The Development of Teaching of Applied Chemistry at Tokyo University, 1874-1900[1]

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Japan underwent a process of institutionalisation of Western-style scientific and technological education in all fields during the Meiji period (1868-1912) as an integral part of the industrialisation policy of the Meiji government. Widely conceived throughout the nineteenth century as the most practical and utilitarian of many scientific disciplines by Europeans and Japanese alike,[2] chemistry was understandably one of the first subjects that gained a departmental status in 1874 together with engineering and law at Tokyo University, one of the major sites of higher education in Meiji Japan. It is also hardly surprising that chemical education there laid particular emphasis on 'applied chemistry' (*ôyô kagaku*).

However, the question of what constituted the teaching of applied chemistry was not at all a simple one, and it took almost a quarter of century for a prototype of the teaching of applied chemistry to emerge at Tokyo. This paper discusses the process and mechanism by which the education of applied chemistry at Tokyo University gradually accumulated three elements of teaching practice – analysis, fieldwork and engineering – in the course of these formative years. In conclusion, this event will be contextualised in the wider process of Japanese industrialisation as a question of knowledge or model transfer across cultural boundaries.

Applied Chemist as 'consulting analytical chemist'

Three chemists, one English chemist and his two Japanese students, were instrumental in the development of the teaching of applied chemistry at Tokyo University between the 1870s and 1890s: these were Robert William Atkinson (1850-1929), Toyokichi Takamatsu (1852-1937) and Iwata Nakazawa (1858-1943).

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Atkinson was born in 1850 in Newcastle-upon-Tyne, and studied chemistry at both University College London (UCL) under Alexander William Williamson (1824-1904) and the Royal School of Mines (RSM) under Edward Frankland (1825-1899) between 1867 and 1872. He worked for two years at UCL as assistant to Williamson and upon his recommendation Atkinson took up a Professorship of Analytical and Applied Chemistry at Tokyo University, in 1874. He was solely responsible for setting up a Chemistry Department there.

As Bud and Roberts have argued,[3] chemical education at UCL and the RSM between the 1850s and 1870s was formulated on the liberal science model, which rested on a dichotomy of 'pure' and 'applied' chemistry, in which only the 'pure' side of the subject could be taught at universities and colleges. Therefore, in his own teaching, Atkinson had to develop an independent course of applied chemistry single-handedly for Japanese officials and students, who were primarily interested in transplantation of Western-style technology and the exploitation of natural resources for the prosperity of their country.

Atkinson's solution to the problem of delivering lectures on 'manufacturing' chemistry was rather conventional. With no prior experience of working in factories, Atkinson explained the scientific principles of well-known chemical industries such as coal-gas and alkali manufacture without mentioning any technical details and could hardly have satisfied Japanese audiences. It was after all what most English chemists did as a part of their lectures on chemistry. A more successful part of Atkinson's curricula was his laboratory course. He could respond to their interest in the exploitation of natural resources by introducing the part of UCL's chemical education designed for training of consulting analytical chemists by one of his teachers, Charles Graham (1836-1909), with commercial goods, foodstuffs and water from various sources as samples of chemical analysis.

For example, Atkinson used samples of domestic natural products such as milk, sugar and iron ore in his basic analytical training courses. Atkinson also assigned water analyses to his students to train their analytical skills, which resulted in papers published by Atkinson as well as his students and partly contributed to the establishment of the Japanese water supply system.[4] In the last case, Atkinson's training at the RSM also possibly contributed to some extent, as his teacher there, Frankland, was famous for his consultancy in water analysis.[5]

In short, the first element of Tokyo's teaching programme of applied chemistry was analytical training for consulting chemists. That was largely the result of Atkinson's effort to make the most of his range of expertise and ideas of applied chemistry formed by his learning experiences in London for his new job in Tokyo.

Applied Chemist as 'fieldworker'

Atkinson's teaching programme did end not at this point, but with a graduation work, whose purpose, according to him, was to 'prepare students to improve the industries prospering in Japan'. As a logical consequence, Atkinson integrated into his course student excursions during summer vacation to traditional Japanese manufacturers. Atkinson's students did fieldwork there and, using the analytical skill obtained in his laboratory course, embarked on laboratory work with samples collected under Atkinson's supervision. These projects resulted in graduation theses, including 'On Japanese pigments' by Takamatsu, 'On Shoyu' [soy sauce], 'The Chemistry of Copper Smelting in Japan' by Nakazawa, and other titles such as 'Japanese tea and tobacco' and 'lacquer'. Atkinson's own research on sake brewing[6] during his Professorship at Tokyo University also originated in the student excursions and was aided significantly by Takamatsu and Nakazawa.

It is important to note that this 'fieldwork' aspect of Atkinson's teaching programme was not just the gathering and examination of raw materials and end products in terms of chemical analysis, as natural product chemists do. Rather, it was comparable to 'participatory observation' that a cultural anthropologist does in his or her fieldwork, entailing long stay in site, intensive interaction with indigenous people and building rapport with them. In fact, apart from results of chemical analysis, the existing thesis copies exhibit knowledge of indigenous manufactures and their technological details, shown frequently using diagrams, which was available only from a close collaboration with local manufacturers as informants.

The comparison between cultural anthropologists and Meiji applied chemists may sound unusual, but it does highlight the essential role of Japanese students in the development of Atkinson's teaching programme of applied chemistry. Just as cultural anthropologists often need informants or collaborators from indigenous societies, Atkinson's project would simply not have been feasible without students' participation as mediators, interpreters and practitioners. This comparison also explains why Takamatsu excelled in Atkinson's teaching scheme and received particular praise from him. This was because most local manufacturers belonged to the same social class as Takamatsu, i.e. wealthy farmers who ran manufacturing businesses. Takamatsu was presumably well prepared for networking, communicating and building rapport with such local manufacturers.

Atkinson's Japanese students also had recourse to *jitsugaku*, Chinese and Japanese indigenous scholarly traditions including *honzôgaku* (the studies of herbal medicine), *nôgaku* (agriculture studies) and *bussangaku* or studies of local products. All of these were based on fieldwork in Chinese and Japanese localities and often resulted in encyclopaedic reference works, which was made widely available by the development of publishing culture in Japan since the early 18th century.[7] All in all, in this second 'fieldwork' element of Atkinson's teaching programme, Atkinson was in many ways a pupil and his students were his teachers who brought Japanese scholarly traditions into Atkinson's teaching.

Applied Chemist as 'works chemist'

Takamatsu, Nakazawa and other Japanese students respected Atkinson as a diligent teacher and researcher. However, it does not mean that they were completely satisfied with Atkinson's approach to 'applied' or 'manufacturing' chemistry. Nakazawa in his later years claimed that Takamatsu, not Atkinson, was *the* founder of the teaching of applied chemistry in Japan. It is to be understood that Nakazawa's words are not to be taken literally, but one can hear his, and probably other students', dissatisfaction with Atkinson's teaching.

The missing ingredient in Atkinson's teaching was for them, the engineering or machine-operation aspect of the chemical industry. Atkinson's own lectures on Western-style chemical industries lacked any information about the technical details of machine operations, and his curriculum for chemistry students did not include any engineering subject, even though one of his colleagues at Tokyo University was an engineering professor. This lack was indeed a serious drawback for Takamatsu and Nakazawa because they were expected by Japanese officials to supervise the establishment of Western-style chemical industries in Japan such as the alkali and coal-gas industries. Both Takamatsu and Nakazawa used their opportunity of doing overseas study in Europe to supplement their learning experiences at Tokyo, albeit in different ways.

Takamatsu attended the course of 'technological chemistry' at Owens College Manchester, for which the Manchester- and Zurich-trained industrial chemist, Watson Smith (1845-1920) designed an educational scheme mainly for training of works chemists.[8] Drawing on his previous experiences in both the alkali and coal tar industries, Smith devoted a large part of his lectures to day-to-day plant operations at chemical works and the engineering aspects of the chemical industry. Smith frequently organised industrial tours to chemical works, and he required students to submit drawings in his examination questions. Takamatsu was awarded the first prize in Smith's course in 1881.

Nakazawa studied mainly in Germany and went beyond the ordinary academic sphere of universities and *Technische Hochschulen*. Nakazawa spent most of his time overseas visiting industrial exhibitions, local technology-related *Fachschulen*, that is German vocational schools and a wide variety of factories for products such as bricks, textiles, pottery, beers, glass, paper, cement and sugar as well as a workshop for dyeing textiles. In some of these firms, he did practical work himself. His overseas study in Germany developed his interest in chemistry-related industries and how modern Western factories actually worked. This in turn was reflected in his teaching at the Department of Applied Chemistry that favoured on-site factory training.

Indeed, Takamatsu and Nakazawa combined this engineering or factory element of applied chemistry with the two elements of Atkinson's teaching programme to produce their own version of applied chemistry teaching for Tokyo University and technical colleges in the late 1880s and 1890s. Their Department of Applied Chemistry used the whole laboratory teaching allocation for the first two years to train students thoroughly in analysis, comprising qualitative analysis, quantitative analysis and technical analysis, as much as in Atkinson's time. In addition, a large part of the curriculum for the first two years was devoted to engineering subjects, such as applied physics, steam engine, pumps, cranes, building construction, and mechanical drawing practice for applied chemistry students.

Its third-year, graduation work, was based on students' fieldwork in either a workshop in traditional Japanese manufacture or in a factory in the Western-style chemical industry and was structured in two sections: one involving a thesis and the other involving factory planning, design and drawing. Strongly reflecting Nakazawa's teaching philosophy, the object of the course of Factory Planning was to assign to students drawing the plans of a whole factory or part of a factory and to require them to add their own design in order to develop their business sense.

Particularly noteworthy were the research topics Takamatsu and Nakazawa gave to students for their graduation theses, which clearly showed the strata of several elements of applied chemistry teaching in Japan. They can be classified as: 1) the improvement of Japanese indigenous manufactures such as the investigation of enamel and cloisonné (*shippô-yaki*), 2) the exploitation of unused natural resources in Japan such as the method of extracting iodine from seaweed produced in Japan, and 3) solving technical problems in modern chemical industries introduced by transfer from Western countries such as glass making. All theses were grounded in analytical chemistry plus fieldwork that explored contemporary and traditional industries from which the samples had been acquired.

The teaching system of Takamatsu and Nakazawa was stabilised in the late 1890s, it became a prototype of applied chemistry teaching in Japan for its subsequent development in the 20th century, and contributed to the formation in Japan of a distinct and multiple identity for chemical technologists (*kagaku kôgyôka*), the differentiation of which from 'ordinary' chemists is epitomised by the separation of the Society of Chemical Industry of Japan (*Kôgyô Kagakukai*) from the Tokyo Chemical Society (*Tokyo Kagakukai*) in 1898.

Conclusion

Three points become clear when looking into the process of the establishment of applied chemistry teaching in Japan. The first point is the more-or-less common issue of teachers' range of abilities and outlook on applied chemistry, i.e. what they could teach and what they thought should be included in the course of applied chemistry. If this process is considered in the framework of model transfer, this point corresponds to the 'transferred' models. The second point is the importance of interaction, collaboration or even frustration, between a Western chemistry teacher and his Japanese students in the construction of the teaching practice of applied chemistry. In this sense, the mixture of analysis, fieldwork and engineering occurred by the mechanism of what sociologists call 'transculturation' within 'contact zones',[9] that is the modification, selection and hybridisation of 'host' and 'guest' cultural practices in a place where people with distinct cultural backgrounds mingle and interact with each other.

The above discussion also stressed the third point, the double role of applied chemistry for transplanting Western-style chemical industries, on the one hand and for innovating in the indigenous Japanese manufactures, on the one other, in Meiji period of Japanese industrialisation. This was where Atkinson showed a weakness as well as a great insight into a potential role of applied chemistry in Japanese industrialisation, by stating that the purpose of the graduation work was to 'prepare students to improve the industries prospering in Japan'. Indeed, contemporary technology-minded Japanese officials were preoccupied with the transplantation of Western-style technology. Most of later historians of Japanese technology followed this assumption and have long considered it to be the sole vehicle of Japanese industrialisation. It is only recently that innovation in indigenous manufacturing sectors using Western scientific and technological know-how has been a focus of historical studies as an equally important feature of Japanese industrialisation.[10] This insight of Atkinson was a major reason why, with all its drawbacks, his teaching of applied chemistry had long-term consequences for his students' teaching activities.

Notes

1 A full version of this paper will be submitted to *Historia Scientiarum*, the Western-language journal of the History of Science Society of Japan.

2 See David Knight, *Ideas of Chemistry* (London: Athlone Press, 1992) on European's images of chemistry, and Togo Tsukahara, *Affinity and Shinwa Ryoku: Introduction of Western Chemical Concepts in Early Nineteenth-Century Japan* (Amsterdam: J.C. Gieben, 1993) for the introduction of chemistry into Japan and the image of chemistry for Japanese in the early nineteenth century.

3 Robert F. Bud and Gerrylynn K. Roberts, *Science versus Practice: Chemistry in Victorian Britain* (Manchester: Manchester University Press, 1984).

4 Atkinson's impact on Japanese water analysis in the early Meiji period is analysed in Hisao Shiokawa, "R.W. Atkinson: Shôgai to kare ni yoru jôsui suishitsu bunseki ni tsuite [R.W. Atkinson: On his life and drinking water analysis]," *Kagakushi* no. 6 (1977): 20-24.

5 See Colin A. Russell, *Edward Frankland: Chemistry, Controversy and Conspiracy in Victorian England* (Cambridge: Cambridge University Press, 1996), p. 362.

6 See Junji Tomozawa, "Atokinson ni yoru Nihon-shu jôzô no kenkyû [R.W. Atkinson's Study of Sake Brewing]," *Kagakusi Kenkyû* 75 (1965): 114-123 for a good summary of Atkinson's research on Sake brewing and the response of Japanese brewers to Atkinson's research. See also Tessa Morris-Suzuki, *The Technological Transformation of Japan: From the Seventeenth to the Twenty-first Century* (Cambridge: Cambridge University Press, 1994), p. 109.

7 *Jitsugaku* literally means 'real learning' 'practical learning' or 'learning with substances' and was used polemically by a variety of scholars and thinkers in the Tokugawa period to criticise the 'futility' of the abstract theories of their rivals which were not based on actual experiences. Here I follow the definition of *jitsugaku* by the Japanese historian Sugimoto Isao as indigenous empirical learning for utilising natural resources for the benefit of people (*riyô kôsei no gaku*). See Isao Sugimoto, *Kinsei Jitsugakushi no Kenkyû: Edo Jidai Chûki ni okeru Kagaku Gijutsugaku no Seisei* [A Study of the History of *Jitsugaku* in early modern Japan: the emergence of science and technology studies in the mid Tokugawa period] (Tokyo: Yoshikawa Kôbunkan, 1962).

8 See also James F. Donnelly, "Getting Technical: the Vicissitudes of Academic Industrial Chemistry in Nineteenth Century Britain," *History of Education* 26 (1997): 125-43, on pp. 131-136.

9 See, e.g., Mary Louise Pratt, *Imperial Eyes: Travel Writing and Transculturation* (London and New York: Routledge, 1992).

10 See, for example, Tetsurô Nakaoka, *Nihon Kindai Gijutsu no Keisei: "Dentô" to "Kindai" no Dainamikkusu* (Formation of Modern Japanese Technology: Dynamics between "traditional" and "modern") (Tokyo: Asahi Shinbunsha, 2006).