attention of Europe, and have become the referee to whose verdict every product of mind must be unconditionally submitted.' (Pattison 1868 p. 162).

While students from all over the world took higher degrees within the German system, the proportion of Americans rose dramatically from one per cent in 1935-6 to 22% in 1891-2, when the number of students was a not inconsiderable 446. The enthusiasm for what these scholars found in the German system--the depth of learning and the methods employed in imparting it--naturally led many to try to introduce these into colleges back in America, to which most returned as faculty members. It however took many decades before the value of higher academic studies was recognized by sufficient numbers of college teachers and administrators that the establishment of graduate studies could be established on an official basis. The caveats usually put forth dealt with the money required, whether a demand that the university provide such existed, and lastly, whether there was any usefulness in graduate education anyway. Efforts were also made to found a national university as a postgraduate institution, to draw on the best products of colleges from all over the States, but this was frustrated by local patriotism and a lack of enthusiasm for federal enterprises, especially during the period leading up to the Civil War.

Yale University, which had been the first in succeeding in instituting an organized course for graduate students in 1841, twenty years later became the first to award a Doctorate of Philosophy. This was granted for an advanced course in chemistry lasting three years beyond the normal college training.

Unfortunately, the U.S. Ph.D., although finally underpinned by an elective system which permitted specialization in the undergraduate curriculum, was with some exceptions still of a low standard. The very speed with which graduate education spread during the last thirty years of the century, the great variety of private colleges, the fierce competition for the small number of high calibre faculty and the general craving to append initials to one's name--a trait which has not at all decreased in America--all contributed to a debasing of the academic currency. One turn-of-the-century education historian states that out of the 300 or so institutions of higher education listed by the Bureau of Education at the turn of the century, no more than six could properly be called universities, with perhaps six more in 'the making.'

The great variation in standards in the Bachelors as well as the PhD degrees, together with the practice of awarding honorary and even bogus degrees by mail, finally led to a strong movement by the universities themselves to protect the standard of their degrees. When the Association of American Universities was formed in 1900, one of its express aims was 'to secure in foreign Universities, where it is not already given, such credit as is legitimately due to the advanced work done in our own Universities of high standing, and to protect the dignity of our Doctor's degrees.' During its first 15 years, the Association carried out surveys to establish the various universities' requirements for the PhD examinations, the selection of topics and the printing of theses, the awarding of Masters degrees, and the possibilities of migration in mid-course.

There were no common standards of instructions such as those imposed by the state examinations which most German students worked for alongside their university degree studies. There was no licentiate such as existed in France, nor external examiners to provide some kind of common denominator as in Britain. The wide variety of institutions found in the U.S. as well as the large number of states involved, made it extremely difficult to devise such a standardizing set of exams. The Association therefore, knowing not to strain after the impossible, contented itself with drawing up a list of those universities and colleges which it could recommend as being of sufficiently high standard that their Bachelors degrees could be accepted by universities abroad for entry into their advanced courses. But it experienced considerable difficulties in doing so and not until 1913 was it able to send such a list to the various authorities in Germany. By this point such a list was even more in demand, since the authorities were beginning to restrict the number of foreign students at their universities and were becoming much more selective.

Three years later, in 1916, the same list was sent to all British universities as a recommended guide to the acceptability of American Bachelors degrees for entry into graduate study leading to higher degrees. The impact of this communication at a time when, for a variety of reasons, the British government and universities were at last becoming aware of the urgent need to organize British graduate education, was remarkable. It pointed up once again that at that point in time in England there still did not exist any doctoral programs. American students studying at German universities could aspire to the coveted PhD, while in Britain they could only hope for another Bachelors or, at most a Masters degree.

It is interested to look back at the history of higher education in Britain, for the parallels between it and Japan. (I have italicized below complaints and comments which have also been made about Japan) By the middle of 19th century it was recognized that the existing system in Britain was outmoded and the separation between the college aspects and the university aspects were creating definite conflicts. The Commission for Oxford produced minor changes in the requirements for the M.A. which pleased nobody.

Germany's revamping of her education, coupled with the great American enthusiasm for the German university system and its attempts to build its own, led to the question whether Britain *could continue to lag so far behind other countries in the training of her scientists and thinkers without serious loss of economic power and national prestige.* In this area of vast industrial expansion, with a growing emphasis on more sophisticated scientific methods, how much longer could she neglect that increasingly vital ingredient of economic progress: human brain-power? For a long time England had relied on her easy access to raw materials and centuries old tradition of practical know-how in manufacturing, but now her economic superiority was beginning to be encroached upon by other nations.

That the threat from a number of European countries was partially related to their emphasis on the development of higher education was at first recognized by only a small band of people. But during the 1870s and 80s this became too evident to continue to be generally ignored. Memorials, petitions, inquiries, and reports of every sort were followed by Royal Commissions on a variety of theses related to the development of scientific advance and higher education, in turn followed by long drawn-out and piecemeal reforms in a process lasting well into the twentieth century. One of the more thoughtful and well-known chemists (Henry Roscoe) complained: "This subject of the national importance of original research is one which is gradually, but surely, forcing itself on public attention....and *yet when we come to look at the provision made for encouraging original research...we are astonished to find that this essential provision as hitherto been almost altogether ignored.* At Oxford and Cambridge thousands of pounds are each year lavished upon the encouragement of classical and mathematical attainments, whilst the claims of original research can scarcely be said to be recognized. Hence these highly endowed Universities, whilst they are justly celebrated for their critical faculties, have ceased to represent in any one direction the productive power of the country."

Roscoe held that *the lack of original scientific work at Oxford was partly caused by the examination system, which tended to repress originality.* Moreover, the prestige which non-scientific liberal education had enjoyed for so many generations was self-perpetuation. The public schools which provided the university with its student population and ultimately also its staff, looked down upon science. They had no facilities for its proper instruction and under such poor conditions, the little science taught was of minimal use. (To give an idea, in the 1860s Eton employed 24 classics masters, 8 in mathematics, and 3 to cover all other subjects.)

The first university to offer both lower and higher degrees in science was London University, from 1860 onwards. The DSc introduced in 1860 was granted purely on the basis of an examination in which the candidate was required to pass in a principal subject as well as one or more subsidiary cognate subjects. There was much enthusiasm for turning this into a research degree, although many argued that this would discriminate against "many learned men, and many excellent Professors, (who) are not remarkable for independent personal research in any particular branch of science, and they should not be deprived of the honour of the degree.' In short, the final result was that the existing syllabus for the DSc Examination' was withdrawn and in its stead to require that ' any Bachelor of Science desiring to proceed to the Degree of Doctor of Science...to submit an original Essay, Dissertation, or Thesis as the foundation of his qualification for the Doctorate."

Neither Cambridge nor Oxford followed with any rapidity.

History of the Japanese graduate system:[4,5]

Higher degrees did not exist in that formal a form before the education reform implemented at the end of WWII. What graduate work existed was half on the lines of what existed in Germany and half on the lines of what existed in the U.S. before formal graduate education was implemented: students, working on their own under a particular professor and dependent on their own funding would produce, after several years of work, a thesis. Certain disciplines tended to attract more graduate students than others: a large percentage of Japan's prewar graduate students were in psychology. [4]

The granting of doctorates was defined in Japan in 1887 by Article 3 of the Academic Degree Ordinance of 1887 [5]:

"1) The doctorate degree will be granted by the Ministry of Education, Science and Culture to those candidates who have entered a graduate school and passed the prescribed examinations."

"2) Or, the doctorate degree shall be granted to those candidates who have scholastic competence equivalent to or greater than that of the above candidates as determined by deliberation of the Teikoku University Evaluation Committee."

In the latter clause one can see the beginnings of the doctorate-by-dissertation, where a scientist is granted a Ph.D. based on the research work he has done over the years (usually in a company laboratory.) The first doctorates granted in Japan were done so under the second clause, not the first. According to the Record of Doctorates in Japan, all of the 32 science doctorates and 31 engineering doctorates between 1887 and 1897 received their degrees under the second clause. Although the second clause may have been included as an interim measure, the continued prevalence of the dissertation doctorate system was tacitly admitted in the Academic Degree Ordinance of 1898, with doctorates being granted to "candidates who have submitted a dissertation paper and requested a doctorate degree and who have been recognized as having scholastic competence equal to or greater than that of other doctorate candidates." Looking at the statistics, a majority of doctorates granted between 1907 and 1911 were obtained as dissertation doctorates. Of the 27 science doctorates granted, 15 were dissertation doctorates.

With the education reform at the end of WWII, graduate students were put on a more official footing. Granting graduate degrees in Japan is governed by the Regulations on Academic Degrees (Ministry of Education, Science and Culture Ordinance No. 9 of April 1, 1953, revised on September 1, 1989). Master's candidates must have taken 30 units of courses as well as a thesis/ final project and a final exam. The section covering doctoral degrees read "With respect to major field, the candidate must possess an advanced level of research competence and an abundance of academic knowledge serving as a basis for the same as necessary for carrying out research activities independently in the field and/or performing other specialist duties of an advanced nature." Doctoral candidates must have completed the doctorate program "at a graduate school whose purpose is to cultivate a high level of competence in research and an abundance of academic knowledge for the same as necessary for carrying out research activities independently in the field of specialization and /or performing other specialized duties of an advanced nature." Another clause provides an exception to this, saying that the doctoral degree can also be granted to "candidates who have submitted a dissertation paper which has been accepted by examination of the graduate school as stipulated by the university and who have been recognized as having academic competence equivalent to or greater than that of candidates who have completed the doctorate program of the graduate school. "[6]

The clause allowing for such "dissertation doctorates" was included at the strong insistence of the Council on University Establishment. The original wording did not allow such, and in fact, the Civilian Information and Education Section of the Allied Occupation had directed that the dissertation doctorate system be abolished.

At present, dissertation doctorates comprise 40-50% of all science doctorates and comprise 56-66% for all engineering doctorates. That these doctorates are awarded, not so much for demonstrating the potential for research (as is in the US and elsewhere) but as a "reward" after a long period of research can be seen by comparing the average age at which doctorates are rewarded. In Japan, the average age for course-work doctorates is 29 years (both in science and engineering), while the average age for dissertation doctorates is 40 years for science PhDs and 42 years for engineering PhDs.[1]

It is probably irrelevant to the questions under investigation as to whether removing the "disseration doctorates" would help the Japanese system or not. The two populations (dissertation doctorates vs. course doctorates) do not mix and rarely come in contact with each other. If people undertaking course doctorates get a broader and more up-to-date education than those going on the "dissertation doctorate" route, then the one arguement that might be raised is that the existence of the disseration doctorate lures people towards immediately entering a company and towards a narrow and restricted education equivalent, rather than for them to go the course doctorate route. On the other hand, the idea that there always exists a path for an eager and intelligent person to use for increasing his education / academic level is quite reassuring and may pull people towards working for a Ph.D. who otherwise would not have the chance. Certainly, the recent advent in the US of "adult education programs" which grant degrees for research done at companies or classes taken on one's own show that there definitely is a market for adult (continuing) education. The difficulty in the US is that most if not all of the universities offering such degrees are of such poor quality that the possession of a "doctorate" means nothing at all. The problem, in Japan and the US, of adult continuous education of a rigorous enough quality and with enough internal competition such that degrees granted in this fashion can compete with the more standard "course" degrees, remains unsolved.

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