CREATIVITY IN JAPANESE SCIENCE AND ENGINEERING: THE CASE OF THE CAREER OF KEN'ICHI FUKUI

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INTRODUCTION

In October 1981 the Nobel prize for chemistry was awarded to Professor Ken'ichi Fukui of Kyoto University, jointly with Professor Roald Hoffmann of Cornell University for important contributions to the theory of chemical reactions. While Hoffmann's Nobel award came as no surprise, given his mainstream career path and well documented rise to prominence, the Fukui award attracted unusual attention partly because his career as a theoretical chemist had developed entirely within an "engineering" context, first as a student, then as a faculty member in the Faculty of Engineering at Kyoto, not in its Faculty of Science. Nonetheless, *Chemical & Engineering News* erroneously described him as a "physics professor," and even the somewhat better informed *New York Times* reported incorrectly that he was "professor of physical chemistry," whereas his actual title had been Professor of Fuel Chemistry, Professor of Petroleum Chemistry, or something else of this sort indicating an emphasis in his work on applied science. This confusion in the United States over Dr. Fukui's title is a non-trivial matter which suggests something important about the history of modern science and engineering in Japan, and about the relationship between "science" and "technology" therein.

FUKUI'S LIFE

Ken'ichi Fukui was strongly interested in mathematics as a youth, but rather than apply to Faculty of Science at Kyoto, a friend of his father — Dr. Gen'itsu Kita — who happened both to come from the same village and was a member of the Faculty of Engineering, steered the young Fukui to that part of the university instead. Kita told Fukui that he would be able to develop his interest in mathematics equally well in an engineering program. This advice proved to be correct, but in a rather roundabout way. Fukui in fact discovered that the applied chemistry program was too practical for his taste, but rather than switch majors as an American student would likely have done, he addressed this situation by frequenting the library of the Faculty of Science where he simply borrowed books on mathematics and theoretical physics to compensate for what he deemed to be the shortcomings of the

engineering program.

World War II had a major impact on Fukui's professional life. Graduating in March 1941 with a baccalaureate degree in industrial chemistry, he joined the graduate program in the same field, headed by Professor Shintaro Kodama. In April a new chair in fuel chemistry was created for which Kodama assumed responsibility with Fukui working under him. In August 1943 Fukui was named to a lectureship attached to this chair and simultaneously began working at the Army Fuels Research Institute in Fuchu, commuting between there and Kyoto for the duration of the war. His work at Fuchu was wholly of a practical character, relating to the development of synthetic fuels, especially aviation gasoline. He received the Order of Technical Merit for this war-time research. His rise to academic prominence was rapid after that. By the war's end he was already an assistant professor at Kyoto, and in 1951 at the very early age of 33, he was named full professor with responsibility for the chair in chemical mechanics, a unit which was originally established as part of a program in fuel mechanics. So far as fuel chemistry was concerned, the research program placed emphasis on high pressure mechanics, materials, and electrothermics. However, at Fukui's direction — as a full professor — the laboratory's research program gradually moved toward theoretical topics, especially the theory of chemical reactions.

FUKUI'S CONTRIBUTION TO THE THEORY OF CHEMICAL REACTIONS

The most conspicuous achievement of Fukui's group is the frontier orbitals theory of chemical reactions. Beginning in 1952 in a series of papers, Dr. Fukui showed that the chemical reactivity of molecules was greatly affected by properties of their electron orbits. Then, building on work by Robert Woodward of Harvard and by Roald Hoffmann, Fukui published more calculations and applications to specific reaction types, and he applied perturbation theory to his original qualitative notions. Since perturbation theory assumes that the highest occupied molecular orbital of one reactant and the lowest unoccupied molecular orbital of the other begin to distort slightly as they approach one another, he was able to extrapolate from this distortion to find the energetics of various reaction pathways. This research won him the Japan Academy Prize in 1962 and ultimately the Nobel Prize with Hoffmann, Woodward having died in the interim.

FUKUI'S ACHIEVEMENT AS A CASE STUDY

Nobel prizes and other such accolades depend on others' reactions, and Fukui has reason to think that there could be a problem for him there. Although he did publish in English, in fact, some of his important early papers appeared in the *Journal of Chemical Physics*, a journal not widely read by Fukui's most likely audience at the time. Moreover, he used quite sophisticated mathematics which, by some reports, was beyond the capacity of many chemists — who would otherwise have been interested — at the time. In fact, the reception of Dr.

Fukui's work in Europe and the United States seems definitely to have been affected by his career-long affiliation with the Faculty of Engineering rather than the Faculty of Science. While European and American engineers have sometimes won Nobel prizes in chemistry (or physics), this has always been for contributions to "hardware," rather than for "software" as was true in Fukui's case. In Japan, moreover, his career path was not particularly unusual. This is because from the early Meiji period forward, Japan has developed its modern scientific and technical research tradition by minimizing (Western-style) divisions between science and engineering or "science" and "technology." Moreover, whereas Western history shows that applied fields long suffered second class treatment by the academy, in Meiji Japan such endeavors were given prestigious housing in the imperial universities virtually from the start. Dr. Fukui was once asked if he had ever been asked to nominate anyone for a Nobel prize before he received it himself, and he replied that he had not been so asked because nomination forms were only sent out to people in a department of chemistry or a faculty of science, never to someone like himself in "engineering." The historical tendency in Japan to either conflate "science" and "engineering" or at least to elevate both has been beneficial to both intellectual domains.