Louis Jacques Thenard's Chemistry Courses at the *Collège de France*, 1804-1830

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When the echoes of the Chemical Revolution were still in the air, a new radical transformation took place in a central aspect of chemistry: in the way in which it was taught. The emergence of new chemistry teaching methods in the 19th century has been depicted as an individual enterprise of a young chemist, Justus von Liebig, who conceived and set up a revolutionary method of laboratory based teaching, which is usually regarded as opposed to the traditional lecture and experimental demonstration.[1] Herein, this picture is questioned by focusing on two main issues: the alleged sudden emergence of new pedagogical methods (sometimes regarded as a revolutionary change) and the assumed sharp contrast between nineteenth-century laboratory-based teaching and eighteenth-century experimental demonstrations. The discussion relies on the study of the chemistry courses given by Louis Jacques Thenard (1777-1857) at the Collège de France during the first third of the 19th century.

Figure 1. Louis Jacques Thenard (1777-1857). Courtesy of Bibliothèque Interuniversitaire de Médecine, Paris, Banque des images (CIPB1034).

First, how lecture demonstrations were previously worked out in the laboratories of the *Collège de France* will be examined. The preparation

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of experiments played a major role in the organization of spaces and manpower. In this activity, the boundaries between teaching and research were blurred.[2] By study of student notebooks, the role and main features of lecture demonstrations, the theoretical and practical knowledge transmitted through them and their position in the structure of Thenard's lessons can be examined.[3] Student notebooks unveil a wide range of experiments that hardly fit in with the usual picture of 'experimental demonstrations' in historical studies on natural philosophy and experimental physics. Thenard's courses, as probably were many others in early nineteenth-century Europe, were spaces of didactic investigation, in which different uses of experiments as didactic tools were tested.

Teaching and research spaces

Since the late 1770s, when the new building of the Collège de France was constructed, spaces dedicated to chemistry were reduced to a single laboratory placed at the end of the left wing, ground floor. There, Jean Darcet (1724-1801) taught chemistry for more than 30 years. An important change took place when Nicolas Vauquelin (1763-1829) was appointed to the chair in 1800. The big amphitheatre of anatomy was transformed into an amphitheatre of chemistry, with the construction of a big furnace, a big table for demonstrations and a system of water and gas conduits. Thenard's appointment to the chemistry chair in 1804 reinforced this trend and consolidated the standing of chemistry teaching in the *Collège de France*. In barely ten years Thenard completed an entire renovation, which extended the facilities for chemistry to include nearly the whole ground floor and part of the first floor of the building's left wing. The amphitheatre became the centre of a network of interconnected spaces with more defined uses. Directly accessible from the main court, the amphitheatre became the stage where lectures were given. A door behind the stage provided access to the '*atelier de chimie*', the work area where Thenard and his assistants designed and rehearsed experiments until they were ready to be performed in the amphitheatre. Separated from this workshop, and with and independent access to the amphitheatre, the storage room was the place where chemical products and instruments could be stored and protected from the corrosive gases produced during experiments. At the far end of the left wing, Darcet's old chemical laboratory, completely renewed, was reserved for the '*grandes opérations*' chimiques. Finally, an independent stair provided direct access from the ground floor to the laboratories of the first floor, reserved to Thenard and his collaborators.[4] According to the central protagonists, all these changes were required to cover the needs of the lecture demonstrations. As said, teaching was the main activity of the chemistry chair and the one around which spaces evolved, took shape and definition.

The diversification of the use of spaces come along with important changes in the division of labour and staff. The preparation of experiments largely shaped the different occupations of laboratory workers. The '*chef des travaux chimiques*' was responsible of the coordination of the different activities carried out by *préparateurs* and *aide-préparateurs,* the former having the responsibility of assisting Thenard in the performance of experiments during lessons. For Thenard's assistants the design, rehearsal and execution of didactic experiments became a way of being trained in the handling of substances, instruments and operations characteristic of a chemical laboratory. The experiments acquired thus a dual didactic function. Laboratory training proved to be very influential in the professional future of Thenard's assistants. They were recruited from among pharmacy apprentices, who had previous experience in laboratory work and had attended chemistry courses, very often those given by Thenard. For all of them, the pharmaceutical profession should have been the most likely of destinies, and yet almost none of them followed that career. After their stay at the *Collège de France*, these pharmacy apprentices were converted into '*jeunes chimistes*', as Thènard referred to them. They developed careers that combined activities tied to research, industry and the teaching of chemistry, and many of them later took up eminent positions in French academic institutions. Apart from these tasks, another activity was also important in terms of understanding the role of these laboratories. The first scientific publications of many of Thenard's assistants were published during their stay at the *Collège de France*, or in the subsequent years. Some of them were a result of collaboration, very often between laboratory heads and their *aide-préparateurs*. In many cases, lecture demonstrations were the origin of some of these research collaborations.[5]

Demonstrating chemical facts

Following a well established learning tradition, Thenard chemistry lectures were written down by several of his students in notebooks, "cahiers de cours". Many of these documents are still conserved in French archives.[6] Thenard's students notebooks show that his lectures were intended to offer a general introduction to chemistry with the main focus on the study of the properties, extraction methods and uses of a range of "chemical species".[7] For each substance, Thenard offered three different levels of information: description, verification and explanation. First, he offered a description of all the relevant facts about a substance ("*le exposé* *[de] tous les faits qui sont connu*"). He followed a constant expositional scheme beginning with the known, the substance in its natural state, and proceeded through observation and techniques of analysis and synthesis towards the unknown, that is, the pure substance, which was identified, described and classified according to its physical properties and its chemical behaviour. This sequence conveyed an ideal method for experimental work. Besides the description of the known facts, Thenard offered two other levels of information, about the chemical operations that *verified* ("*constater*") the previously described facts, and their *explanation* ("*une explication des faits*").

"*Constater les faits*", that is to say, to verify chemical and physical properties of substances, meant to reproduce them experimentally. Thenard offered meticulous descriptions of instruments, practical directions and advice for their correct use, warnings in order to avoid accidents and conduct accurate experiments, and also suggestions as to implement and improve experimental designs. Thenard employed simple methods such as physical division, dissolution, filtering or decanting, as well as more complex techniques such as distillation. In all the cases, he employed relatively simple and versatile utensils. Among the dozens of experiments described in Thenard's student notebooks just a few groups of objects are mentioned, such as "instruments": thermometers, eudiometers, calorimeters and a few other examples. The other objects were apparatus ("*appareils* ") made of all kinds of glass vessels and connecting tubes, ceramic dishes, furnaces, gas collectors, etc., the traditional items present in an apothecary workshop.

After the "description" and "verification" Thenard proceeded to the "explanation" of the phenomena observed in the demonstrations. To offer the "*théorie des faits*" (theory of facts) meant to explain the changes that substances undergone in their composition during the reaction. To this end, Thenard described the composition of reagents and products, and, then, he compared them and deduced the recombination process. The "*théorie des faits*" offered a plausible explanation of *what* happened in the chemical reaction and *why* it took place under certain experimental conditions. Thenard's explanations mostly relied on the theory of affinities, a topic to which students were introduced from the first lessons. The "théorie des faits" introduced an abstracted ingredient in the lectures that greatly differed from the descriptive character of many other parts of the lecture demonstrations. The listeners were abruptly transported from the observation and description of substances, apparatus and operations to their interpretation in terms of forces and particles which were quantified, calculated and represented on a blackboard by means of algorithms and charts.

During this part of the lectures, many demonstrations were presented in a very "illustrative" vein. They served to *prove* ("*prouver*") that the "*théorie*" was the "*expression des faits*". In these cases, experiments played a subsidiary role with regard to the theoretical interpretations that preceded and predicted their outcome. Nonetheless, in other cases, the role of experiment was completely different. That was the case when, for instance, controversies surrounded an interpretation, or when it was accepted that there was not available data for substantiating an explanation. When dealing with the action of caloric, one of the students wrote "in the present state of science, no one can completely decide which of the two theories, is the best".[8] Experimental demonstrations could also show phenomena for which there were no plausible explanations. For example, after meticulously describing the procedure in which carbon was made to react with nitrogen, Thenard concluded that "so far we do not know ("*on ignore"*) what happens in this experiment". [9]

In other lectures, demonstrations were transformed into crucial experiments between two rival theories. Take the case of potash and soda Thenard and Gay-Lussac did not accept the conclusions of the analyses performed by Humphrey Davy who regarded potash and soda as oxides of two new metallic elements. In the midst of the controversy, Thenard described the two alkalis substances in several lectures given by the middle of February 1809. It is worth noting that Thenard employed in his lectures a course of reasoning as well as experiments that resembled those included in the report he presented (with Gay-Lussac) to the *Institut de France* some months before.[10]

The uses of experiment in Thenard's lectures sharply contrast with the stereotyped picture of traditional demonstration lectures. From the conception and production phases, lecture demonstrations could play a broad range of didactic and heuristic roles. Experiments were designed to support Thenard's lectures but they also contributed to the scientific training of his *préparateurs;* and sometimes they turned out to be a starting point for a relevant research that was published in one of the main scientific journals of the time. This multifaceted nature of the experiments in their production phase persisted when they were performed in the amphitheatre. They were used to "make sensitive" ("*rendre sensible*") and "make more tangible" ("*rendre plus palpable*") the physical and chemical properties that enabled the chemical species under study to be identified and classified. The experiments also served to show instruments, apparatus and chemical operations at work. Showing chemical apparatus and utensils, explaining their use through diagrams and drawings, describing in detail how to handle them in order to carry out the most common operations in the chemical laboratory, understanding the physical aspects and behaviour of chemical substances, their uses and dangers, all constituted pedagogic goals of their own, and could be separated from the explanations and interpretations that could be derived from the chemical phenomena being demonstrated.

Finally, besides showing phenomena and instruments, it was equally important to know how to produce the former by means of the latter. According to Thenard's arguments, the ultimate purpose of such detailed descriptions of the instruments, devices and operations was to enable the students to repeat these experiments by themselves, as this was considered the most effective way of learning a science like chemistry. Reproducing and learning to reproduce the facts being "*exposés*", appeared as inseparable aspects of their verification.

Some conclusions and new questions

One could claim that the *Collège de France* was an exceptional case. According to the foundation documents and statutes, the *Collège de France* was an institution of higher and specialised education meant to train people with previous university or professional backgrounds, and, therefore, hardly representative of the chemistry courses of its time.[11] However, the class registers still conserved at the Archives of the Collège de France offer a different picture. [12] They show that Thenard's audience was mostly made of medical students and pharmacy apprentices. For this public, Thenard and other chemistry professors offered an ordered, systematic and comprehensive introductory course on chemistry, assuming that their audience had never studied this science. Chemistry played a minor role in French secondary school curricula during most of the first part of nineteenth-century.[13] As a result, medical students became one of the most important audiences for the public and private courses on chemistry offered in Paris during that period. A guide for medical students, written by Professor J. P. Maygrier, remarked that "chemistry cannot be learnt in books but in the lectures, where the experiments, which are often repeated and skilfully performed, speak to the eyes rather than to the mind". According to Maygrier, these courses would permit "students who are not initiated in this beautiful science yet" to acquire the necessary knowledge to follow the courses at the Faculty.[14] Pharmacy students registered in Thenard's chemistry lectures obtained their title of "*maître en pharmacie"* after further studies. Aspirants to the title of pharmacist could choose between a long period of apprenticeship with a pharmacist or by three years of academic education in a school of pharmacy followed by a shorter period of apprenticeship. The first group, the most numerous one during the first half of nineteenth-century, received the traditional apothecary training, whereas the second one mirrored the new idea of professional pharmacists, whose practice was founded on the scientific knowledge provided by chemistry and natural history.[15] In the case of Thenard's students, most of them were members of the second group[16]. Thenard's courses at the *Collège de France*, as well as those given at me *Muséum d'histoire naturelle* or in the large number of private courses mentioned by Maygrier in his guide, offered introductory courses on general chemistry. These chemistry lectures met a demand emerged after the important changes in early nineteenth-century French medical and pharmaceutical education. They were mostly attended by students looking for a basic chemistry training needed to pass the academic and professional examinations.[17]

Most of Thenard's foreign students had also a medical or pharmaceutical background. For them, public chemistry courses given at the Collège de France offered the chance to acquire in a few months a general view of chemistry. In addition and as often happened, it was possible for them to follow similar courses given by other professors, and thus know different ways of organizing and teaching chemistry. Both circumstances proved to be of special interest to foreign students who wanted to acquire, in a short period, the training needed to carry out activities related to the teaching of chemistry in their countries of origin.[18]

Thenard's ideas about the didactic role of chemical manipulations were far from being rare inside the contemporary chemical community. Many early nineteenth-century French chemistry textbook authors defended similar views that shaped the type of experiments included in Thenard's books, the way of describing them and, of course, the instruments and apparatus to be used. The meticulous descriptions of utensils, reagents, and operations resulted in a narrative style approaching that of cookbook recipes intended to be made, rather than an explanation conceived to be understood.[19] Second, arguments supporting practical learning were particularly well understood by those who — like Thenard, his assistants and a good part of his audience — had been trained as pharmacists, within a tradition in which practical learning through personal experience had been the norm for long time and remained so, despite the new training avenues opened up after the reforms pushed through during the Revolution.[20] Finally, many direct testimonies also confirm that these wishes and efforts by professors, authors and editors had the desired effect on the readers of their textbooks and the students on their courses. Mateu Orfila, one the of Thenard's students in the course 1808-1809, recalled in his memoirs that, along with reading the principal chemical treatises and attending the lectures, nothing had been more useful in learning chemistry as the repetition of experiments described and shown in lectures and textbooks.[21] Student notebooks also provide evidence of this kind of autonomous experimental activities. Among the numerous footnotes in which notebooks' authors commented, completed or criticised the contents of Thenard's lessons, there are some in which the opinions were based on experiments conducted by students themselves.[22]

An explanation of an exceptional situation and, even less, for antecedents or a precursor of a revolutionary achievement is not being sought. Most probably, exceptionality is just apparent and a consequence of certain aprioristic ideas, like examples such as the Collège de France oblige one to revisit. At least two explanations are suggested. First, the reconsideration of what "experimental demonstration" means in chemistry when employed as didactic tool. Studies on the form and roles of experimental demonstration in the teaching and popularization of science have mostly focused on experimental physics. However, in chemistry, phenomena, instruments and explanations are of a different nature and this may be one of the reasons why it is so difficult to extrapolate conclusions from one field to the other. The phenomena shown in Thenard's chemistry lessons do not have a value or meaning of their own. It is not about producing a vacuum or an electric fluid and showing the effects produced by these physical phenomena. In Thenard's lessons, phenomena were physical and chemical properties ("*propriétés*") that served to identify and classify chemical species. Experiments did not establish matters of fact. Facts only acquired their meaning in the context of a classificatory system that was built up lesson after lesson. As far as the "instruments" were concerned, as above mentioned, apart from those presented in the introductory lessons (thermometer, calorimeter, and eudiometer), there were no singular instruments shown, but rather a collection of very traditional receivers, tubes and furnaces combined in different ways according to the particular operation to be carried out. The secret was not in the working of the instrument but in the way it was built up and handled. Contrary to what has been stated for experimental physics demonstrations, the minute detail of the descriptions observed in the narratives of chemical experiments does not appear to have as its objective the creation in the reader's mind of an image of experiments and their results as obviating the need for replication, but on the contrary the necessary conditions for its replication.[23]

Second, the co-existence of different uses of experiments as didactic tools should be of no surprise in a period in which a crucial step took place in science teaching methods, and which had a special repercussion in the case of chemistry.[24] The experiment and the laboratory, considered as the main means and place for the acquisition of new knowledge about nature, became the instrument and space *par* *excellence* for the teaching of such knowledge. The transformation of the laboratory, the place of individual and private research, into an open and public space dedicated to the transmission of knowledge implied a number of important, conceptual, social and cultural barriers to be overcome. It is difficult to imagine that such an important transformation took place spontaneously and in a single place. It is not a matter of looking for antecedents or influences, but of understanding what type of changes were taking place in terms of how the teaching of chemistry was understood and practiced in other European institutions during the first third of the nineteenth century and how these pedagogical ideas were transmitted and appropriated in different contexts. The *Collège de France* was probably one of a number of places where, during this period, forms of teaching that combined very different didactic models were tried out, mixing rhetorical strategies and ways of using the experiment that decades later would be unthinkable in a teaching space. Examples like the Collège de France shows the importance of a further and more detailed study of chemistry teaching and learning practices in a period in which the didactic models arose that characterise the teaching of this science until almost the present day.

Notes

[1] William H. Brock, "Liebigiana: Old and new perspectives", *History of Science* 19 (1981): 201-218.

[2] The evolution of spaces and its consequences for the organization of chemistry teaching and research activities at the Collège de France has been studied in Antonio García Belmar and José Ramón Bertomeu Sánchez, "Teaching and research spaces. The chemistry chair of the *Collège de France*, 1770-1840", in *Spaces and Collections*, ed. Ana Carneiro and Marta Lourenzo (forthcoming).

[3] Thenard's teaching methods and the interplay between teaching and research activities has been studied in Antonio García Belmar, "The didactic uses of experiment: Louis Jacques Thenard´s lectures at the Collège de France", in *Chemistry, Medicine and Crime. Mateu J.B. Orfila (1787-1853) and His Times*, ed. José Ramón Bertomeu Sánchez and Agustí Nieto-Galán (Sagamore Beach: Science History Publications, 2006), 25-54.

[4] Files F13/1082-1085 of the Parisian *Archives Nationales* contain the collection of documents concerning the works carried out in the building of the Collège de France during the first half of the 19th century.

[5] Between 1822 and 1823, Louis René Le Canu (1800-1871), recently named *chef des travaux chimiques* published a series of reports in collaboration with Serbat, who was at the time one of the *aide-préparateurs*. In one of them, they presented a method for obtaining a pure sample of uranium oxide from pitchblende. The new method had been developed "to obtain a certain quantity of uranium that we need for the chemistry lessons at the *Collège de France*" (L. R. Le Canu and Serbat 'Procédé pour obtenir l'oxyde d'urane pur', *Journal de pharmacie,* 9 (1823), 141-45).

[6]A large selection of these documents can be consultable at <*www.inrp.fr/she/cours_magistral/table/index.html*>.

[7] These conclusions are based on the analysis of two student notebooks (*Cours de chimie. Redigé d'après les leçons de Mr Thenard, Professeur au Collège de France, par Nicolas Jean Baptiste Gaston Guibourt, année 1809* (vol. I) and Id. *année* 1810 (vol. II) (Bibliothèque Interuniversitaire de Pharmacie de Paris (Ms. 22-23) and *Cours de chimie minérale de Mr. Thenard, recueilli et résumé par Joseph Coldefy. Décembre 1808.* (Bibliothèque Universitaire de la Sorbonne, Ms. 1767). See García Belmar, "The didactic uses of experime".

[8] *Cours de chimie. Redigé d'après les leçons de Mr Thenard, Professeur au Collège de France, par Nicolas Jean Baptiste Gaston Guibourt, année 1809* (vol. I) and Id. *année* 1810 (vol. II) (Bibliothèque Interuniversitaire de Pharmacie de Paris (Ms. 22-23), I, 65-66.

[9] *Cours de chimie minérale de Mr. Thenard, recueilli et résumé par Joseph Coldefy. Décembre 1808.* (Bibliothèque Universitaire de la Sorbonne, Ms. 1767), 30.

[10] L.J. Gay-Lussac and L.J. Thenard, "Extrait de plusieurs notes sur les métaux de la potasse et de la soude, lues à l'Institut depuis le 12 janvier jusqu'au 16 mai", *Annales de chimie* 66 (1808): 205-217.

[11] This was the main role of the *Collège de France* according to the *Lettres patentes du Roi concernant le Collège Royal données à Versailles le 16 Mai 1772. Régistrées en Parlement le 26 mars 1773* (Paris: Simon, 1773).

[12] *Registre des inscriptions pour le cours de Chimie par M. Thenard au Collège Impérial de France*, ACF, (A-XIV-20), 35 pp. Paris, ACF (A-XIV). The archives of the Collège de France (ACF) contain a collection of inscription registers in several courses with substantial information about the students. Inscription register started in 1808 (excepting those for medicine courses that begun in 1776 (A-XIV-8.)) and followed with continuity until 1830 and with growing discontinuity up to 1841. Signatures include information about student's origin, age and activity.

[13] On chemistry teaching for medical students see A. Bescher**,** *L'enseignement de la chimie en médecine au début du XIXe siècle* (Lyon: PhD, 1958) and J.R. Bertomeu Sánchez; A. García Belmar "Mateu Orfila's Eléments de chimie médicale and the debate about chemistry applied to medicine during the early XIXth century in France", *Ambix 47* (2000): 1-27. On the evolution of chemistry in 19th century secondary education curricula see Bruno Belhoste, *Les sciences dans l'enseignement secondaire en France, 1789-1914* (Paris: INRP, 1995).

[14] Jacques-Pierre Maygrier, *Guide de l'étudiant en médicine*…(Paris: chez l'auteur, 1818), 41-42.

[15] Jonathan Simon, *Chemistry, Pharmacy and Revolution in France, 1777-1809* (Aldershot and Burlington: Ashgate, 2005).

[16] *Procès-verbaux…,* BIPh (Reg.24-25) and *Régistre...* Paris, ANF (AJ16/2427).

[17] Thenard offered his own views about this issue in a polemic paper about the "necessity of joining the practice to the theory of chemistry, in order to make useful applications to the arts". Among the numerous *citoyens,* who needed to learn chemistry in order to develop their professional activities, Thenard singled out "those who wanted to devote to chemical arts, pharmacy or medicine". To them, a "society of old students of the Ecole Polytechnique", to which Thenard belonged, offered since the beginning of nineteenth-century courses on practical chemistry given by young teachers "trained by the best teachers and experienced in all kind of chemical manipulations" (Louis Jacques Thenard "Sur la nécessité de réunir la pratique à la théorie de la chimie, pour en faire d'utiles applications aux arts", *Annales de chimie* 34 (1800): 106-110).

[18] Antonio García Belmar and José Ramón Bertomeu Sánchez, "Constructing the centre from the periphery. Spanish Travellers to France around the Chemical Revolution", in *Travels of*

Learning. A Step towards a geography of science in Europe (Dordrecht: Kluwer Academic Publishers, 2003), 143-188.

19 As to the narration of experiments in chemistry manuals, see Bernadette Bensaude-Vincent, Antonio Garcia-Belmar and José Ramón Bertomeu-Sánchez, *L'émergence d'une science des manuels. Les livres de chimie en France (1789-1852)* (Paris: Archives Contemporaines, 2003), 183-203.

20 Simon, *Chemistry, Pharmacy and Revolution...* As to the influence of the pharmaceutical tradition on chemistry teaching models, see Frederic L. Holmes, "The Complementarity of Teaching and Research in Liebig's Laboratory," *Osiris* 5 (1989): 121-164.

21 M.G. Chapel d'Espinasoux, "La Jeunesse d'Orfila. Fragment d'une autobiographie inédite publié par ...", *Revue Hebdomadaire* 22-3 (1914): 615-34, 86-113, and 632.

22 García Belmar, "The didactic uses of experiment", 45.

23 See, among others, G. Sutton and V. Geoffrey, *Science for a Polite Society: Gender, Culture, and the Demonstration of Enlightenment*, (Boulder: Westview Press, 1995) and Larry Stewart, *The Rise of Public Science. Rhetoric, Technology, and Natural Philosophy in Newtonian Britain, 1660-1750* (Cambridge: Cambridge University Press, 1992); the special issue "Science Lecturing in the 18th century" of the *British Journal for the History of Science*, 28 (1), (1995); A.Q. Morton, "Lectures on natural philosophy in London, 1750-1765," *British Journal for the History of Science* 23 (1990): 411-434; J. Mertens, "Shocks and Sparks: The voltaic pile as a demonstrative device," *Isis* 89 (2) (1998): 300-311; T.L. Hankins, J.S. Robert, *Instruments and the Imagination*, (Princeton: Princeton University Press, 1995) (especially the chapter "The magic lantern and the art of demonstration"); J. N. Hays "The London lecturing empire, 1800-50," in: Ian Inkster and Jack Morrell, *Metropolis and Province: Science in British Culture, 1780-1850*, (London: Hutchinson, 1983) and I. Ikster, "The public lecture, an instrument of science education for adults —the case of Great Britain c. 1750-1850," *Paedagogica Historica* 20, (1) (1980): 80-107.

24 Studies on the teaching of chemistry inside and outside the Universities of Glasgow and Edinburgh in the second half of the eighteenth century and the first third of the nineteenth century offer a good example of the variety of teaching and learning forms that coexisted in this period and the different meanings that the idea of experimental and practical teaching could have. (See on this topic studies by J.B. Morrel 'The chemist breeders: the research schools of Liebig and Thomas Thomson', *Ambix* 19 (1972): 1-58 and D. Fenby 'The lectureship in chemistry and the Chemical Laboratory, University of Glasgow, 1747-1818', in *The development of the laboratory: essays on the place of experiment in industrial civilization*, ed. F.A.J.L. James (Basingstoke: Macmillan, 1989), 22-36. Another example of that is the account made by Smeaton in 1954 of the European institutions where different forms of "laboratory instruction before 1794" were carried out (W.A. Smeaton, 'The early history of laboratory instruction in chemistry at the Ecole Polytechnique, Paris, and elsewhere', *Annals of science* 10 (1954): 224-33.