11

Inventing Laboratory Science in Meiji Japan

Yoshiyuki Kikuchi

Introduction

In this chapter, I address the question of how laboratory science emerged in Japanese universities in the Meiji period (1868–1912), with a strong emphasis on the 'laboratory' as both a concept and a physical space designed to facilitate students' training. In the following, I discuss how three issues—the concept, design, and training function of the laboratory—developed and became inseparably intertwined with each other. In the Japanese case, I argue that there was an additional linguistic element; hence, the chapter starts with the following question: How was the word 'laboratory' understood by the Japanese in the vernacular?

Making Sense of the Laboratory

The Meiji Restoration in 1868 is often credited as the starting point of Japan's introduction to Western science and Western culture more broadly. But this is not exactly the case. One should also consider the development of Dutch learning in Japan during the Tokugawa period (1603–1868) from the eighteenth century onward, mainly through the activities of medical doctors and astronomers.[1] Dutch learning was later expanded into 'laboratory' science, including chemistry, by the 1840s, exemplified by the landmark publication between 1837 and 1847 of *Seimi kaisō* 舎密開宗 (*Introduction to Chemistry*), based on William Henry's highly experimental

[1] For an overview of the history of Dutch learning in Japan, see Tadashi Yoshida, 'Tenbō: Rangakushi', *Kagakusi Kenkyū*, 23 (1984), 73–80. On the chemistry components of Dutch learning, see Togo Tsukahara, *Affinity and Shinwa Ryoku: Introduction of Western Chemical Concepts in Early Nineteenth-Century Japan* (Amsterdam, 1993).

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Epitome of Chemistry (1801) and other chemistry textbooks translated by UDAGAWA Yōan 宇田川榕菴 from Dutch.

That said, the laboratory as a specific space for experimentation was relatively new to Japan, despite some practitioners of Dutch learning who were familiar with experimentation. It is known that Udagawa added the outcomes of his own chemical experiments to *Seimi kaisō*.[2] Nevertheless, no specific term seems to have been coined to designate the place where practitioners conducted experiments, in spite of the fact that they, including Udagawa, were masters at creating Japanese neologisms. This strongly suggests that scholars of Dutch learning in the Tokugawa period did not recognize the laboratory as a concept worthy of being assigned a vernacular term.

It is still difficult to pinpoint when the laboratory as a concept was introduced to Japan; however, one of the earliest documented examples of a laboratory in Japan was the Osaka Seimi-kyoku 大阪舎密局, a chemistry teaching laboratory established by the Dutch army surgeon and chemist, Koenraad Wolter Gratama in Osaka in 1869. It had its origin in a laboratory attached to the Dutch-run shogunate hospital and medical school in Nagasaki, the Seitokukan 精得館.[3] Gratama himself called the Seimikyoku *het Laboratorium* in his letters to his brother.[4] It therefore makes sense to tentatively consider *Seimi-kyoku* as a candidate for the first Japanese translation of 'laboratory'.

This conjecture is supported by a perusal of contemporary dictionaries. An English-Japanese dictionary published in 1869 defined a laboratory as 'the workplace of chemists (*seimi-ka*)'.[5] The author of this entry was clearly aware of the laboratory's connection with chemistry, but could not yet find or coin a Japanese term corresponding to it. Two years later, a French-Japanese dictionary was published that translated the French word *laboratoire* into the Japanese *Seimi-kyoku*, following the example of the Osaka Seimi-kyoku.[6] One senses, here, how the name of a particular institution began to crystallize the Japanese notion of a laboratory that had already vaguely existed, but was not yet well articulated.

Seimi-kyoku, as the translation of 'laboratory' (*seimi* meant chemistry) might puzzle and surprise Japanese scientists today, who are used to *jikken shitsu* 實驗室 or *jikken sho/jo* 實驗所 as the translation of 'laboratory'.

[2] Ibid, 147.

[3] H. Beukers, A. M. Luyendijk-Elshout, M. E. van Opstall, and F. Vos (eds.), *Red-hair Medicine: Dutch-Japanese Medical Relations* (Amsterdam and Atlanta, GA, 1991).

[4] K. W. Gratama, *Leraar onder de Japanners: Brieven van Dr K. W. Gratama betreffende zijn verblijf in Japan, 1886–1871 (*Amsterdam, 1987), 103 *et passim.*

[5] My translation, in *Eiwa taiyaku shūchin jisho/A Pocket Dictionary of the English and Japanese Language*, second and revised Edition (Tokyo, 1869), 221.

[6] *Kankyo Futsuwa Jiten/Nouveau Dictionnaire Français-Japonais renfermant les Principaux Mots composés et un grand nombre de locutions* (Shanghai, 1871), 239.

Indeed, reflecting the relative novelty of the laboratory as a concept in Japan, there was no fixed Japanese term for a laboratory until the 1890s. To illustrate this, I shall take as examples Tokyo University (*Tokyo Daigaku* 東京大學) and the Imperial College of Engineering (*Kōbu Daigakkō* 工部大學校), Tokyo, as the two flagship institutions for higher education in science and technology in Japan during the 1870s and early 1880s.

Shiken Shitsu or *Jikken Shitsu*? Translating 'Laboratory'

The calendars and annual reports of Tokyo University during this period, in both English and Japanese, show a noticeable dichotomy and eventual convergence in their translations of 'laboratory' into Japanese. The two terms most often used are *shiken shitsu* 試驗室 and *jikken shitsu* 實驗室. *Shitsu* means a room and was often replaced by *jō* 場, meaning a place, as in *jikken jō* 實驗場 or 試驗場 *shiken jō*, without changing its meaning.

In 1874, a *jikken jō* first appeared in university annual reports, referring to a physics laboratory (i.e., *butsurigaku jikken jō* 物理學實驗場). By contrast, a chemistry laboratory was first called *kagaku seiren jō* 化學製煉場, literally a 'chemical refining place', but renamed *shiken shitsu* the following year.[7] The 1874 annual report of Tokyo University did not mention a laboratory for any other subject than physics and chemistry.

This *jikken/shiken* dichotomy continued until 1877, when a laboratory for chemistry started to acquire a term similar to that of a physics laboratory, namely, *jikken shitsu*.[8] From 1878, *jikken shitsu* gradually spread to other subjects taught at Tokyo University, such as metallurgy, mining, and zoology.[9] These developments were codified in 1880, when *jikken jō* started to be used as the translation of 'laboratory' in Tokyo University's calendar, within the instruction that '[the] lecture-rooms and laboratories assigned to Professors are put under the care of their respective assistants, or under the care of the secretary of the University'.[10] The point here is that *jikken jō* was adopted as a generic term applying to all the laboratories in Tokyo University by 1880. It took some time for *jikken shitsu/jō* to become part of the Japanese vocabulary; it was in the 1900s that

[7] Tokyo Daigakushi shiryō kenkyūkai (ed.), *Tokyo Daigaku nenpō* (6 vols, Tokyo, 1993–1994), i, 18 and 25. This source is hereinafter referred to as *Tokyo Daigaku Nenpō*.

[8] Ibid, 68.

[9] Ibid, 94, 115, and 157.

[10] *Tokyo Daigaku Hō- Ri- Bungakubu Ichiran, Meiji jūsan yon nen*, 132; University of Tokyo, *Academic Calendar 2540–41 (1880–81)*, 82. See also the calendar for the Medical Faculty of Tokyo University, *Tokyo Daigaku Igakubu Ichiran. Meiji jūsan yon nen* (Tokyo, 1881), 98–9.

English-Japanese and German-Japanese dictionaries started to adopt *jikken shitsu* as the primary translation of 'laboratory'.[11]

I have so far explained these linguistic minutiae because there were subtle, but important, differences between a *shiken* and *jikken*. On the one hand, *shiken* simply means 'to examine' or 'to prove'. For example, if one examines a person, it means an examination, but if one examines materials, it means an analysis or assay. That is why *shiken shitsu/jō* was first used to refer to a chemical and assaying laboratory designed specifically to use blowpipes at Tokyo University.

In this context, it is worth mentioning that the Imperial College of Engineering, Tokyo, adopted *shiken jō* for both physical and chemical laboratories throughout its existence between 1873 and 1886, when it merged with Tokyo University to form Tokyo Imperial University.[12] It is important to keep in mind that the Imperial College of Engineering was, as its name suggests, an *engineering* school under the control of the Ministry of Public Works. Examining materials such as chemicals, ores, and electrical wires was the main concern of both the physics and chemistry laboratories there; it is arguably for this reason that they retained the name of *shiken jō*. Indeed, this industrial connotation of *shiken* is underscored by the fact that industrial research laboratories were consistently called *shiken jo* 試驗所, at least until the mid-twentieth century.[13]

Meanwhile *jikken* has a more complex history,[14] essentially being a composite term of *jissai* 實際, meaning 'in actuality' or 'actually', and *shiken*. It can also be a composite of *jitchi* 實地, meaning 'on site', and *keiken* 經驗, meaning 'experience'. One could shuffle these words to obtain various combinations. *Jikken shitsu/jō* then meant a place 'to actually experience/examine' natural phenomena—a suitable term for scientific pedagogy applicable to physics, chemistry, and other subjects. In addition, in the medical context, there was a long-standing tradition

[11] Naibu Kanda et al. (eds.), *Shin'yaku Eiwa Jiten* (Tokyo, 1902), 558; Shinkichi Fujii (ed.), *Nijusseiki Dokuwa Jisho/Deutsch-Japanisches Wörterbuch des Zwanzigsten Jahrhunderts* (Tokyo, 1907), 580. By contrast, in the 1880s and 1890s English-Japanese dictionaries adopted more industry-oriented translations such as *seiren kyoku* (refining place), *kōsaku jo* (workshop), and *gunki seizō sho* (arsenal) in addition to the earlier *seimi kyoku*; for example, Shōkichi Shibata and Takashi Koyasu (eds.), *Eiwa Jii/An English and Japanese Dictionary, Explanatory, Pronouncing and Etymological* (Tokyo, 1882), 566; Sumio Nakazawa et al. (eds.), *Eiwa Jiten/A New English-Japanese Dictionary. Based on the Current English Literature* (Tokyo, 1897), 359.

[12] *Kōbu Daigakkō daini nenpō (Meiji jūroku nen shigatsu yori Meiji jūshichi nen sangatsu ni itaru)*, 70 *et passim*.

[13] See, for example, Chikayoshi Kamatani, *Gijutsu taikoku hyakunen no kei: Nihon no kindaika to kokuritsu kenkyū kikan* (Tokyo, 1988), 17.

[14] See Kiyonobu Itakura, 'Nihon ni okeru jikken gainen to sono kotoba no rekishi', *Kasetsu jikken jigyō kenkyū*, 3/5 (1994), 22–53.

dating back to the eighteenth century of equating *jikken* 實驗 with 實見, meaning 'to actually see', which later turned into 'to diagnose'.[15] In Japanese (though not in Chinese) these two words are pronounced in exactly the same way. *Jikken*, in the annual reports of Tokyo University's Medical Faculty during the 1870s and 1880s, followed this definition.[16]

Thus, the gradual renaming of a chemical laboratory, from *seiren jō* and *shiken shitsu* to *jikken shitsu,* at Tokyo University likely signaled the broadening of its meaning. It came to include both a place to refine chemicals and analyze samples and a place for students to see and experience natural phenomena, such as in a physics laboratory. The University's adoption of *jikken shitsu* or *jikken jō* as the generic translation of 'laboratory' by the early 1880s was due to its capacity to convey wide-ranging meanings. That is, 'to actually examine/experience/see' or even 'to diagnose'.

I argue that this broad meaning of *jikken shitsu/jō* qua laboratory led to its proliferation in a variety of disciplines at Tokyo Imperial University by the early 1900s,[17] when it became part of the Japanese vocabulary. Two informative, albeit incomplete, sources to consider at this point are the bilingual albums of Tokyo Imperial University, published for display at the International Expositions in Paris in 1900 and in St. Louis, Missouri, in 1904.[18]

Photographs included in the 1900 album featured an anatomy laboratory at the College of Medicine; laboratories for electrical engineering, mechanical engineering, applied chemistry, and assaying at the College of Engineering; laboratories for zoology and geology at the College of Science; and a laboratory for agricultural chemistry at the College of Agriculture.[19] When this album was revised for the 1904 International

[15] See, for example, the memoir of Sugita Genpaku (1733–1817), the pioneer of Dutch-style medicine in the Tokugawa period, *Rangaku kotohajime* (1815). Sugita Genpaku (annotated by Ogata Tomio), *Rangaku Kotohajime* (Tokyo, 1959), 36 et *passim*. I owe this point to Masao Uchida of Dokkyo University.

[16] For example, *jikken roku* 實驗録 meant medical records typically taken in consultation rooms. See, e.g., *Tokyo Daigaku Nenpō*, i (1881), 214. James R. Bartholomew, *The Formation of Science in Japan: Building a Research Tradition* (New Haven, CT, 1989), 93, briefly mentioned *jikken* in the medical context, but simply translated it as 'experimentation' and did not discuss the various meanings of *jikken*.

[17] More precisely, it was first named the Imperial University (*Teikoku Daigaku* 帝國大學) in 1886 and was renamed Tokyo Imperial University (*Tokyo Teikoku Daigaku*) in 1897 when the second imperial university, Kyoto Imperial University, was instituted. Throughout this chapter, I use Tokyo Imperial University to avoid confusion.

[18] Kazumasa Ogawa, *Imperial University of Tōkyō/Tokyo Teikoku Daigaku* (Tokyo, 1900) and its 1904 version.

[19] The 'Colleges' referred to in this paragraph were constituent units of Tokyo Imperial University, equivalent of the German idea of *Fakultäten* (faculties). The College of Engineering was an independent institution before its merger with the university.

Exposition, the laboratories for physiology (both a vivisectorium and laboratory for electro-physiology), pathology, pharmacology (both a laboratory of kymographic experiments and a chemistry laboratory), hygiene, internal medicine, medical chemistry, and ophthalmology were added—all as part of the College of Medicine. An important example not included in the 1904 album was the laboratory for psychophysics, completed in 1903 and attached to the Department of Philosophy at the College of Literature in Tokyo. It is in this laboratory that the history of experimental psychology began in earnest in Japan.[20]

Although these rooms had a variety of forms, functions, and equipment, they shared the common purpose of giving students opportunities for individual training, enabling them to actually witness and experience disciplinary practices. That is why they were called, in the same way as in Japanese, *jikken shitsu.* The rapid development of experimental medicine, physiology, and psychology in Europe and North America throughout the nineteenth century is certainly part of the story.[21] The broad, all-encompassing nature of *jikken* in Japanese science was also a factor in this development.

Research Training at the *Jikken Shitsu* in Tokyo

If the common purpose of laboratories in Japanese universities at the turn of the century was to provide students with individual training in, and actual experience of, disciplinary practices, how did such training relate to the training of researchers, which is the main theme of this volume?

To address this question, one first has to look broadly into the way in which research activities were situated within Tokyo Imperial University during the Meiji period. Article One of The Imperial University Ordinance, enacted in 1886 to give a legal basis to Tokyo Imperial University, laid out the objective of the institution as instruction in the sciences (*gakujutsu* 學術) and arts (*gigei* 技藝, or skills) according to the needs of the nation, and the profound study [*unnō o kōkyū suru* 蘊奥ヲ攷究スル] of such sciences and arts. Within the university, *bunka daigaku* 分科大學 (subject-based undergraduate colleges or faculties such as the College of Science) were instituted as the places for instruction, and the *daigakuin* 大學院 (the graduate school attached directly to the Imperial University) as the place for 'profound study' (Article Two of the ordinance). These designations

[20] Tatsuya Satō, *Nihon ni okeru shinrigaku no juyō to tenkai* (Kyoto, 2002), 338–62.

[21] William Bynum, *Science and the Practice of Medicine in the Nineteenth Century* (Cambridge, 1994), 92–117.

suggest that places for instruction and for advanced research were neatly divided within Tokyo Imperial University from its inception in 1886.

The reality, however, was much messier and the positioning of research much more ambiguous within Tokyo Imperial University throughout the whole Meiji period. It continued until the establishment of the Institute of Physical and Chemical Research (*Rikagaku Kenkyūjo* 理化學研究所 or RIKEN) in 1917, except for a few practical fields such as medicine, engineering, meteorology, and seismology.[22] As SAKURAI Jōji 櫻井錠二, one of the founding professors of the Department of Chemistry at the College of Science, Tokyo Imperial University, vividly recollected in his autobiography:

> No funds in the university budget were allocated to research expenditure. Professors only secretly diverted part of the budget, which was officially allocated to student experiments based on the number of students, to their own research.
>
> It is beyond comprehension that there are no funds at all allocated for research expenditures within university budgets in spite of the fact that its object was grandly defined as 'to instruct the theory and application of sciences and arts in needs of the nation and to study them deeply' in Article One of the Imperial University Ordinance in 1886 as well as of the University Ordinance in 1918. By the same token, the so-called 'graduate school' was almost nothing but a name. These are an utter contradiction to half of the objectives of the university, which were completely forgotten.[23]

This is an important statement, because the original 'laboratory science' in Japan was none other than chemistry, as discussed. Nevertheless, if, as Sakurai suggested, the institutional push for research was nominal in Tokyo during the Meiji period, it does not necessarily follow that research training was non-existent there. To verify its existence, we must go beyond the macro-level institutional framework of decrees and budgets (though they were both important) and look into the development of laboratory training at the micro level.

A good focal point for such micro-level investigations is the first chemistry laboratory project completed at Tokyo Imperial University: the

[22] James R. Bartholomew, *The Formation of Science in Japan*, 111–24 and 162–98; and Ito Kenji, 'The question of research in prewar Japanese physics', in David. G. Wittner and Philip C. Brown (eds.), *Science, Technology, and Medicine in the Modern Japanese Empire* (London and New York, 2016), 193–210.

[23] My translation, from Sakurai Joji, *Omoide no kazukazu: Danshaku Sakurai Jōji ikō* (Tokyo, 1940), 18–19. This statement was referred to in Bartholomew, *The Formation of Science in Japan*, 213; and Yoshiyuki Kikuchi, *Anglo-American Connections in Japanese Chemistry: The Lab as Contact Zone* (New York, 2013), 104.

construction of the Main Building of the College of Science (*Rika Daigaku Honkan*) between 1885 and 1888, the second floor of which accommodated a laboratory for its Department of Chemistry (while the first floor was shared by the Department of Physics, the Department of Mathematics, and the College of Science Administrative Office).

As I discussed elsewhere,[24] this building was first designed by NAGAI Nagayoshi 長井長義, a pharmaceutical chemist trained at the University of Berlin by August Wilhelm Hofmann. Nagai designed a laboratory complex accommodating a variety of laboratories, a lecture theatre, lecture rooms, and operation rooms, imitating the Chemical Institute at Berlin designed by Hofmann (Figures 11.1 and 11.2). This contained only one office for a full professor and one for an assistant professor, clearly reflecting the one-chair-per-discipline system of the German universities. It also had a 'pharmaceutical research laboratory', which in all likelihood was intended as Nagai's personal laboratory and would have been in a good position to facilitate the laboratory work of students and assistants. This had been the main concern of Hofmann in planning his laboratories.

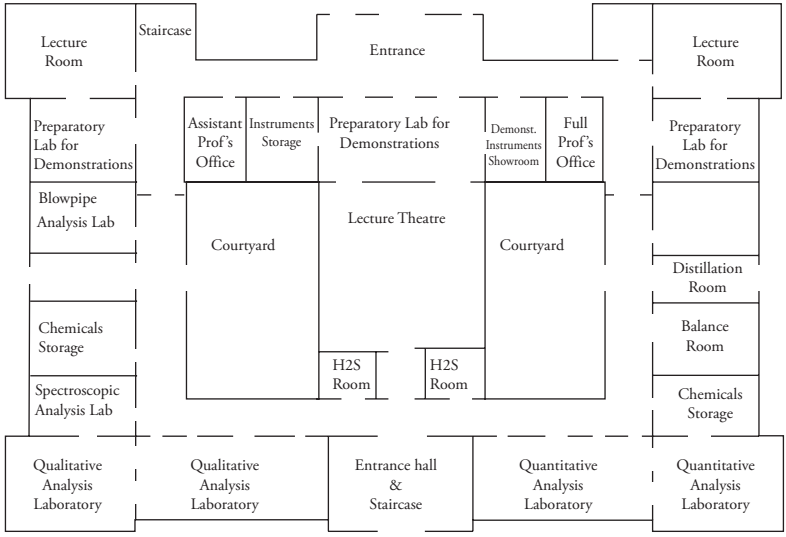

Figure 11.1 Nagai's Laboratory Design (First Floor). Reproduced from Yoshiyuki Kikuchi, *Anglo-American Connections in Japanese Chemistry: The Lab as Contact Zone* (New York: Palgrave Macmillan, 2013), 112. Courtesy of the author.

[24] Ibid, 107–26.

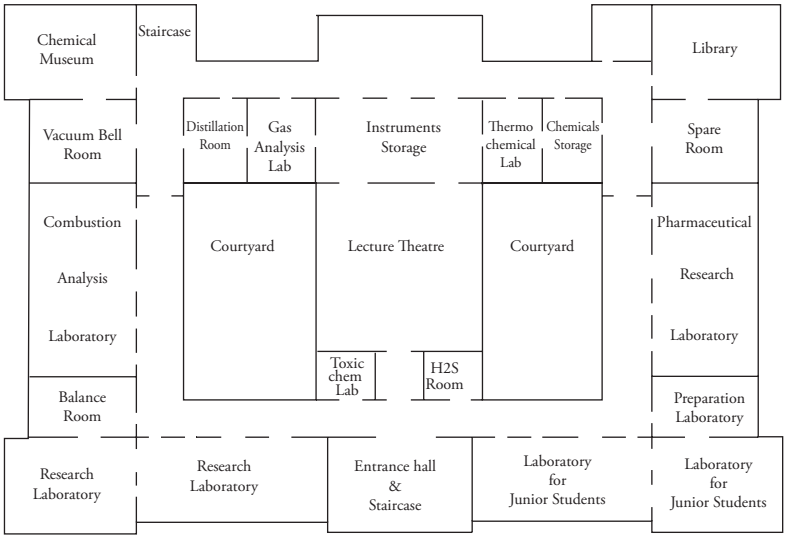

Figure 11.2 Nagai's Laboratory Design (Second Floor). Reproduced from Kikuchi, *Anglo-American Connections in Japanese Chemistry*, 112. Courtesy of the author.

This, however, was eventually finished and partly occupied by Edward Divers and Sakurai, the two founding professors of the Department of Chemistry at Tokyo Imperial University. Prior to his appointment at Tokyo Imperial University, Divers was trained at the Royal College of Chemistry (RCC), London, and taught at the Imperial College of Engineering, Tokyo. Sakurai was first trained at Tokyo University, then at University College London (UCL), and taught at Tokyo University, his alma mater. Divers and Sakurai adapted Nagai's design while keeping its basic character as a departmental space for chemistry. Though adaptation was needed anyway to cope with the reduction of space for chemistry, other factors, I argue, were influential.

To understand this, one has to look at Divers' and Sakurai's views of the training of researchers. The idea of educating students through research had existed before the establishment of Tokyo Imperial University in 1886. Robert William Atkinson, the first professor of chemistry at Tokyo University and a teacher of Sakurai, left this testimonial in 1875:

> The second-year students of this department showed a remarkable aptitude for chemistry through this year's learning and began to do chemical investigations (*kagaku shiken*) on their own. From this I have to say that they take this science seriously and more and more aspire to study it.[25]

[25] My translation, cited in Ibid, 44.

Sakurai was included in these 'second year students' and later started his career as a research chemist at UCL with Atkinson's former teacher, Alexander William Williamson.[26]

Likewise, in 1877, during his professorship at the Imperial College of Engineering, Tokyo, Divers formulated a view of the pedagogical meaning of laboratory training:

> The best of them [chemistry students] have shown powers of close observation of the phenomena which they have developed in their experiments, and, as a consequence, a capacity for making original observation [*sic*], and, along with this, the ingenuity and perseverance necessary to give fruit to their observations.[27]

Therefore, the question one should address here is not whether, but how, Divers and Sakurai trained students in chemical research in the laboratory.

Divers's approach to research training was what might be called an 'apprenticeship model'. It arguably originated in his experiences at RCC, where he attended the lectures of August Wilhelm Hofmann and received laboratory training from William Crooks, who was then a teaching assistant. At Queen's College, Galway, he was a teaching assistant serving the professor of chemistry. Divers's teaching style crystallized at the Imperial College of Engineering, Tokyo, in which '[the] students have been assisted at their work by the assistants and myself, and the juniors by the seniors'. Divers was actively engaged in joint research with assistants and advanced students, both at the Imperial College of Engineering and then Tokyo Imperial University, which often led to papers with joint authorship.[28]

Divers' experience in research training described above included three categories of people: professors, assistants, and students. When professors trained students, what was the role of assistants? Interestingly, Divers considered assistants both as trainers and trainees. As he wrote in 1877:

> The aid I have hitherto had in the laboratories has been that of three assistants, only two of whom had any knowledge of chemistry. These officers have always shown themselves exceedingly willing to do their best, but they seem to me to have not taken much interest in teaching. In saying this I do not mean to impute any blame to them, for their time has been too occupied by their duties to improve themselves. [...] In such ways and others they prove themselves most useful and necessary to me, but at the same

[26] Ibid, 65.

[27] Cited in Yoshiyuki Kikuchi, 'Cross-National Odyssey of a Chemist: Edward Divers at London, Galway and Tokyo', *History of Science*, 50 (2012), 289–314; on 299.

[28] Kikuchi, 'Cross-National Odyssey', 301f and Kikuchi, *Anglo-American Connections*, 138–40.

> time are deprived of much opportunity of training themselves as teaching assistants.[29]

This quotation shows what Divers expected from assistants: they *should* have taken interest in teaching and *were supposed* to be engaged in self-training. Divers was clearly frustrated with Japanese assistants at the Imperial College of Engineering, since his assistants did not meet these expectations. It is not difficult to understand why Divers struggled to find suitable talent in 1877. The first chemistry students in his laboratory did not graduate until 1879, meaning that the assistants with whom Divers had been working in 1877 had not received adequate training. He finally succeeded in finding such talent in HAGA Tamemasa 垪和爲昌, one of Divers' best students (who graduated in 1881), who later became assistant professor at the Imperial College of Engineering, and his life-long collaborator there and at Tokyo Imperial University.

By contrast, Sakurai's approach can be characterized as a laissez-faire, individualistic approach to research training. Following Williamson as a role model, he considered lecturing as the main pedagogical medium, whereby he suggested promising research topics, but rarely supervised students' laboratory work, which he delegated to a teaching assistant.[30] Himself a research chemist with a modest output, Sakurai published papers only in singular authorship and never conducted joint research.[31]

Instead, in the hope of nurturing students' independence and 'inquisitive minds' through presentation and discussion, Sakurai helped introduce to the Department of Chemistry the reading seminar in the form of the *Zasshi-kai* 雜誌會, which was managed by students.[32] *Zasshi-kai* as a term was coined by KUHARA Mitsuru 久原躬弦, Sakurai's classmate at Tokyo University, who later studied at the Johns Hopkins University with Ira Remsen. It was a direct translation of 'journal meeting' as organized there by Remsen. However, Sakurai had a similar pedagogical experience in UCL's Chemical and Physical Society, which had a student-centered structure similar to that of the *Zasshi-kai*. For Sakurai, it was important that students be voluntarily engaged in research.

The above discussion shows that Divers and Sakurai held different views on the training of researchers. There was, however, one commonality in their views: the crucial role of a teaching assistant (played by a junior professor) as a supervisor of students' laboratory work and as a mediator between students and senior professors. Together with the Japanese

[29] Imperial College of Engineering *(Kobu-Dai-Gakko)*, Tokei, *Class Reports by the Professors for the Period 1873–1877* (Tokyo, 1877), 36.
[30] Kikuchi, *Anglo-American Connections*, 118 and 129–35.
[31] Ibid, 142–5. [32] Ibid, 120–3.

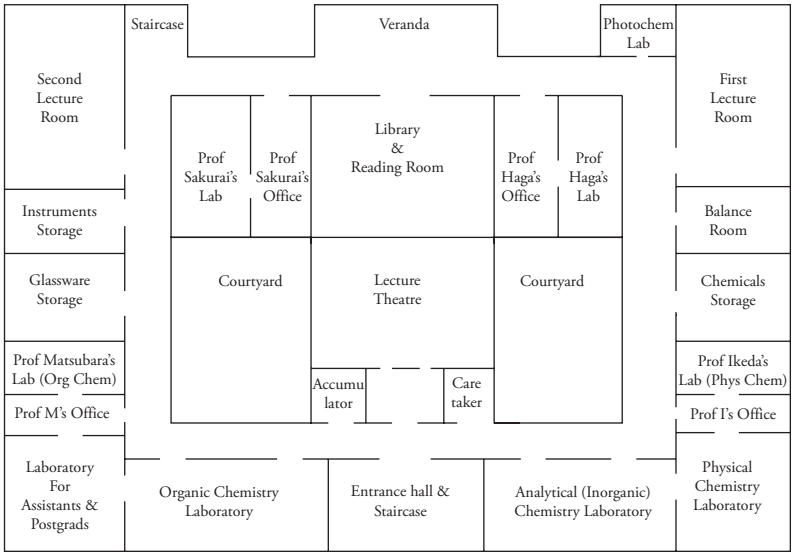

Figure 11.3 Sakurai and Divers' Laboratory Design: Reproduced from Kikuchi, *Anglo-American Connections in Japanese Chemistry*, 117. Courtesy of the author.

conceptualization of laboratories as *jikken shitsu*, this is key to understanding Divers' and Sakurai's laboratory design (Figure 11.3).

Firstly, unlike Hofmann's and Nagai's laboratories that focused on analytical training and were divided into junior and advanced spaces, Divers' and Sakurai's student laboratory was divided into laboratories for organic, analytical (inorganic), and physical chemistry, based on Sakurai's own laboratory teaching program that aimed to provide students with a wide range of experiences and was aligned with the broad meaning of the *jikken shitsu* at Tokyo University. In the drawing (Figure 11.3), these student laboratories filled the base of the quadrangular building, together with a small laboratory for assistants and postgraduates. Laboratories for undergraduates and postgraduates were divided, though they were labeled with the same designation: *jikken shitsu*. We cannot tell from the plan which laboratories were for basic training and which were for research training, and there were no formal postgraduate curricula or courses for the whole period this chapter covers.

The positions of the professors' offices and private laboratories in relation to those of the students' laboratories were important features of Sakurai's and Divers' teaching spaces. According to their laboratory design (Figure 11.3), the two offices for senior professors, facing the courtyards, were

close to lecture rooms, but physically isolated from the students' laboratories. By contrast, the two offices for junior professors were located between senior professors' offices and the students' laboratories and were directly connected to the latter. Students could enter the junior professors' offices and vice versa, without using corridors.

This arrangement effectively defined the respective roles of the senior and junior professors as determined by Sakurai and Divers, who designed the entire floor. The supervision of students' experiments *at all levels* was basically the responsibility of junior professors, whereas the main role of the senior professors, in relation to the undergraduates, was to prepare and deliver lectures. The centrality of the *Zasshi-kai* in the pedagogical regime of Sakurai's Department of Chemistry is underlined by the central location of the departmental library and reading room in the departmental space, adjacent to the offices of two senior professors.[33] Perhaps the scarcity of Western books and periodicals made a specialized library all the more important for science professors and students in Meiji Japan. But the central location of the library is also due to the important role Sakurai ascribed to the *Zasshi-kai* in his transfer of 'pure' chemical research, as mental training, to Japan.

One implication of this pedagogical structure was its effect on how research practice developed in Tokyo's Department of Chemistry. Though its curriculum did not include a graduation thesis for final-year students in 1886, close relationships in laboratories between junior professors and chemistry undergraduates, which were encouraged by the spatial structure of the department, did occasionally lead to research partnerships. Haga's supervision of MAJIMA Rikō's 眞島利行experimental training resulted in research partnerships.[34] IKEDA Kikunae 池田菊苗, who succeeded Haga as assistant professor to Divers, also co-authored research papers with his students.[35] By the same token, as a long-time collaborator of Divers, Haga also played a role in bridging students and Divers, which resulted in fruitful research collaborations. The annual departmental conference for the presentation of graduation theses (*Sotsugyōsei Gyōseki Hōkokukai* 卒業生業績報告會), where final-year students were obliged to present graduation theses, was instituted in 1906, though not at the

[33] Ibid, 122–3.

[34] See their research paper: Tamemasa Haga and Riko Majima, 'Über einige anhydrobasen aus diaminen der Fettreihe', *The Journal of the College of Science, Imperial University of Tokyo, Japan*, 19 (1903), Article 7.

[35] Kikunae Ikeda and Tokuhei Kametaka, 'Dōzokutai no futten ni tukite', *Tokyo Kagaku Kaishi,* 20 (1899), 5–41. See also Masao Katayama, 'Über die Natur der Jodstärke', *Zeitschrift für anorganische Chemie*, 56 (1907), 209–17, in which Katayama acknowledged Ikeda's help, but not Sakurai's.

initiative of any senior professors, but on the suggestion of Majima, who was then assistant professor and had already started to look to Germany rather than England for a model to follow.[36] In the 1900s, the culture of instilling the 'research imperative' among students at the Department of Chemistry was initiated by junior professors rather than top-down from senior professors. The publication of research by students had started earlier, in the early 1890s.[37] These papers were generally published when their authors were postgraduates, but as the above Departmental Conferences showed, research training at Tokyo's Department of Chemistry started when students were advanced undergraduates.

Study Abroad

It is important to emphasize that the training of most Japanese scientists in the Meiji period was not complete without government-funded overseas study. As seen above, Nagai and Sakurai had studied abroad and brought home what they considered the ideal chemical teaching and laboratory from their time abroad. Nagai's overseas study, spanning between 1871 and 1884, was based at one institution, the University of Berlin. It was funded by the Japanese government, but his status changed from a student to a Japanese government employee in 1876, and Nagai received additional income as Hofmann's assistant starting in 1881 when he acquired his PhD at Berlin.[38] Sakurai's study abroad, from 1876–1881, was shorter than Nagai's, but was still substantially longer in comparison with those of Japanese scientists later. He was also based at one institution alone—University College London. His stipends, first paid by the Japanese government, were augmented by a scholarship from UCL.[39] Both Nagai and Sakurai were awarded the Japanese degree of Doctor of Science (DSc) in 1888 by the recommendation of the Imperial University Council (*teikoku daigaku hyōgikai* 帝國大學評議會, the highest governing body of the University) after their overseas study. Their degrees mainly recognized their publications that had started in Europe. Indeed, they were essentially products of European research education.

[36] See Majima, 'Waga Shōgai no Kaiko', *Kagaku no ryōiki*, 8 (1954), 1–11 and 137–46; on 6.

[37] Kikunae Ikeda, 'Capillary attraction in relation to chemical composition, on the basis of R. Schiff, *The Journal of the College of Science, Imperial University, Japan*, 3 (1890), 241–68. A list of publications from the department is appended to Jitsusaburō Sameshima, 'Kagakuka', in *Tokyo Teikoku Daigaku gakujutsu taikan: Rigakubu, Tokyo Tenmondai, Jishin Kenkyūjo* (Tokyo, 1942), 122–36.

[38] Seizō Kanao, *Nagai Nagayoshi den* (Tokyo, 1960), 453–5.

[39] Kikuchi, *Anglo-American Connections*, 65–70.

In a later period, overseas study became shorter but continued to be a *sine qua non* for Japanese academics. They usually studied abroad in multiple places when they were assistant professors, and were promoted to full professorships after the study.[40] They did not study for degree abroad, and often received doctorates at home after their time abroad. Connections between their overseas study and the conferrals of their Japanese doctorates became more complex. Doctorates then were conferred either on the recommendation of the university council, as in the above cases of Nagai and Sakurai, or based on the evaluation of their published papers from research done either before or during overseas study.[41] Ikeda was awarded a DSc in 1902 *after* his overseas study at Leipzig and London between 1899 and 1901, but the conferral of his degree was based on papers published *before* overseas study.[42] In pursuing research in Japan, Ikeda often received advice from Sakurai.[43] Haga, in contrast, was awarded a DSc in 1894 *before* his overseas study (1896 to 1898) in Germany, France, and Britain on the basis of his previous publications. He was an exception because, fortunately, he could work with his former teacher, Divers, at Tokyo.[44] One of Haga's study destinations was the laboratory of organic chemist Carl Harries at the University of Kiel, which proved of great use for his later teaching (rather than research) at Tokyo Imperial University, as he initiated Majima into the experimental methods of organic chemistry after his return to Tokyo.[45]

Majima's case was somewhere in the middle. He studied overseas between 1907 and 1911 first with Harries in Kiel and then with Richard Willstätter at the Zurich Polytechnic. He was awarded a Japanese DSc in 1907 while he was studying overseas with Harries. His dissertation project on the urushiol compounds, the main components of Japanese lacquer, had started in 1905 while he was assistant professor at Tokyo Imperial University, that is, before his overseas study. The key techniques for the experimental part of the project (distillation under reduced pressure and ozonolysis) were only available at Harries' laboratory. It is important to

[40] Yoshiyuki Kikuchi, 'International Relations of the Japanese Chemical Community', in S. C. Rathmussen (ed.), *Igniting the Chemical Ring of Fire: Historical Evolution of the Chemical Communities in the Pacific Rim* (Singapore, 2018), 139–55; on 141.

[41] Ikuo Amano, *Daigaku no tanjō, jō: Teikoku daigaku no jidai* (Tokyo, 2009), 193–7.

[42] Kōzō Hirota, *Kagakusha Ikeda Kikunae: Sōseki, umami, Doitsu* (Tokyo, 1994), 68.

[43] Kikuchi, *Anglo-Japanese Connections*, 140–1.

[44] 'Rigaku hakushi', in Kurō Iseki (ed.), *Gakui taikei hakushi roku*, 14th ed. (Tokyo, 1939), 1–3. The first Japanese scientists to be awarded the DSc on the basis of a written examination were the physicist Hanshichi Muraoka and the chemist Mitsuru Kuhara in 1891, but they were both trained abroad, at the University of Strasbourg, then in Germany, and the John Hopkins University, USA.

[45] Yūji Shibata, 'Edward Divers sensei to Haga Tamemasa sensei', *Kagaku*, 16 (1961), 782–6; on 785. See also Note 34 in this chapter.

note, however, that such a well-calculated choice of destinations for overseas study would not be possible without advice and a letter of introduction from Majima's former teacher, Haga, who had known Harries personally.[46] Doctorates awarded on the basis of purely domestic research became the norm in the 1920s and early 1930s in Japanese chemistry, as shown by the careers of SAMESHIMA Jitsusaburō 鮫島實三郎, who specialized in colloid and surface chemistry, and MIZUSHIMA San-ichirō 水島三一郎, a specialist in conformational analysis. Both of them became professors of physical chemistry at Tokyo Imperial University during this period.[47]

In summary, there was a transition that took place between 1890 and 1930. Prior to this period, doctoral degrees were awarded on the basis of the research done during overseas study. Gradually, scientists received their doctorates based on research they did at home. This transition seems to have been completed by 1930. It is important to note that there was no doctoral coursework before, during and after this transition at Japanese universities.

Conclusion

This chapter has examined the development of research training in the first 'laboratory science', chemistry, at Tokyo Imperial University from the late nineteenth until the early twentieth century. Although heavily restricted by limited resources and the weak position of postgraduate education, research training existed and is best characterized by the gradual emergence of research practice and the 'research imperative' from laboratory pedagogical practice at the undergraduate level. It is difficult to exactly demarcate research training from basic laboratory training. But advanced undergraduate and postgraduate students were trained well enough to produce research outcomes, though supervised by teaching assistants or assistant professors, at the Department of Chemistry of Tokyo Imperial University.

In detail, the difference between Nagai's laboratory design and that of Divers and Sakurai reflected the shifting meaning of a laboratory in

[46] Takashi Kubota, 'Rikō Majima: Founder of Organic Chemistry in Japan, Part 1', *Kagakushi*, 30 (2003), 36–51, on 41 and 44–5; and Kubota, 'Rikō Majima: Founder of Organic Chemistry in Japan, Part 4', *Kagakushi*, 30 (2003), 231–55, on 251. See also Majima, 'Waga Shōgai no Kaiko', 4 and 7–8.

[47] On Mizushima, see Yoshiyuki Kikuchi, 'Mizushima, San-ichiro', in Noretta Koertge (ed.), *New Dictionary of Scientific Biography*, 8 vols. (Farmington Hills, MI, 2008), v. 167–71. On Sameshima, see Tarō Tachibana, 'Academic Achievements of Dr. Jitsusauro Sameshima', *Kagakushi*, 9 (February 1979), 23–36, and 10 (June 1979), 39–47.

Meiji Japan and their learning, research, and teaching experiences in Berlin, London, Galway, and Tokyo. First, Nagai's focus on analytical training would have suited the earlier chemistry laboratory qua *shiken shitsu* ('a place to examine') whereas Divers and Sakurai's design was more in line with its later broad meaning of *jikken shitsu/jō*; that is, 'a place to examine/experience/see'. It is also noteworthy that the latter assigned an important role to the departmental library as a venue for reading seminars (the *Zasshi-kai* at Tokyo's Department of Chemistry) for aspiring original researchers. Manual training in the laboratory, in the narrower sense, was complemented by discussion in the library (just as in the humanities), both of which comprised the laboratory in the wider sense, better captured by the Japanese *jikken shitsu/jō* than *shiken shitsu/jō.*

The difference between Nagai's, Divers' and Sakurai's, laboratory designs was also clearly expressed in how they embedded the hierarchical structure of supervisory practice in the chemistry laboratories as pedagogical spaces. In contrast to Nagai's director-centered design, Sakurai's and Divers' answer to this problem was a binary structure based on the two-chair departmental system. The latter also underlined the crucial role of junior professors qua teaching assistants as mediators between students and senior professors, and as laboratory supervisors.

The development of laboratory supervision and its setting in Tokyo did not stop there. For example, Sakurai and Divers adopted an alignment of laboratory benches running parallel to the main, longer walls, presumably to make the most of the natural light and ventilation through the large windows. They were not alone in adopting this alignment: it had been used in Liebig's famous analytical laboratory at Giessen, built in 1840, and adopted in UCL's Birkbeck Laboratory when it was built in 1846.[48] However, it was not an ideal layout for efficient laboratory supervision, since supervisors had to walk along the aisles several times, their vision being blocked by bottle racks on the benches. This was not a problem with the small number of enrolled students at the Department of Chemistry in the 1880s, but it would become so in the 1890s when the number reached 20 in 1897.

Later laboratories of Tokyo Imperial University, such as the Chemical Laboratory in the Institute of Pharmacology (1902), the Laboratory of Medical Chemistry (1901, Figure 11.4), the Laboratory of Applied Chemistry

[48] Peter J. T. Morris, *The Matter Factory: A History of the Chemical Laboratory* (London, 2015), 92–6 and 109–15.

Figure 11.4 Laboratory for Medical Chemistry, College of Medicine, Tokyo Imperial University. Reproduced from Ogawa Kazumasa, *Imperial University of Tokyo* (Tokyo: Ogawa Shashin Seihanjo, 1904). Courtesy of the National Diet Library, Japan.

(1896), and the Laboratory of Agricultural Chemistry (1899, Figure 11.5), adopted a different layout,[49] similar to the one in the laboratory of Hermann Kolbe at the University of Leipzig, completed in 1868. There, a wide aisle ran down the middle of the room and parallel to the main walls, with several benches laid between the aisle and a wall on both sides and perpendicular to them.[50] This arrangement spread to other laboratories in Europe and North America and, indeed, reached Tokyo by the turn of the century, arguably because it was more efficient for supervising ever-increasing numbers of students in laboratories.

In conclusion, I have shown that the training of researchers in laboratory science in Japan started to take root by the 1900s in a modest way,

[49] Ogawa, *Imperial University of Tōkyō*. For the dates of the erection for these laboratories, see *Tokyo Teikoku Daigaku Gojūnenshi*, ii (Tokyo, 1932), 1258–83.

[50] Morris, *The Matter Factory*, 155–7; Alan J. Rocke, *The Quiet Revolution: Hermann Kolbe and the Science of Organic Chemistry* (Berkeley, CA, 1993), 278–86 and the picture of Kolbe's teaching laboratory at Leipzig between pages 264 and 65.

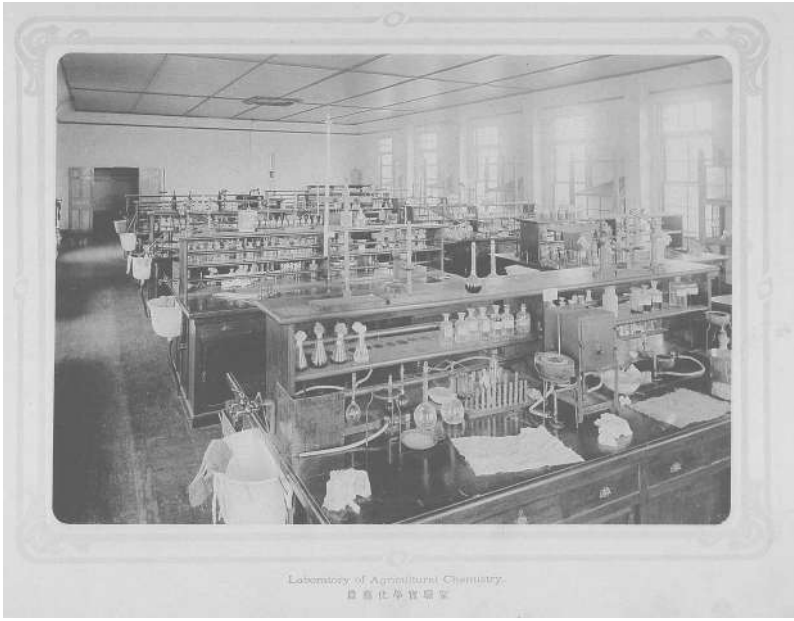

Figure 11.5 Laboratory for Agricultural Chemistry, College of Agriculture, Tokyo Imperial University. Reproduced from Ogawa, *Imperial University of Tokyo*. Courtesy of the National Diet Library, Japan.

when *jikken shitsu* as the translation of 'laboratory' also became part of the Japanese vocabulary, and that the domestic production of doctorate holders became the norm by the early 1930s. The process started in the late 1860s and included a variety of elements—conceptualizing the laboratory, designing and building it, systematizing laboratory supervision, training skilled teaching assistants, building research partnerships, setting up seminars, securing the publication of research findings, creating the culture of the 'research imperative' among students, and implementing the ideal of laboratory research that the chemists brought home from their study abroad. This list is not likely to be complete, but is enough to show the complexity of laboratory science and the training of its researchers in a non-Western country.

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