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Essay review

Philosophical Instruments: Notion Displayers, Black boxes, and Their Usefulness

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Volta: science and culture in the age of Enlightenment
Giuliano Pancaldi; Princeton University Press, Princeton & Oxford, 2003, pp. xvii + 381, Price £24.95 hardback, ISBN 0-691-09685-6.

Shortly after John Frederic Daniell, professor of chemistry at King's College, London, invented the so-called constant battery in 1836, this electrical instrument was redefined and converted into a technological tool by two applied scientists (Daniell, 1836). First, Charles Wheatstone turned it into a source of electric current to work his electromagnetic telegraph, and as a piece of telegraphic equipment the Daniell battery continued to play a role for about thirty years until it was superseded by Georges Leclanché's 'theoretical' manganese dioxide cell. Second, it was redefined as a copper depositor by Moritz Hermann von Jacobi who subsequently developed the art of galvanoplastics or electrometallurgy. But these two developments went far beyond Daniell's intentions. Daniell intended his constant battery to play the role of a philosophical instrument, and philosophical instruments served two purposes. In the first place Daniell used his constant battery in lecture demonstrations in order to impress upon his pupils the truth of Michael Faraday's theory of the definite chemical action of electricity. In the second place Daniell's philosophical battery was a scientific laboratory research tool, an instrument to produce experimental phenomena that could be made to play an argumentative role in the (in)validation of hypotheses and theories including Volta's and Faraday's theories of electrochemistry.

Pancaldi's book on Alessandro Volta can be read as a study of the Enlightenment, a study of cisalpine enlightenment, a history of eighteenth-century science, a

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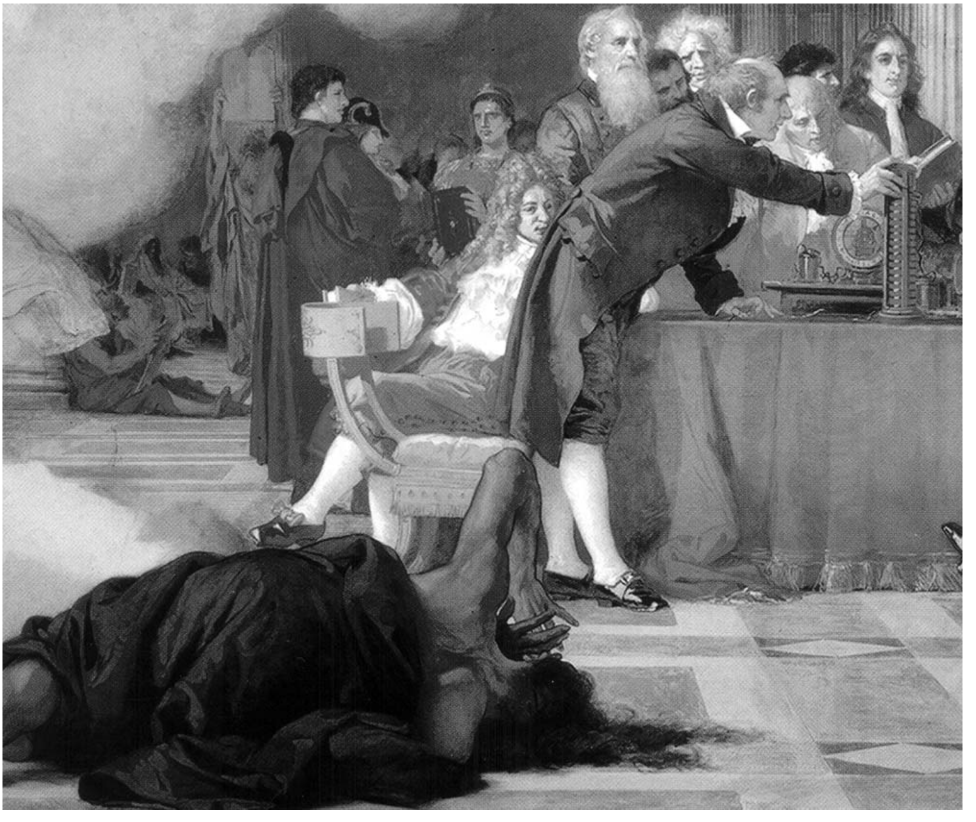

Fig. 1. Obscurantism defeated, Nicolò Barabino, *Il trionfo della scienza*, 1876, detail (from Pancaldi, 2003; used with the permission of Princeton University Press).

history of electrical theory, but also as a treatise on philosophical instruments and Volta's philosophy of experimental apparatus.

It was in 1763 that Volta started his career as an electrician. Aspiring to gain recognition as a natural philosopher he sent letters to Jean-Antoine Nollet and Giambattista Beccaria that contained sweeping generalizations and bold speculations as to the nature of electricity. This first, theoretical, episode of Volta's scientific career was concluded with the publication of a theory of electricity in terms of Newtonian attractive forces (*De vi attractiva ignis electrici*, 1769). It was also the end of Volta's explicit theorizing. The lukewarm reactions of Nollet and Beccaria made him decide to abandon theoretical natural philosophy and embrace the investigative style of experimental physics. In the words of Pancaldi, Volta adopted the attitude of a reluctant theorist, 'a none-too-convinced adept of the instrumentalist bent of late-eighteenth-century physics' (p. 8).

Volta's first attempt at conquering a place in the international community of physicists not as a theorist but as an inventor of electrical instruments dates form his theoretical period. In 1765 he began to apply his general theory of electricity to the phenomena of triboelectricity. He did not do so by formulating a special theory of electricity but by developing an electrical machine. This was the first example of a whole series of philosophical instruments Volta developed between 1765 and 1800. The step he took was the application of his notions on triboelectricity to the construction of a piece of apparatus. In the words of Pancaldi, Volta's silk electrostatic machine

> was the first of a long series of devices Volta conceived with the explicit purpose of displaying at work, as it were, the notions he was developing at the conceptual level. (p. 83)

I will call these philosophical instruments 'notion displayers'. Pancaldi, following Marcello Pera, calls them 'instruments-displaying-theory-at-work'. [On 20 March 2004, the 204th anniversary of Volta's famous letter to Sir Joseph Banks, I went to Como and secretly entered Volta's grave. I asked him whether he liked Pancaldi's designation 'instruments-displaying-theory-at-work'. He answered that he thought it was quite precise terminology but since choosing catchy names was instrumental—and here he gave me a wink—in gaining reputation he assured me that he preferred my notion displayers.]

In 1771 Volta developed two new notion displayers, an all-wood electrostatic machine and a wood Franklin square. These instruments were described in his memoir entitled *Novus ac simplicissimus electricorum tentaminum apparatus* and they 'displayed at work the principles Volta invoked in the theoretical part of his essay' (Pancaldi, 2003, p. 92).

Then, in 1775, with the development of the perpetual electrophorus, Volta took a further step, from notion displayer to phenomenon displayer. The electrophorus was a simple, easily replicable, portable machine to be used in displaying electricity, and 'electricity' did not refer to any electrical theory but to a series of electrical phenomena. The theoretical content of phenomenon displayers is minimized, implicit, put between brackets, embodied. In fact, the theory of the electrophorus was very unclear even to Volta himself who did not publish his tentative account of the internal workings of the electrophorus until three years later. The electrophorus was not intended to illustrate theoretical notions but to produce electrical phenomena.

In 1782 Volta came up with a new philosophical instrument, an amplifier of weak electricity called a *condensatore* or micro-electroscope. It was a typical notion displayer, displaying the central notions from Volta's theory of electrical atmospheres. However, this instrument should be ranged halfway between notion displayers such as the silk electrostatic machine and phenomenon displayers such as the electrophorus since the notions involved—capacity, tension, actuation (induction)—have the character of mid-range conceptualizations. These mid-range notions can be defined operationally in terms of measurable quantities, and the *condensatore* is thus a measuring instrument or quantity displayer.

In the 1780s Volta developed two additional measuring instruments, the electrostatic balance and the straw electrometer for precise measurement of a quantity called electric force.

All these philosophical instruments and especially the electrophorus and the *condensatore* made his name as a brilliant inventor of electrical apparatus among electricians belonging to the eighteenth-century cosmopolitan network of natural philosophers. Volta did not remain passive in Pavia. He undertook a series of propagandist activities. When describing a new instrument he included precise replication instructions as well as a repertoire of experiments to be carried out with the instrument. He dispatched instruments ready to use to influential persons. He organized public demonstrations. And on the three philosophical trips he made between 1777 and 1784 he carried a travelling bag packed with instruments to be demonstrated before his hosts.

In this way he gained international recognition as an experimental philosopher. Pancaldi distinguishes four types of electrician, in the order of decreasing social status: natural philosopher, inventor, instrument maker, juggler. Since Volta had abandoned explicit theorizing early in his career and put all his energy into the development of notion displayers, the recognition he obtained had second level quality. According to Pancaldi, however, Volta's success as an instrumentalist had wider consequences. Volta succeeded in rendering electrical instruments, experiments and measurements more *salonfähig* and thus shortened the social distance between philosophers and inventors. In this way Volta contributed to the transition from eighteenth-century natural philosophy to nineteenth-century experimental science.

In 1796 Volta had Giuseppe Re, his instrument maker at the University of Pavia, construct a replica of William Nicholson's revolving doubler. This instrument dated from 1788 and was designed to detect and measure extremely small amounts of electricity. According to Volta, it worked on the same principles as his own *condensatore*. Volta, however, did not use his doubler as a 'normal' amplifier of weak electricity. By substituting discs of various metals for the brass ones of Nicholson's machine he redefined it as a detector of 'metallic electricity'. Volta's theory of metallic electricity stated that electricity could be set in motion by the contact of different conductors, and this theory had been deployed against Galvani's idea of animal electricity. Nicholson's doubler had been an amplifier of weak electricity. Volta converted this measuring instrument into an original notion displayer. Volta's revolving doubler got the function of demonstrating 'at work' the notion of metallic electricity, and in this sense it is a precursor of the voltaic pile. The notions displayed are, again, mid-range notions, such as resistance and electromotive force, that is, the power metals possess of pushing the electric fluid into humid conductors.

Between 1796 and 1800 no new, major, conceptualization took place according to Pancaldi. At first sight, therefore, the instrument invented at the end of 1799, which we now call the voltaic pile or the electric battery, seemed just another, only more spectacular, displayer of the notion of metallic electricity. This is also suggested by the English title added by the editors of the *Philosophical Transactions* to the letters written in French that Volta addressed to Joseph Banks: 'On the electricity excited by the mere contact of conducting substances of different kinds' (Volta, 1800). Volta himself alluded to the idea of a notion displayer when he justified his neologism *appareil électro-moteur*:

> We must give new names to instruments that are new not only in their form, but in their effects or the principle on which they depend. (Ibid., p. 576)

The principle Volta's electromotive apparatus depended on was metallic electricity or, in a more 'mid-range' formulation, the difference in electromotive power of the two metals incorporated in the pile.

However, in the memoir he sent to London he underplayed the theoretical aspects of his new invention in favour of a detailed description of how to construct various versions of his electromotive apparatus and how to perform experiments with it on different parts of the experimenter's body. In this he acted like he did in 1775 when he presented the perpetual electrophorus. For all practical purposes the battery was a phenomenon displayer.

And it was precisely as such that the battery was received by natural philosophers in England, Scandinavia, and France. There *were* scientists who were interested in what happened between the first silver disc and the last zinc disc: Marsilio Landriani, Hans Christian Ørstedt, Jean-Baptiste Biot, William Hyde Wollaston. But the majority completely passed over the internal workings of the voltaic pile and devoted all their attention to what happened between the wires connected to the pile: Carlisle, Nicholson, Robertson, Ritter, Henry, Haldane, Davy, Berzelius, Hisinger. Both Etienne-Gaspard Robertson and Johann Wilhelm Ritter used the battery for producing a series of sensations on the human body and thus extended the repertoire proposed by Volta, but the overwhelming majority of scientists who replicated Volta's invention used it for producing electrochemical phenomena. The first to do so were Nicholson and Carlisle who were more Catholic than the Pope since they put Volta's contact theory and any other possible explanation of the pile's working between brackets and used the pile as a black box producing an electric current that was made to decompose water. They redefined Volta's electromotive apparatus as a philosophical instrument that could produce electrochemical phenomena, and Davy and Berzelius followed in their footsteps. Volta's invention became a 'source of an electric current, independently of any assessment as to how the current was produced' (Pancaldi, 2003, p. 232). In the hands of Humphry Davy it became an electrolytic machine, 'an engine, by means of which the compounds whose constituents adhered to each other might be separated' (Thomson, 1831, p. 264). This approach to the battery remained the dominant one during the first decades of the nineteenth century until Michael Faraday came up with his electrochemical theory of the voltaic pile. Volta himself had presented, however reluctantly, a notion displayer. English electrochemists such as Humphry Davy did not even adopt the name electromotive apparatus and radically turned Volta's invention into an electrolytic machine, and never mind how it worked. It was only in 1836 that Daniell reintroduced the idea of a notion displayer, his constant battery displaying at work both Faraday's electrochemical theory and his own theory of polarization.

Generalizing a remark made by Pancaldi on the subject of the electrophorus, one can say that philosophical instruments play a role in four social settings: public demonstrations, education, scientific research (pursuit of knowledge, cultivation of science), and technology (public utility).

As to public demonstrations, eighteenth-century Enlightenment culture favoured the popularization of experimental physics through entertainment and amusement. Electricity was quite fashionable in salons and gardens, and experimenters such as Gray, Du Fay, Franklin, Nollet, Sigaud, Charles, and Desaguliers became quite famous. Volta participated in this movement in various ways. He performed electrical experiments in fashionable salons in Lombardy, the physics theatre of the University of Pavia, and the streets of Milan. In 1775/1776 the electrophorus found its way to Milan, Vienna, London, Paris, Berlin, and Prague. Volta showed his instruments to his various hosts during his trips to Switzerland, Tuscany, Holland, France, England, Austria, and Germany. This tradition of public demonstrations survived into the nineteenth century. For electricity and electrochemistry the Royal Institution established in 1799 had special significance. The public lectures given by Thomas Garnett, Humphry Davy and Michael Faraday were very well attended.

Prior to the 1770s the Italian universities were not offering the best education available in the sciences, to use Pancaldi's understatement. When De Lalande visited the University of Pavia in 1766 he found 'facilities' (that is, its store of philosophical instruments) unsatisfactory or non-existent. Twenty years later, the situation had greatly improved, not in the least by the efforts made by Carlo Barletti and Alessandro Volta. In the 1770s, both secondary and university education were being reformed in Lombardy. Reform proposals envisaged strengthening the teaching of science and favouring experimental science at the expense of theoretical natural philosophy. Volta was active in this movement both in Como and Pavia. In 1774 he was appointed superintendent of the secondary schools in Como, and here he formulated his plans for educational reform, including the acquisition of a collection of physical instruments for research as well as for teaching and public demonstrations. In 1778 he was appointed professor of physics at the University of Pavia. His lectures invariably included some experimental demonstrations by means of philosophical instruments constructed by Giuseppe Re or ordered in England or Germany. In the 1830s, the transition from natural philosophy to experimental science having been completed, lecture room demonstrations were standard educational procedure. Chemical philosophy is essentially an experimental science, Daniell maintained in his opening lecture at King's College in 1839,

> and all its inductions are founded upon palpable phenomena. Hence it is absolutely necessary that its truths should be taught by experimental demonstrations. (Daniell, 1839, p. 3)

And among the philosophical instruments to be used to produce these palpable phenomena could be found the Wollaston battery, which is a particular form of the voltaic battery, 'that splendid instrument of experimental research which so justly perpetuates the name of Professor Volta, of Pavia' (Daniell in his 1843 textbook, p. 501).

Not a great deal has to be added about philosophical instruments as devices of scientific research. Research, the pursuit of knowledge, the cultivation of science, is the chief domain of their use. As research instruments they do not have the character of notion displayers, which played such an important part in eighteenth-century 'instrumentalized' natural philosophy. Rather, they are either measuring instruments or 'machines' for producing experimental phenomena. Thus, during the first four decades of the nineteenth century the voltaic pile or variations such as the copper/zinc trough models devised by Cruickshank and Wollaston were intensively used to produce electrochemical and electromagnetic phenomena. This is the period of the investigations of Nicholson, Davy, Berzelius, Ørstedt, Ampère, Faraday, to name only the most famous. They 'received' Volta's invention as a splendid instrument of experimental research (Daniell), a magnificent instrument of philosophic research (Faraday), that gave access to an ample field of experimental speculation (Cavallo). By 1835, according to Auguste Comte, the voltaic pile belonged to the standard equipment of scientific research laboratories (Comte, 1835, Vol. 2, p. 363).

After serving for about forty years as a philosophical instrument in the pursuit of knowledge the battery, as a device for manufacturing current electricity, finally began to produce 'useful knowledge' that led to technological applications such as the electric telegraph and electrometallurgy. In the last chapter of his book Pancaldi considers the following question:

> What exactly were the links between the emphasis on 'utility,' proper to Enlightenment culture, and the introduction of instruments like the battery, which had only limited useful applications [medical, mainly], and yet paved the way for technological developments that would modify an entire civilization? (p. 275)

Now Pancaldi begins to lose some of his usual acuity. The voltaic battery was almost a *useless* machine, he says. But here he proves himself to be a true child of our thoroughly technological culture since he embraces a strictly technological interpretation of the ideas of utility and useful knowledge. In the eighteenth century, however, scientific knowledge was also considered useful as criticism of ignorance, superstition, blind habit, obscurantism, prejudice, and 'medieval' or 'Gothic' ways of thinking. 'Enlightenment' has many meanings and shades of meaning, but at its lowest level, according to Norman Hampson,

> the Enlightenment began with the substitution of information for an oral tradition of folk-memory, superstition and blind habit, and the mere practice of regular reading was at least a step along the road. (Hampson, 1990, p. 143)

An example, often repeated and involving the theory of electricity, is the case of the lightning conductor in Saint-Omer in 1783. Lightning is not the wrath of God but a perfectly natural electrical phenomenon. That is what was at stake. Franklin's knowledge of electrical phenomena was useful for combating and ridiculing the backwardness of Saint-Omer's inhabitants including the neighbour of Mr. De Vissery. The case of the lightning conductor also figures in Comte's theory of the decline of theological thinking. The theological way of viewing natural phenomena, he says, is based on the belief that they are brought about by some supernatural being. This type of explanation can be destroyed in two ways. First, the exact prediction of certain phenomena on the basis of scientific knowledge will evaporate the idea of divine direction. The second will produce the same result, but in this case, the case of technology, human direction has supplanted divine intervention. As an example, Comte goes on to say, take the case of Franklin who has irrevocably destroyed the religious theory of the thunderbolt by proving that man is capable of directing those flashes of lightning. Franklin has had a real influence on the subversion of theological prejudice.

Pancaldi refers to this kind of useful knowledge twice. At the time when Volta tried to make a career by approaching Nollet and Beccaria with his Newtonian theory of electricity he also wrote a didactic poem in the style of Virgil and Lucretius. More than 2000 years ago Lucretius had been fighting obscurantism and 'theological' explanations of the thunderbolt:

> Nature is free and uncontrolled by proud masters and runs the universe by herself without the aid of the gods ... Who can be in all places at all times, ready to darken the clear sky with clouds and rock it with a thunderclap—to launch bolts that may often wreck his own temples, or retire and spend his fury letting fly at deserts with that missile which often passes by the guilty and slays the innocent and blameless? (Lucretius, 1971, II.1090–1104)

According to Volta in his poem, the eighteenth century would become a more enlightened age. The blind superstition of former ages would be replaced by the rational explanation of phenomena that had been terrifying and that had been thought the result of supernatural powers. Lightning comes up again as an example. Lightning is an electrical phenomenon, and the electrical theories of Franklin, Nollet, and Beccaria represent knowledge useful for bringing about a more enlightened age.

Pancaldi's second reference to useful knowledge in the non-technological sense can be found in his interpretation of Nicolò Barabino's painting 'The triumph of science' (Fig. 1). Here we see obscurantism defeated, and the voltaic pile has a leading part in the victory. In the 1870s electrical engineering was developing fast: electrometallurgy, telegraphs, dynamos, electric motors, storage batteries, telephones, the incandescent lamp. But none of these technological objects can be seen in Barabino's picture. Obscurantism is defeated, not by electrical engineering but by an instrument that opened up the possibility of electrical engineering. The voltaic pile is a symbol of the natural power called electricity, more precisely current electricity since no eighteenth-century electrostatic machine can be seen. But the pile is not viewed as a technological tool since in that case we would expect the Leclanché battery, which was commonly used in the 1870s. In my opinion the voltaic pile in Barabino's painting should be considered a philosophical instrument. It is to the battery as a philosophical instrument that obscurantism has had to yield. And the experimental research in the fields of electrochemistry and electromagnetism has yielded the knowledge that was so useful in combatting the 'theological' legacies of former ages. In a certain sense it is the triumph of positivism that Barabino has painted.

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