INTRODUCTION: NEGLECTED USES OF INSTRUMENTS AND EXPERIMENTS IN SCIENCE EDUCATION

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The teaching of science and its best practice, whether in schools, colleges or universities, has been a major concern for a long time and an issue of debate for scientists, educators, and the public at large. In the public opinion, much is seen to be at stake if societies do not manage to educate citizens about their scientific and technological culture, as well as to train enough technicians, engineers and scientists sufficiently well in order to develop it further. No matter how diverse the positions, the debating parties share the conviction that personal experience in the form of experiments and observations either carried out by students, or performed as demonstrations by teachers, are essential to the pedagogy of science. Yet, this is not a timeless observation. Consequently, one should ask how this conviction has been put into practice.

This book focuses on the history of experiments and instruments within the history of teaching science. It brings together two themes which so far, according to our knowledge, have never been brought together in one edited volume. One theme is the history of experimental practice, scientific instrumentation and material cultures of science; the other is the history of teaching science. The history of experiments, scientific instruments and scientific practice came into focus in the history of science with the 'pragmatic turn' in the 1980s and 1990s.[1] More recently, material cultures have come into prominence with the rise of cultural studies of science on one hand, and the (re)discovery of material heritage and historical collections at universities and other scientific institutions on the other.[2] The origins and the development of science teaching, in contrast, is one of the topics that is just beginning to receive more attention within the larger scholarship on the history of science. Education still needs to be moved from the periphery of

1 Two important monographs in this respect—to which we refer in the title of our introduction—are Franklin (1986) and Gooding et al. (1989). Other influential examples from this period are Shapin and Schaffer (1985) and Galison (1987).

2 An example for the interest in scientific objects inspired by cultural studies is Daston (2004). In the last decade a number of national as well as international initiatives, networks, and conferences have been organised to protect scientific heritage at universities, and to mobilise it for teaching, research and for public exhibitions. See Lourenço (2005) about historical collections at universities in Europe.

science to its centre (Kayser, 2005).[3] This deficit in its recognition seems to be surprising as the importance of training in the formation of scientists has been stressed for some time by epistemologists as well as historians. Moreover, the standardisation of scientific education can be seen as a crucial step in the establishment of experimental science: "Laboratory training and access to scientific instruments are essential for the professionalisation of science in the middle of the last century" (Rabkin, 1992, p. 62).

Addressing this under-represented field in the history of science was one of our main motivations to organise the symposium 'Learning by Doing: Instruments and Experiments in the History of Science Teaching' that took place at the University of Regensburg on 4 and 5 April 2009. The other was to bring together historians of science and science teachers who are interested in the historical development of science teaching. As historians we firmly believe that, in order to understand the present state of science teaching as well as to envision potential future developments, one has to have some understanding of its history. This volume should therefore be of interest not only to historians of science and of education, but also to science educators. Most contributions have been presented at the Regensburg symposium and subsequently developed further. However, some others have been added.

Our motivation to initiate the symposium and to edit this volume was to address questions such as the following ones:

- How did demonstration experiments and experimental lectures emerge, and how have they further developed? When, why and how were student experiments and organised laboratory courses introduced in science teaching in different disciplines and different institutions? How have these changed?
- What are the relations between scientific research and teaching? How have scientific instruments in research and teaching developed? To what extent have the same instruments been used in both activities, and to what extent have separate teaching or research technologies evolved? How were research experiments transformed into teaching experiments?
- What were the differences between various types of educational institutions, like public schools, vocational schools and universities? How did regional, political and cultural differences matter? What were the differences in the various scientific subjects?

The papers presented in this volume offer some answers to these questions; at the same time, they raise some new questions. They present an overview of and an insight into the role of experiments in science teaching in different time periods

3 This observation has been made by Kayser (2005). Important exceptions are the studies by Kathryn M. Olesko (Olesko 1989, 1991, and 1993) and the Special Issue of the journal Science & Education: Textbooks in the Scientific *Periphery,* edited by José Ramón Bertomeu-sánchez, Antonio García-Belmar, Anders Lundgren and Manolis Patiniotis (2006). Studies in the history of science education include Foellmer (2007), Lind (1992), and Wickihalter (1984).

from the Enlightenment to the twentieth century as well as geographical contexts in Europe and North America. As an integral part of science as a social activity, the teaching of science is as old as science itself. Both are indisputably interlinked. So why would we want to drive a distinction between the two by singling out the teaching aspect? The answer is quite simple. Science teaching is still looked at rather as context or the boundary of scientific research in universities, both by historians as well as by scientists. Parallel to the *neglect of experiment* (Franklin, 1986), one could use the phrase of a *neglect of science teaching* in the history of science. As Ian Hacking (1983) has established for experimenting, science teaching also has a life of its own. In the first paper of this volume, Peter Heering discusses common aspects in the relation between research and teaching apparatus, denouncing the idea of a simple transfer from the former to the latter. Instead of reducing the history of the teaching of science to the context of research history, we have to treat it in its own right and examine the complex inter-relations between both. Heering identifies four strategies: simplification, downscaling, stabilisation and iconisation, which seem to be important in the transformation of many research instruments into teaching devices.

Conducting experiments in public lectures had a prominent place in the European Enlightenment. In many instances and contexts, public demonstrations or university lectures rather than written papers was the way of presenting new scientific discoveries.[4] But in the eighteenth century, public lectures and entertaining demonstrations were also presented to a public that was not part of the scientific societies, but rather a lay audience, as Pete Langman exemplifies for the case of Newtonian experimental philosophy in England. Many devices from the early remaining scientific collections were designed, along with popular texts, to illustrate scientific principles rather than to generate new experimental knowledge and competences.

It is generally assumed that textbooks of science do not take part in scientific controversies but convey generally accepted and therefore noncontroversial scientific knowledge to students and other newcomers in a field.[5] Pere Grapi challenges this view by arguing for an important role of chemistry textbooks and teaching institutions in the controversy about chemical affinities in early nineteenth century France.

School and university collections for science teaching started to emerge in the eighteenth century. Lissa Robert's paper on Dutch orphanages exemplifies the underlying peculiar political and economic, as well as pedagogical discourses. From her study, it becomes evident that it was not always the universities that had

4 One of the best known examples in this respect is the work of Joseph Black on latent heat. Black communicated his findings only in his lectures which appeared in print only after his death. However, while it was common knowledge throughout Europe then, it was also known that these findings were related to Black (McKie and Heathcote, 1975).

5 There are of course some exceptions; most notably see Frercks (2006) on the controversy on Lavoisier's chemistry.

the best equipped teaching collections. Likewise, her study illustrates that science teaching is not just influenced by scientific ideas and conceptions, but also by political beliefs that shape the educational systems. This aspect becomes even more explicit in the study by Constantine Skordoulis, Gianna Katsiampoura and Efthymios Nicolaidis of the role of experiments in science teaching in Greek speaking communities in the late eighteenth and early nineteenth centuries. Their paper demonstrates the political meaning of introducing natural philosophy experiments in the Greek science teaching. Adopting the experimental method was a way of connecting to the European Enlightenment. Advocates of the new Newtonian ideas were, however, confronted with representatives of a neo-Aristotelianism who claimed a specific Byzantine tradition and rejected the use of instruments.

An important function of many teaching devices is to show and enlarge visual representations of scientific phenomena. Willem Hackmann presents a very nice and almost timeless instrumental example in his discussion of the projections that could be made with a magic latern. This instrument shows several aspects that are relevant for the entire volume: it was used for entertaining and educational purposes at the same time (and one could ask when education was separated from entertainment). It is—according to Hackmann—the 'precursor of PowerPoint', a teaching technology which is very much state of the art in the early twenty-first century. And it is in some sense the ambivalence between an instrument that is considered to be part of natural philosophy on the one hand, and magic and illusions on the other. Whilst the latter association is fairly unique, the role of wonder and entertainment in science teaching and the related instruments is a topic that deserves further attention.

The nineteenth century has been described as a period of differentiation, institutionalisation and professionalisation both for science and for education. We are cautious to avoid a separation at the onset between science teaching at schools on one hand, and institutions of higher education, like universities, on the other. We rather wish to debate what connected teaching at different institutions and where the differences lay. Universities became a space for both, teaching and research, and to some extent both fields were intertwined as lecturing was one common way to publish new findings and theories. At the same time, universities were also the place to train teachers for secondary schools. Countries that view themselves in the periphery of the scientific and educational reforms are often found to copy the examples from the cultures which they perceive as centres and potential reference. Mar Cuenca-Lorente and Josep Simon show that the development of physics and chemistry collections in mid-nineteenth century Spanish secondary schools largely followed examples of France which were implemented through and combined with local developments.

Collections of an entirely different type are the focus of Dawn Sanders' contribution: turning from physics to biology, she presents a history of the changing use of plant specimens in botanical teaching in the nineteenth and twentieth centuries. In particular, the Royal Botanical Gardens in Kew had a strong agenda in teaching, offering teachers plant specimens for educational purposes.

These were not limited to biological courses but also geography was adressed whose teachers used such specimens to show the 'products of empire'. But her analysis is not limited to British institutions—she also draws explicitly on the example of high school biology in New York City between 1900 and 1925.

In the standard historiography of science, teaching laboratories started to emerge at universities from the middle of the nineteenth century, following the well-known example of Justus Liebig's chemical laboratory at the University of Giessen (see, for example, Holmes, 1989). Until then, it had mainly been the lecturer or demonstrator who performed the teaching experiments. With the model of laboratory teaching, students were supposed to perform their own experiments. This development has been studied by Michelle Hoffman for science teaching in Canadian high schools, and by Steven Turner, using the example of the inclined plane, for American science education. Chemistry and physics should be taught experimentally, and botany practically. The objectives of science education were both moral and intellectual. But the steady implementation of the new experimental method of teaching met, as Hoffman argues, bureaucratic hurdles of school administration and the challenges of everyday pedagogical practice. The amount and importance of student experiments constantly increased during the second half of the nineteenth century. Until the turn to the twentieth century, student experiments were also introduced in school teaching, as the importance of science teaching and experiments increased in the curriculum.

The growing school market was not always that interesting to the large and established makers and therefore accommodated local makers also, as the study of Steven Turner shows. Some of the teaching instruments were designed as didactical devices, whereas others were modelled after research instruments, but these were often not as precise as the research instruments and altered to the requirements of teaching. Richard Kremer challenges the claim made by other historians of science that American physics teaching in the late nineteenth century was largely influenced by, if not being a copy of, German teaching practices, methods and instruments.[6]

Paolo Brenni describes the evolution of teaching instruments in physics and gives an overview of the instrument market through the nineteenth and early twentieth century. The last decades of the nineteenth century saw a drastic demand for scientific education that led to an extreme growth in the market for didactic instruments.[7] After the Franco-Prussian War, German instrument companies such as Max Kohl and E. Leybold's Nachfolger took the leading position

6 It is remarkable that, at the beginning of the twentieth century, three US institutions served as a role model for technical education in Spain, namely, "the Worcester Polytechnic Institute, …; Sibley College, at Cornell University, …; and the Stevens Institute of Technology" (Roca-Rossell et al., 2006, p. 151).

7 One could ask whether this is the result of an increasing number of pupils at schools and students at universities, or whether this can also be taken as an indication of a growing importance of students' experiments in science education.

from the British and French makers to satisfy the growing mass market. For school teachers, the professionalisation of science left less and less space to carry out research and be an active part of the scientific community.[8] With the increasing transformation of research experimentation from table-top arrangements to complex, highly specialised laboratories and black-boxed instruments, teaching technology has distanced itself further from research technology. After the World War I, the character of demonstration experiments in experimental physics lectures changed. Roland Wittje presents us Robert Wichard Pohl as the most important renovator of lecture demonstrations in Germany during the inter-war period. After World War II, however, the importance of demonstrations in science teaching has decreased drastically.

Hayo Siemsen brings us to the present day science education, even though he is not advocating the 'standard model of science education'. In his paper, he develops a very particular perspective on the role of scientific instruments in educational processes, a perspective that is strongly inspired by the phenomenological positivism of the Austrian philosopher and physicist Ernst Mach. This paper clearly shows that the role and status of scientific instruments in science education even nowadays is not completely settled, but can be controversial. In this respect, Siemsen's paper forms an implicit demonstration of the necessity to have also a historical perspective on the use of instruments in science education.

Naturally, the papers represent only a partial, episodic and incomplete picture of this history of experiments and instruments in teaching science. Therefore, this collection is more to be understood as being a starting point in this field instead of a closure. We would have liked to include papers from other geographical regions in order to add some more facets to our picture, as well as case studies covering the post-war period. Case studies from teaching physics dominate, giving only little space to biology and chemistry teaching, and ignoring disciplines such as geology and medicine. We nevertheless think that this volume fulfils an important function in raising crucial issues concerning the role of experiments and instruments in the history of teaching science, and its relation to the history of science at large.

The title page shows the physics lecture room of the Anna-Gymnasium Augsburg; it is likely that the picture was taken in the 1910s.[9] It was made available to us by the late Inge Keil, whose generosity was only exceeded by her scholarship. We are grateful for financial support for this publication from the Regensburg University Foundation Hans Vielberth and the EWE Stiftung. We would also like to thank An Rettig for her editorial assistance.

8 There are of course exceptions such as Elster and Geitel who, being school teachers, managed to carry out substantial research in the early twentieth century (see http://www.elster-geitel.de/, accessed on 19 September 2010).

9 We owe this information to Karl-August Keil, who also granted us permission to reproduce the image.

REFERENCES

Bertomeu-Sánchez, J. R., A. García-Belmar, A. Lundgren and M. Patiniotis (eds). 2006. 'Textbooks in the Scientific Periphery', *Science & Education*, 15 (Special Issue), pp. 657–880.

Daston, L. (ed). 2004. *Things that Talk: Object Lessons from Art and Science*. New York: Zone Books.

Franklin, A. 1986. *The Neglect of Experiment.* Cambridge: Cambridge University Press.

Frercks, J. 2006. 'Die Lehre an der Universität Jena als Beitrag zur deutschen Debatte um Lavoisiers Chemie', *Gesnerus*, 63(3–4), pp. 209–39.

Foellmer, R. 2007. *Naturlehre: die Entwicklung des Physikunterrichts an den Volksschulen der Rheinprovinz (1815–1968)*. Köln: Böhlau.

Galison, P. 1987. *How Experiments End*. Chicago and London: Chicago University Press.

Gooding, D., T. Pinch and S. Schaffer (eds). 1989. *The Uses of Experiment*. Cambridge: Cambridge University Press.

Hacking, I. 1983. *Representing and Intervening: Introductory Topics in the Philosophy of Natural Sciences*. Cambridge: Cambridge University Press.

Holmes, F. L. 1989. 'The Complementarity of Teaching and Research in Liebig's Laboratory', *Osiris*, 5, pp. 121–64.

Kayser, D. (ed). 2005. *Pedagogy and the Practice of Science: Historical and Contemporary Perspectives.* Cambridge, Mass: MIT Press.

Lind, G. 1992. *Physik im Lehrbuch 1700 - 1850. Zur Geschichte der Physik und ihrer Didaktik in Deutschland*. Berlin: Springer.

Lourenço, M. C. 2005. *Between Two Worlds: The Distinct Nature and Contemporary Significance of University Museums and Collections in Europe*. PhD thesis, Conservatoire Nationale des Arts et Métiers, Paris.

McKie, D. and N. H. d. V. Heathcote. 1975. *The Discovery of Specific and Latent Heats*. New York: Arno Press.

Olesko, K. M. 1989. 'Physics Instruction in Secondary Schools before 1859', *Osiris* 5, pp. 92–118.

Olesko, K. M. 1991. *Physics as a Calling: Discipline and Practice in the Koenigsberg Seminar for Physics*. Ithaca, NY: Cornell University Press.

Olesko, K. M. 1993. 'Tacit Knowledge and School Formation', *Osiris* 8, pp. 16–29.

Rabkin, Y. 1992. 'Rediscovering the Instrument: Research, Industry and Education', in R. Bud and S. E. Cozzens (eds), *Invisible Connections: Instruments, Institutions and Science*. Bellingham, WA: SPIE Optical Engineering Press, pp. 57–72.

Roca-Rosell, A., G. Lusa-Monforte, F. Barca-Salom and C. Puig-Pla. 2006. 'Industrial Engineering in Spain in the First Half of the Twentieth Century: From Renewal to Crisis', *History of Technology*, 27, pp. 147–61.

Shapin, S. and S. Schaffer. 1985. *Leviathan and the Air-Pump*. Princeton: Princeton University Press.

Wickihalter, R. 1984. *Zur Geschichte des physikalischen Unterrichts: unter besonderer Berücksichtigung von Reformbestrebungen*. Thun: H. Deutsch.