Learning by Doing: Experiments and Instruments in the History of Science Teaching

An international symposium in Regensburg, Germany, 4-5 April 2009

Abstracts

Instruments of Science and Citizenship: Science Education for Orphans during the Late Eighteenth Century

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Two of the best instrument collections in the Netherlands during the second half of the eighteenth century - rivaling the much better known collection at the University of Leiden - belonged to the Mennonite Seminary in Amsterdam and an orphanage in The Hague that was specially establish to mold hand-picked orphans into productive citizens. The educational program at this orphanage, one of three established by the Fundatie van Renswoude, grew out of a marriage between the socially-oriented generosity of the wealthy Baroness van Renswoude and the pedagogical vision of the institute's director and head teacher - a vision that fit with the larger movement of economic patriotism. Economic patriotism, similar to 'improvement' and 'economic' movements in other European countries and their colonies, sought to tie the investigation of nature to an improvement of society's material **and** moral well-being. Indeed, it was argued that these two facets of society should be viewed as inseparable from each other. While a number of the key figures in this Dutch movement also became prominent Patriots during the revolutionary period at the end of the century, fighting against the House of Orange, they did not have a monopoly on economic ideas of societal improvement. This is demonstrated by the fact that an explicitly pro-Orangist society, Mathesis Scientiarum Genetrix, was organized in 1785 to teach science and mathematics to poor boys and orphans for very similar reasons: to turn them into productive and useful citizens. As was the case with the Fundatie van Renswoude, as special collection of instruments was assembled to help make this possible. This story is of interest because it reveals the pedagogical use that scientific instruments were put to during this period, while linking such concerns to the highly charged question of citizenry.

Were Didactic Scientific Instruments really used? The Evolution of Teaching Physics between 1850 and 1930

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In the decades between 1850 and the beginning of the 20th Century didactic instruments changed remarkably. In the first half of the 19th Century, the core of a typical teaching collection was composed by apparatus, which were very similar to the ones proposed in the 18th century by 's Gravesande, Nollet, Desaguliers and others lecturer demonstrators and makers. Since 1850 circa, new didactic instruments were introduced. Most of them concerned the fast developing branches of physics such as wave optics, electromagnetisms and acoustics. Instrument makers (and many scientists as well) were extremely prolific in inventing new devices for better demonstrating all the laws of physics and for clearly visualizing all its phenomena. Therefore, around 1900 all the most important German, French and British makers proposed in their thick catalogues thousands of didactic apparatus. But were all these instrument really used? Probably not. Many of them were acquired by schools and universities because they were considered "status symbol" marking the importance and the completeness of a collection. Others were simply shown as "tri-dimensional" illustrations.

For various reasons, during the first decade of the 20th century the number of available didactic instruments was drastically reduced. The introduction of student training laboratory, the increasing cost of labour and of materials after WWI, the needs of a more standardized production, the progresses of physics not only eliminated from the trade catalogues many of the classical but old fashioned instruments but also stimulated the use of modular and simpler didactic apparatus.

Science Pedagogy and the Material Culture of the Nineteenth-Century Classroom: Working with Collections in the Valencian Secondary Schools

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This paper introduces an ongoing project developed at the University of Valencia and within the Catalan Commission for Scientific Instruments (COMIC). Our aim is to catalogue and study the physics and chemistry collections preserved in the main secondary schools of the Valencian, Catalan and Balearic regions in Spain. In our pilot project, we have worked in three schools, located in the three capitals of the Valencian region. In parallel, we are creating with the support of COMIC an online resource, which will communicate our results and also offer support and resources to professionals, teachers and students. Our collections contain a large number of nineteenth-century physics and chemistry instruments, instrument maker catalogues, manuscript and printed instrument inventories, and some student notebooks and examinations. During the last decade, several members of our team have also developed a valuable experience in the study of textbooks and the narratives of pedagogy and experiment expressed through them. From this standpoint we are working with the aim of reconstructing the pedagogical experience in the nineteenth-century science classroom by analyzing the combination of manuscript, printed and material sources described above. In this paper I will provide our first results for the case of Valencian schools and discuss methodological problems arisen in the course of our research.

Showing Procedures, Demonstrating Facts: Epistemological Uses of Chemistry Courses ca. 1800

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In the first part of the paper, I explore different functions of showing chemical procedures in chemistry lectures at universities. This is based on the analysis of the multiple chemical activities of J. F. A. Göttling at Jena. Discussing research, production, entertainment, instruction, and information at first, I reach the conclusion that the core function of showing chemical procedures is the demonstration of facts. Since facts were seen as the epitome (Inbegriff) of chemistry as a science, this function appears natural for a series of lectures on pure chemistry. However, in the second part of the paper, I venture the hypothesis that chemical facts are not merely conveyed by the lecturer and learned by the student by means of showing procedures. Rather facts are stabilized as facts in an enduring and perfomative process. Drawing on the dialectical theory of theatre of Arno Paul, I argue that the "facticity of facts" resides in the interaction between the lecturer and the students via the demonstration. Although this mechanism is impossible to prove head-on, it is suggested by the specific rhetoric of the lecture notes taken by a student named Pruninger during one of Göttling's series of lectures: Pruninger does not describe his local experience but the abstract essence of what is shown. If lecture demonstrations really function in this dialectical way, they would be an inextricable part of science. In addition, the students' participation, albeit passive, would be indispensable. In general, the realm of teaching would be an integral part of science, not only socially or institutionally, but also epistemologically.

The role of Chemistry Textbooks and Teaching Institutions in France at the Beginning of the XIXth Century in the Controversy on Berthollet's Chemical Affinitie

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After Lavoisier's execution, the leading French chemists were Antoine-François Fourcroy, Louis-Bernard Guyton de Morveau and Claude-Louis Berthollet. At the beginning of the nineteenth century, Berthollet introduced a new conception of chemical change hat challenged the theory of elective affinities which had dominated chemistry for nearly a hundred years. Berthollet's new affinities raised controversy among chemists and had to coexist with the firmly established theory of elective affinities. Apart from the public debate in research articles, Berthollet's affinities also had to compete with the influence that Fourcroy and his school exerted in many leading teaching institutions as well as in the textbook market in France. This presentation seeks to assess the extent to which this context contributed to the marginalize Berthollet's innovation.

The Magic Lantern: For Scientific Enlightenment and Entertainment

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Audiences today are accustomed to the sophisticated computerized visual displays produced by software such as PowerPoint, which have become indispensable aids in the teaching of science. However, these techniques have evolved over centuries, and have their roots in the Renaissance science of optics.

The Magic Lantern, the precursor of PowerPoint presentations, was developed as an optical device by natural philosophers, and was popularized by itinerant showmen from the 1720s onwards. This device quickly moved from the relative obscurity of the laboratory and the cabinet of curiosities to the public arena, and by the late eighteenth-century was recognized as an indispensable aid in science education. It was this dual capability of the Magic Lantern both to entertain and to act as a visual aid in describing the latest scientific discoveries that made its use so fruitful in the popularization of science. Its power to draw in and to teach audiences was recognized by science lecturers of the stature of Michael Faraday at the Royal Institution, and John Henry Pepper (of 'Pepper's Ghost' fame) at the Royal Polytechnic Institution.

Initially the Magic Lantern accompanied science discourses with projected static images (similar in function to textbook illustrations), but in the mid-nineteenth century considerable improvements in optics and mode of illumination resulted in a boost in the development of the lantern slide, and in the function of the lantern, which could now also be used to create scientific effects and project these onto the screen.

As I could not bring my Victorian triunial mahogany and brass lantern to Regensburg, I have tried instead to recreate by means of PowerPoint and digital projector some of the scientific effects of these extraordinary Victorian mechanical lantern slides with such exotic names as 'kaleidotrope', 'phenakistiscope', 'wheel of life', 'choreutoscope', and 'chromatic wheel'[1]; thereby merging the old and the new ways of 'Learning by Doing'.

The Magic Lantern blurred the lines between experiment and performance, between laboratory and theatre, and made the phenomena of science both visible and accessible.[2]

1. David Robinson, Stephen Herbert and Richard Crangle (eds), Encyclopaedia of the Magic Lantern (London: The Magic Lantern Society, 2001).

2. Brenda Weeden, The Education of the Eye. History of the Royal Polytechnic Institution 1838-1881 (London: University of Westminster, 2008).

The Audience is Listening: Differing Literary Representations of Newtonianism

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John-Theophilus Desaguliers explained the problem with Newton's theories when he wrote that 'The Thoughts of being oblig'd to understand Mathematicks have frighted a great many from the Newtonian Philosophy', going on to explain that through the use of demonstrative experiments, 'Things might be made more intelligible to such of my Auditors as were not acquainted with Mathematicks.' Thus the use of experiments was predicated on the difficulty of Newtonian mathematics. But Desaguliers' lectures merely catered for one particular audience - and an audience which was predisposed to investing in technologies, both literary and experimental, in order to further its own knowledge. There were several other audiences to whom lecturers would reach out, not least women and children - naturally, each lecturer had the same raw materials to draw from.

This paper will investigate the changing nature of the representation of Newton's theories, as lecturers and writers adjusted their strategies to fit their audiences. In what ways did Tom Telescope's Philosophy of tops and balls differ from Algarotti's Newton's Philosophy Explained, for the Ladies, and how did each translation affect the reception of each text? Furthermore, do the different editions of these works tell us anything about the nature of the audience or, indeed, the state of knowledge at the time. An example will perhaps help here.

In 1739, Francisco Algarotti published his delightfully titled Newton's Philosophy Explained, for the Ladies, a book of great interest not merely because of its changing nature over several editions, but one whose translation can also tell us much about the ways in which these texts were treated.

The copy in the British Library is particularly interesting, as it is inscribed. It starts with a letter, stating that the recipient has been given two copies, one for the author and one for a certain Thomas Birch. It's a difficult signature, but further investigation reveals its secrets. Thomas Birch, perhaps significantly, was the one-time secretary of the Royal Society. The question is whether it was delivered to him as representative of the RS, or as a private individual - each possibility raises different questions, each possibility says different things about the dissemination of these Newtonian works.

As well as the letter, it is also inscribed with these words: 'Ex dono interpretis doctissime & elegantissime elizab.carter'. The book was given to Birch by Elizabeth Carter, who was a ferocious bluestocking, friend of Mary Cavendish and inveterate taker of snuff, as well as being the work's (anonymous) translator. Furthermore, Carter was the victim of Birch's perhaps unsubtle courting techniques - it turns out that this was the subject of Birch's proposal of marriage in 1739, the year of publication, at which point she turned tail and fled London.

What is not apparent, however, is whether the book was given before or after the proposal - a factor which changes one's interpretation of this transaction greatly. Was the donation a business transaction, allowing the Royal Society to include the work in its libraries, or a personal gift? It is this slightly uncertain status, along with the changing nature of this and other texts over

several editions, which allows us to draw inferences regarding the ways in which the audience was viewed.

The experimental lectures of the eighteenth century catered for many tastes, many audiences, and took many formats. Their source materials, however, were essentially the same. Furthermore, the lecturers themselves had aims beyond the mere imparting of knowledge - they wished to make money through subscriptions, sales of lecture texts and machinery. The audience certainly was listening, but did it actually understand what was being said?

Multi-media Presentations of Enlightenment Material Culture

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As evidenced by the success of the Newton Project (www.newtonproject.sussex.ac.uk) thus far, the digital medium has proved itself to be eminently capable of revolutionising the content and practice of scholarship. Freely available to any reader with access to the Web, over three million words of previously unseen writings by Isaac Newton are now fully searchable, and there are millions of words of expository and other historical materials that accompany the core Newtonian texts. Nevertheless, the creation of scholarly digital materials continues to pose a number of problems in making information accessible and usable rather than merely available. This is particularly true at a time when there is pressure placed on academics to justify their work to the general public. General problems with designing multi-audience sites include the need to make the resources available through the site comprehensive, the extent to which users/ readers need to be guided through materials or allowed to roam freely through readily available resources, and, crucially, the need to use non-textual supporting information such as the filming of interviews and of recreated scientific experiments.

A particular issue arises in designing interfaces for analysing and interpreting historically significant foreign language scientific texts, where from the outset, site creators need to produce a substantial amount of introductory and supporting materials. In this case, a number of opportunities are lost if the expository materials are presented only in textual form. In the JISC-sponsored 'Enlightening Science' project, we are developing new ways of thinking about how to present the difficult physical principles contained in Newton's Principia and Opticks to three separate audiences: scholars; the general public; schools. Alongside making all editions of these canonical texts fully available online, our solution to the problem of accessibility involves recreating and filming experiments performed in universities and public lecture series offered in the eighteenth century. This solution is especially apt, since the original lectures were themselves an attempt to solve the problem of making Newton's scientific achievements comprehensible to a much broader set of publics. Our project will provide a full set of relevant manuscript and print texts related to these works, as well as a number of expository articles and book chapters from modern assessments of Newton's scientific writings. We will also make available the most significant popularisations of Newton's scientific principles, along with the texts of lecture series that accompanied the lectures themselves. From the latter, we have selected a number experiments that we will recreate and film in period dress and with authentic apparatus. We will also present relevant interviews with major historians and scientists.

Using students from a number of schools as user groups, we aim to make this an enjoyable and informative resource that can be fitted by teachers (through Teachers TV and other outlets) to specific examinations at GCSE, AS-level and A-level. The site aims at both scholarly and non-academic audiences, and which makes full use of the opportunities offered by the different media of the Internet, TV and film.

Similar but Separate: The Complex Relationship between Physics and Physics Teaching in the 19th Century

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The wave theory of light emerged in the early 19th century, largely in France. It was widely considered the highest intellectual achievement of physics and was seen as a model for future scientific inquiry. Around the middle of the 19th century a new introductory physics curriculum emerged in France. It was built around the wave theory of light and sought to show how its discovery had been a logical, deductive process. It also showed how the principles of waves could be used to explain a wide range of physical phenomena. It described what we now call "classical physics."

The new curriculum came to America largely through a single textbook. Atkinson's translation of Ganot's Physics quickly became the standard textbook for introductory physics in America, and remained in use for almost 50 years. The course became part of the shared experience of generations of Americans, and the lessons they learned from it affected the way they viewed both science and the physical world.

But Ganot's heavily illustrated text shows instruments that never graced a scientific laboratory. Looking closely at how these instruments were used - and understood - provides clues to the deeper lessons being taught. It may also illuminate the relationship between science and science education.

"Simplicity is the Sign of Truth": Demonstration Experiments in Physics Teaching before and after WWI

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Lecture demonstrations, which used to be the hallmark of experimental physics lectures, have in the second half of the 20th century given way to the once-mocked chalk and blackboard physics. What was the nature and purpose of demonstration experiments? What was actually demonstrated? How and why had lectured demonstrations changed and finally lost their importance? With these questions in mind I want to draw a line from lecture demonstrations in physics teaching around 1900 to the interwar period. I especially want to draw upon the examples of the concept of lecture demonstrations and physics teaching marketed by the dominating German instrument companies Max Kohl and E. Leybold Nachfolger before, and the system of lecture demonstrations developed by the Göttingen Professor of Experimental Physics, Robert Wichard Pohl after WWI.

In 1924 Pohl and the instrument company Spindler & Hoyer started a co-operation to produce a system demonstration instruments which were organised along the lines of Pohl's series of physics textbooks. Vividness, simplicity and the reject of historicity were the main features of the teaching system. Pohl's ideas for the re-organisation of lecture demonstration fitted well in a time of rapid changes in physics, shortage of money and German postwar society. His elaborated system of textbooks and demonstration technology turned out to renew and soon to dominate lectures on experimental physics at universities and other higher education institutions in Germany and other countries.

Teaching Physics at American Universities and Colleges around 1900: Laboratories, Apparatus, and European Practices

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In 1875-76, the newly appointed Hopkins physicist Henry Rowland traveled through Europe, inspecting physics laboratories and purchasing apparatus. Upon reaching Berlin, he wrote the Hopkins president: "You were right when you said I would find no lack of scientific spirit here, and the apparatus shows it. In America we have apparatus for illustration, in England and France they have apparatus for illustration and experiment, but in Germany, they have only apparatus for experimental investigation."

This paper explores the transfer and appropriation of German laboratory design and apparatus by American physicists around 1900. Robert Frank has examined late nineteenth-century Americans who traveled to study physiology in German laboratories. He concluded that the travelers brought back laboratories, instruments, and a research ethos, but that they themselves did not become productive physiologists, i.e., they "brought back everything but physiology." Likewise, historians of American physics such as Daniel Kevles, John Heilbron, and Spencer Weart have argued that American physicists, despite traveling to Europe (especially Germany), had by the 1920s failed to "mature," i.e., to incorporate the latest theoretical physics into their teaching and research. Both of these historiographies, concerned with transnational moments in fin-de-si_cle science, emphasize theory. By emphasizing pedagogy, I will reconsider the "maturity" thesis for American physics by following nearly 100 American students of physics who went abroad between 1875 and 1915.

Socialist Experiments in Physics Teaching at School? The Role of Practical Work in School Science Education in the former GDR

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The school system of the former GDR as well as the system of teaching and learning was established on the basic principles of Marxist theory and the formation of the socialistic personality. This resulted in a unified system of comprehensive schools, the combination on theoretical and practical training (polytechnic education) and a strictly centralist organisation of teaching. Within the science education handbooks and journals there were not only high standards for systematic instruction of subject matter but also of the social and historical role of science. For the preparation of the teachers so-called "Unterrichtshilfen" were published which should guarantee a constant quality of instruction throughout the whole country, including experiments and hints for their performance. Following the ideal concept of the unity of manual labour and intellectual activities demonstration experiments as well as experiments carried out by the students were brought to the fore in the process of instruction and learning. Experimental devices needed for teaching purposes were produced centrally by a special manufacturer owned by the state. Furthermore, the psychology of learning physics by experimental action and methods of evaluating students' achievements during experimental work formed important fields of research in science education.

Besides an analysis of the didactic fundamentals given above a comparison between the ideological demands and everyday practice in schools is drawn in our contribution.

What Makes a Lecture an Exemplar? Bunsen's 'Experimentalchemie'

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According to John Tyndall's testimony, "Bunsen was a master of the language of experiment, thus reaching the mind through the eye as well as through the ear." Accordingly, he considered "Bunsen as the nearest approach to my ideal of a university teacher." (Tyndall, New Fragments, 1892, 238). Tyndall was by no means alone with this view. Several leading scientists of the time regarded Bunsen's course as the very archetype of its kind. Focusing on Bunsen's Heidelberg period (1852-89), I am going to analyse the lecture on 'Experimentalchemie' he taught 34 years in a row. What kind of didactic, visual and rhetorical resources and instrumental teaching aids did Bunsen use? How can we explain the great reputation of his lectures?

Lecture notes of former students or the less common source of Bunsen's 'Vorlesungsbuch' give valuable information about the contents, but do not explain the reasons for Bunsen's success as a teacher. Often personal autobiographical documents of his pupils give a truer account of the peculiarity of Bunsen's lectures as to the point of the performative dimension of science teaching.

Icons from Electrochemistry and their Reconstruction in Teaching

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The departments of chemistry and physics at the Norwegian University of Science and Technology have collected historical instruments, chemicals and glassware from the former Norwegian Institute of Technology, which was inaugurated in 1910. These objects were mainly used in a teaching context, especially in lecture demonstration. In order not to remain with a "dead" collection we commit ourselves on a regular basis to undertake investigations and reconstruction of experiments that have been performed with the instruments, reviving their role and function in the teaching context. These experiments are then integrated into our History of Science course. So far we have chosen instruments and experiments from electrochemistry, which have obtained an iconic status in chemistry as well as physics. We have previously reported on our experiments with a historical water decomposition apparatus and a voltaic pile. In this presentation we tell about the enjoyable and surprising experience of reconstructing experiments with our galvanic cells, and in particular with our Daniell cell.

Last change on this page: 15 March 2009

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