Science and Technology as Cognitive Domains in Japan : A Comparative Perspective

著者(英)	James R. Bartholomew
journal or publication title	Senri Ethnological Studies
volume	46
page range	61-70
year	1998-03-20
URL	http://doi.org/10.15021/00002923

SENRI ETHNOLOGICAL STUDIES No. 46 1998

Science and Technology as Cognitive Domains in Japan —A Comparative Perspective—

James R. BARTHOLOMEW
Ohio State University

It has long been commonplace in Western intellectual discourse to emphasize distinctions between the domain of "science" and the domain of "technology." "Science," we are told, is "a method of investigating nature by the experimental method in an attempt to satisfy the need to know" [FEIBLEMAN 1961: 305]. "Technology, "however, deals with problems which are "nearer to practice" (illustrated, for example, by the physician who prescribes a medication for a patient) and is more apt to develop "generalizations" from practice rather than "laws which are intuited" [FEIBLEMAN 1961: 310–311]. One may, of course, choose to regard such formulations (by philosophers especially) as pure abstractions with socially neutral implications. Indeed, much evidence suggests that this view has long been widely accepted in the United States, in Europe and in many other places. It is suggested here, however, that: a) these formulations are not socially neutral; b) that they have had significant, negative consequences in many societies; that c) Japan seems historically to have developed a different way of thinking about and acting upon perceived connections between the two realms; and that d) this pattern has (despite costs) been socially and intellectually beneficial to Japan. Some reasons for offering these conclusions will follow.

Recognition of cleavages between "science" and "technology" have historically run deep in a great many societies. Universities in medieval Europe were populated with intellectuals who speculated about the nature of matter but rarely, if ever, did actual experiments; manipulation of materials, dissections of cadavers or construction of equipment fell to individuals with no competence in Latin or even formal schooling [HALL 1962: 36–40]. Confucian philosophers in imperial China - with a few exceptions like the great Chu Hsi (d. 1200), an amateur palaeontologist as well as a theorist - expounded ideas but rarely dirtied their hands; while actual craft skills were developed and passed on by (among others) self-proclaimed Taoists who sought the elixir of life by mixing substances together [NEEDHAM 1969: 158, 162, 250–251]. This social separation of "technology" from "science" seems to have begun in the preclassical, even ancient period of world history and is said to reflect, among other things, a reliance on slavery in many ancient societies. The use of slaves, it is argued in turn, not only impeded the search for devices to save labor but led many societies to consider "thinking" prestigious and "manufacturing" or "making" déclassé [STAVRIANOS 1988: 152–153]. And certainly the emergence and extended persistence of feudalism in Europe helped to perpetuate the separation of intellectual life from manufacturing or physical experimentation with material substances or natural phenomena.

Only with Europe's "Scientific Revolution" of the 16th and 17th centuries did this cleavage begin to break down. Indeed, it is a commonplace theme in European historiography that Galileo Galilei (in particular) both benefitted from and contributed to its partial demise in Italy by consorting with shipwrights and craftsmen in formulating his scientific ideas as Professor of Mathematics at the University of Pisa [ZILSEL 1942: 544–562].

By most historical accounts, however, the achievements of Galileo or other early modern scientists in Europe represented merely a relaxation of traditional barriers, not their full elimination. Most European universities still catered to the interests of the landed aristocracy or the emerging bureaucracies of the national states (France, England or Prussia) and thus offered a curriculum of strictly traditional content. One could study Latin, Greek, pure mathematics, medicine or law at such institutions as Oxford, Cambridge, Bologna, Paris or Erfurt; but even experimental science - to say nothing of engineering - remained completely outside their purview. Of course, the French Revolution at the end of the eighteenth century, brought certain changes in traditional European patterns of higher education. France's revolutionary government (or the Napoleonic regime which followed) created the new *grandes écoles* for mining, for experimental science and for engineering subjects among which the Ecole Polytechnique was particularly important. And certainly these developments set a chain of events in motion which would eventually lead to such significant institutional breakthroughs as the West Point Military Academy (with its engineering curriculum) or the engineering-based land grant university in the United States of America [BEN-DAVID 1971: 88–107, 139–142].

Nevertheless, these events in France - despite important effects in France itself and even some degree of emulation abroad - did little in the short run to eliminate the cleavage between "technology" and "science" in the West as a whole. Consideration of developments in the higher educational systems of Britain and Germany is instructive for understanding the general situation. While the Scottish universities offered work in experimental medicine, basic science and engineering, the English institutions bitterly resisted any change for the first two-thirds of the nineteenth century. The institutionalization even of laboratory science instruction at Oxford and Cambridge had essentially to be forced on a reluctant professoriate from outside as part of a reform in the early 1870s. And engineering disciplines continued to be excluded. Just to institutionalize laboratory work in basic science was no easy task as opposition to change remained intense. The Cambridge physicist James Clark Maxwell once asked his mathematician colleague Isaac Todhunter about 1875 if he would like to see an experimental demonstration of conical refraction, only to be told: "No. I have been teaching it all my life, and I do not want to have my ideas upset" [Crowther 1975: 9; Todhunter 1873: 1–32]. In fact, Todhunter's views, though peculiar in some ways, are also instructive because he openly expounded the traditional aristocratic view that access to higher education in virtually any discipline should be wholly confined to members of the upper class! [Todhunter 1873: 21]

German developments in the nineteenth century showed greater pragmatism than those in Britain, but they basically ran in a parallel direction. The process of reform in German higher education was heavily influenced by the example of Berlin University (founded in 1810) where a nationalistic agenda tied to "cultural" considerations was formulated by Alexander von Humboldt and tended to set the pattern in German-speaking regions. In this model, basic science acquired pride of place and came to be included in universities as part of the faculty of philosophy. While this schema did not originally include experimental science, it too was added to the university curriculum as a result of the demonstration effect of Justus von Liebig's program in chemistry founded at the (small) University of Giessen in 1828 [Ben-David 1971: 118, 124].

Missing altogether, as in Britain, was any university provision for engineering disciplines. Needless to say, the German industrial movement, which gathered steam rapidly after political unification in 1871, could not do without modern engineering, so some provisions had to be made. The solution chosen by German authorities is instructive. Rather than attempt to force the universities to accept fields of study they considered inappropriate, the central government and various *Länder* regimes chose to create new institutions called (initially) *technische hochschulen.* These institutions offered the engineering specialties needed by modern industry, but in addition made laboratory science instruction available to a broader clientèle than that which had historically attended the established universities. Interestingly enough, this nineteenth century solution to an historically European pattern of cleavage between the two broad domains of "science" and "technology" has basically persisted in Germany down to the present. In 1991 only two German universities (one of them Goettingen) were teaching engineering, though the redesignation of the *technische hochschulen* as *technische universitäten* after 1945 may perhaps be seen to represent a more "modern" reformist impulse at the heart of the German system![1]

The historical record of higher education in the United States seems to represent a stronger attempt to overcome the traditional cleavage between "science" and "technology" than any yet seen in Europe (outside the former Soviet Union). American colleges and universities before the Civil War had low aspirations and limited curricula, whatever was taught. But passage of the Morrill Act in 1862 authorized endowments of land for universities in the various states, and by so doing made possible both an unprecedented expansion of higher education and the incorporation of engineering ("technology") into many American universities.

---

1) Private communication, Professor Alan D. Beyerchen, February 1992.

New institutions based on the land grant model like Cornell or Ohio State naturally offered both "science" and "technology" (engineering), but the movement did not end there. Stanford included engineering as well as basic science from the start; in fact, its founder, Senator Leland Stanford, initially wanted an "engineering school" [VEYSEY 1970: 112–113, 397–398]. And even leading East Coast institutions like Harvard, Princeton and Yale introduced formal engineering programs to complement their programs in various fields of basic science.

But even the United States has retained significant vestiges of the ancient cleavage between the domain of "science" and the domain of "technology." There continues to be in Washington, D.C. a National Academy of Sciences for "scientists" and a National Academy of Engineering for "engineers." Some prestigious comprehensive universities (e.g. Indiana), still do not teach engineering. And in the 1950s (especially), many American corporate research laboratories were often designed to look like university buildings, complete with ivy growing on the outside walls, so that "scientists" - socialized to think that academic employment was best - could function comfortably as "engineers" in the corporate world" [KORNHAUSER 1962a: 71ff; 1962b: 30–42; MARCSON 1961: 52–57]. This kind of reassuring gesture seems to be necessary in a society where a noted academic philosopher in 1961 could contrast "applied scientists" with "pure scientists" by calling the former (compared to the latter) "men of greater skill but of lesser imagination [FEIBLEMAN 1961: 309].

Japan's historical experience with "science" and "technology" has differed sharply from that of either Europe or the United States. To begin with, the Tokugawa period social cleavage which may have made an historical difference in the growth of the Japanese scientific tradition was not the one between "technology" and "science" but rather the bifurcation which developed between *wasan* mathematics and the physical sciences. During an era in which political authorities tried to freeze the population into rigid social classes while economic forces were deepening conflict between them, a pattern of social control in the physical sciences by one class (*samurai*) and competing control of mathematics by another (commoners, i.e. affluent peasants and merchants) was at best an invitation to intellectual stagnation [BARTHOLOMEW 1989].

Secondly, the Meiji regime which came to power in 1868 was led by samurai who either keenly appreciated the importance of basic science and engineering, or declined to recognize a difference between them. Tokyo University, founded at their instigation in 1877, taught several engineering specialties, together with physics, mathematics and chemistry in a single program prior to the establishment of separate faculties in 1885 [BARTHOLOMEW 1989: 93]. Kyoto University, founded a dozen years later, had to make do with a single Faculty of Science and Engineering for more than twenty years. And both the Tokyo Academy of Sciences (created in 1879) and the Imperial Academy' of Sciences (established in 1907) included members for *all* of the learned disciplines recognized in Japan [BARTHOLOMEW 1989: 95, 118]. Not only were there no separate academies for "engineers" and "scientists," the only indicator of separate status for different fields even *in* the Imperial Academy itself was the use of the terms "Division I" (humanities and law) and "Division II" (technical fields) [NIHON GAKUSHIIN 1962: 249–332].

If anything, the European (or ancient) prestige hierarchy of academic disciplines so common in other places was turned upside down in Meiji Japan. That is, applied science (including engineering) got preferential treatment up to a point. Academic posts were established at Tokyo University in ordnance engineering and naval architecture in the late 1880s when "no university in Europe taught such subjects" [NAKAYAMA 1978: 221]. Successive ministers of education continually expounded on the importance of research in "applied science" as a major part of the national agenda [BARTHOLOMEW 1989: 133]. And even influential scientists like Terao Hisashi, Director of Tokyo University's Astronomical Observatory, tended to accept the preference for engineering or applied science. In 1889 he gave a lecture to a group of young mathematics students in which he declared that it was wrong to study mathematics "solely because of one's personal interests." One had to use it in service to society [OGURA 1935].

Nor were such attitudes and preferences confined to Meiji. One finds plenty of evidence from the interwar period *and* from the period since 1945 pointing either to: a) a deliberate (or unconscious) blurring of dividing lines between "science" and "technology" as cognitive domains, or b) to an active preference for "technology" over "science." After its founding in 1918, research grants through the Ministry of Education's Science Research Grants Program (*Mombusho Kagaku Kenkyu Hi*) were made to applicants from a very wide array of disciplines through the same funding agency.[2] In the National Research Council (*Nihon Gakujutsu Kaigi*) created in 1920, one finds members from engineering, medicine, agriculture and basic science [KO FURUICHI DANSHAKU KINEN JIGYOKAI 1937: 202–213]. And in 1924 when Nagaoka Hantaro (physics), Mita Sadanori (serology) and Nagayo Mataro (pathology) decided to organize a Natural Sciences Research Association (*Shizen Kagaku Kenkyu Kai*), they decided that its primary goal should be to promote joint cooperation between the four "fields" of science, medicine, engineering and agriculture (*ri-i-ko-no*) without distinction [SHIZEN KAGAKU RENGO GAKKAI 1921: 41–42].

There are some reasons to think that the aforementioned attitudes (represented by a) and b) above) grew even stronger after 1945 than they had been before. For one thing, members of the U.S. occupation's science advisory team (especially the physicist Harry C. Kelly) argued against support for basic science and in favor of a preference for "applied science" on the grounds that economic rebuilding after the war would require every intellectual resource that Japan could muster. Indeed, Kelly insisted that basic science was a "luxury" in the light of postwar conditions.[3]

---

2) For the early history of the Ministry of Education's Science Research Grants Program (*Mombusho kagaku kenkyu hi*), see Bartholomew [1989: 247–254].

3) Quoted in Nakayama, [1984: 357–358].

Moreover, the overriding political priority given to economic rebuilding strengthened the hard of conservative, risk-averse business leaders like Shoriki Matsutaro who recklessly tried to boost energy production in Japan by shortcircuiting research activities required for the importation and deployment of nuclear powered reactors, even when a need for basic, related research was advocated by so eminent a scientist as Yukawa Hideki.4) Whatever the constellation of factors may have been, postwar Japan has developed an institutional support base for research and development activities that is probably not truly duplicated anywhere else in the world. By the most recent reports, about 70 percent of Japanese research activity takes place in laboratories attached to private corporations.5) The rest, based in government laboratories and academic institutions, represents a percentage of total effort well below that of other OECD nations.

From a Eurocentric or American point of view, it is tempting to conclude that all but a small fraction of the research done in Japan since World War II is application-oriented or product development-driven and hence could never contribute to the worldwide store of basic scientific knowledge. At a high level of generalization this may, perhaps, be true; it is not my purpose here to say whether it is or is not true. There is a different sort of point to be made: The argument would be that in a few instances - in one extraordinary instance at least - an "engineering" context seems to have provided a highly favorable environment for one of the world's major achievements in chemistry of the postwar era. This is Professor Fukui Ken'ichi's formulation of the frontier orbitals theory in the 1950s.

However typical or atypical one may consider Dr. Fukui's career at Kyoto University to have been, it was certainly a career for which American or European analogues would be hard to find. In essence, though Dr. Fukui was formally trained as an engineer in Kyoto University's Faculty of Engineering and made his whole career in engineering, he is now known for contributions to science of a highly theoretical character. The basic facts of his career are instructive. In 1938 he entered the Kyoto program in industrial chemistry where he pursued a course of study (1938–41) he himself described as "very practical." Indeed, the members of his program did work on the synthesis of hydrocarbon fuels and high pressure polymerization of ethylene which subsequently formed the basis for the polyethelene industry in Japan [KYOTO DAIGAKU 1967: 7–9]. Fukui became somewhat dissatisfied with what he considered the excessively "practical" orientation of his laboratory group and the Faculty of Engineering in which it

---

4) See Hideo Sato, "The Politics of Technology Importation in Japan: The Case of Atomic Power Reactors," Unpublished paper Prepared for the Conference on Technological Innovation and Diffusion in Japan (sponsored by the Social Sciences Research Council), Kona, Hawaii, February 7–11, 1987, pp. 7, 16, 22, 25, 48–49.

5) As of 1980 it was estimated that two-thirds of Japanese research was based in industry. See Anderson [1984: 104].

functioned but did not attempt a transfer to the Faculty of Science as some American or European scientists might have done in a similar situation. Instead, he worked to redefine the context itself in such a way that the engineering environment could serve *his* purposes rather than the other way around [YAMABE 1982]. It clearly helped that he was able to become a full professor at the age of 31. In any case, Fukui was able to pursue his entire academic career quite effectively within in the Faculty of Engineering while carrying out highly theoretical, indeed fundamental, work using quantum mechanics to predict the course of chemical reactions, showing that the chemical reactivity of molecules was greatly affected by certain properties of their electron orbitals [BOFFEY 1981: 16]. For this he shared the Nobel Prize for Chemistry in 1981, at which time his achievement and that of his co-laureate, Roald Hoffmann, were referred to by distinguished chemists abroad as the "most important conceptual advance in [chemistry] of the past... 30 years" [BOFFEY 1981: 16].

There are cases in the 20th century of European researchers who did very basic science in an "engineering" context. But these men were largely Jewish scientists working in the pre-World War II era who functioned as "engineers" because discriminatory barriers seemed less formidable to them in corporate laboratories than in those of the (especially German) university system.[6] With the possible (theoretical?) exception of Korean scientists doing basic science in an "engineering" context in Japanese industry as a way of escaping prejudice, it is difficult to imagine any career pattern in Japan even remotely like that of certain prewar Jewish scientists in Europe.

What does this mean? It would seem to mean that Dr. Fukui's career developed in a Japanese academic context in which the cognitive barriers between "technology" and "science" were either weaker or at least far more permeable than those in Europe or United States. Whether the overall structure or cultural system of science at Kyoto University during Dr. Fukui's career was good or bad for him is difficult to say; perhaps timely transfer to the Faculty of Science might have worked better. One well understands that this was *not* a real option for him at the time. A more interesting question is whether the permeability of cognitive boundaries between "science" and "technology" in Japan did not somehow facilitate his work as a whole. To be sure, the original "practical" character of the industrial chemistry program in 1938–41 may have seemed stultifying. *But* the funding priority given to it by the Japanese government at the time was surely a function of the push toward synthetic fuels which wartime conditions had stimulated, and in that sense he may well have had access to material resources that might have been lacking in the Faculty of Science.

It is tempting to argue on the basis of the worldwide distribution of contributions to basic science and Nobel prizes received that American and

---

[6] Private communication, Professor Erwin Hiebert, Harvard University, December 2, 1989.

European patterns in the distribution of effort between "science" and "technology" are fundamentally superior to those of Japan, and that therefore it is Japan which must change to the historical European and American pattern of greater stress on "basic science" with relatively less emphasis on engineering or "technology" One may indeed sympathize fundamentally with the view that Japan should make a substantially greater effort in basic academic science, with all that this implies about improved facilities and working conditions in the universities. But it is much less clear that Japan should closely emulate the historical and institutional patterns of either European countries *or* those of the United States.

To begin with, Britain in particular has developed a rather negative pattern of disdain for the work of engineers and a set of attitudes about manufacturing (as compared, say, to finance or basic research as career tracks) which are rather dysfunctional and prejudicial to its survival as a successful industrial power. Indeed, this point is widely recognized in Japan, even if not in Britain itself [MORITANI 1982: 159–165]. Nobel prizes, which British scientists continue to receive all out of proportion to their numbers in the worldwide scientific community, will not save their economy. Nor, as one recent study by the National Science Foundation also reveals, will Nobel prizes save the economy of the United States, where some of the some negative patterns as those in Britain have also appeared (though so far in a less extreme form) [HILL 1986]. This does not mean that Britain and the United States should abandon basic science, but it does mean that they should cast off the last remaining vestiges of condescension toward "technology" and seek a more productive relationship between the two cognitive realms. In this regard Japan's experience is highly instructive.

BIBLIOGRAPHY

ANDERSON, Alun M.
1984 *Science and Technology in Japan*. London: Longman.

BARTHOLOMEW, James R.
1989 *The Formation of Science in Japan: Building a Research Tradition*. New Haven and London: Yale University Press.

BEN-DAVID, Joseph
1971 *The Scientist's Role in Society: A Comparative Study*. Englewood Cliffs, New Jersey: Prentice-Hall.

BOFFEY, Philip M.
1981 2 Share Nobel in Chemistry; 3 Win in Physics. In *The New York Times* Vol. CXXXI No. 45, 107.

CROWTHER, J.G.
1975 *The Cavendish Laboratory, 1874–1974*. New York: Science History Publications.

FEIBLEMAN, James K.
1961 Pure Science, Applied Science, Technology, Engineering: An Attempt at Definitions. In *Technology and Culture*.

HALL, A. Rupert

1962 *The Scientific Revolution, 1500–1800: The Formation of the Modern Scientific Attitude*, Second Edition. Boston: Beacon Press.

HILL, Christopher T.

1986 *The Nobel-Prize Awards in Science as a Measure of National Strength in Science.* Washington, D.C.: U.S. Government Printing Office.

KO FURUICHI DANSHAKU KINEN JIGYOKAI (ed.) (故古市男爵記念事業会編)

1937 『古市公丼』 故古市男爵記念事業会。

KORNHAUSER, William

1962a *Scientists in Industry: Conflict and Accommodation.* Berkeley: University of California Press.

1962b Strains and Accommodation in Industrial Research Organizations in the United States. In *Minerva* Vol. I No. 1.

KYOTO DAIGAKU (ed.) (京都大学編)

1967 『京都大学七十年史』 京都大学。

MARCSON, Simon

1961 *The Scientist in Industry.* New York: Harper & Row.

MORITANI, Masanori

1982 *Getting the Best for the Least: Japanese Technology.* Tokyo: The Simul Press, Inc.

NAKAYAMA, Shigeru

1978 Science and Technology in Modern Japanese Development. In William Beranek and Gustav Ranis (eds.), *Science Technology and Economic Growth: A Historical and Comparative Study*, New York: Praeger.

1984 The American Occupation and the Science Council of Japan. In Everett Mendelsohn (ed.), *Transformation and Tradition in the Sciences: Essays in Honor of I.B. Cohen*, Cambridge: Cambridge University Press.

NEEDHAM, Joseph

1969 *The Grand Titration: Science and Society in East and West.* Toronto: University of Toronto Press.

NIHON GAKUSHIIN (ed.) (日本学士院編)

1962 『日本学士院八十年史』第一巻 日本学士院。

OGURA, Kinnosuke (小倉金之助)

1935 『数学史研究』第一巻 岩波書店。

SHIZEN KAGAKU RENGO GAKKAI (ed.) (自然科学連合学会編)

1921 『教育時論』No. 1422 自然科学連合学会。

STAVRIANOS, Lefton S.

1988 *The World to 1500: A Global History*, Fourth Edition. Englewood Cliffs, New Jersey: Prentice-Hall.

TODHUNTER, Isaac

1873 *The Conflict of Studies and Other Essays on Subjects Connected with Education.* London: Macmillan and Company.

VEYSEY, Laurence R.

1970 *The Emergence of the American University*, Pheonix Edition. Chicago and London: The University of Chicago Press.

YAMABE, Tokio (山邊時雄)

1982 『ノーベル賞科学者 福井謙一』 化学同人。

Zilsel, Edgar
1942 The Sociological Roots of Science. In *American Journal of Sociology* Vol. XLVII No. 4.