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Between teaching and research: Adolphe Ganot and the definition of electrostatics (1851–1881)

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ABSTRACT

Adolphe Ganot's *Traité* was a canonical physics textbook in 19th-century Europe. In this period, static electricity was largely based on research conducted during the eighteenth century. However, the discussion on the theories of electricity had an important role in the configuration of physics as a discipline through the replacement of imponderable fluids by other frameworks such as the conservation of energy. In spite of this process of unification, the practices defining nineteenth-century electrostatics were not uniform. In this paper we intend to provide a big picture of nineteenth-century electrostatics and to launch a fruitful dialogue between historians and scientists.

1. Introduction

In 1851, Adolphe Ganot (1804–1887) published in Paris his *Traité élémentaire de physique expérimentale et appliqué* [1] The book was the result of twenty years' experience as a science teacher. The *Traité* met with rapid success, running through eight editions in eight years. Ganot produced successive editions of his book until 1881, when he retired and handed them over through contract to Hachette, the leading French publisher of secondary school textbooks. According to Ganot, the last edition of the *Traité* (18th, 1880) that he prepared himself, had a print-run of 20,000 – a considerable number in this period [2] –and he claimed to have produced 204,000 copies of the book since 1851 as stated in the 18th edition [3].

Furthermore, during the second half of the century, the *Traité* was read in French in many countries, and it was translated into twelve languages. Namely, Italian (1852), Spanish (1856), Dutch (1856), German (1858), Swedish (1857–60), Spanish (Paris, 1860), English (1861–63), Polish (1865), Bulgarian (1869), Turkish (1876), Serbian (1876–77), Russian (1898) and Chinese (1898) (dates between brackets indicate the year of first editions, in most cases there was more than one; the Spanish and English editions were almost as numerous as the French). Although the translation of French physics textbooks was common in this period [4], Ganot's textbooks were certainly amongst the most widely translated and read, and as such made a major contribution at an international level to the making of physics as a discipline. By the 1880s, they were considered standard works of physics by a wide range of readers across the educational, cultural and social spectrum in France and other countries. This conferred them with a canonical cultural status in science, in international perspective [5–7].

Accordingly, Ganot's textbook is an excellent source for historians of physics, offering a major opportunity to characterize the discipline. With his *Traité*, Adolphe Ganot managed to combine fundamental characteristics of previous major textbooks by Claude Pouillet (1790–1868), Eugène Péclet (1793–1857) and Marcel Despretz (1789–1863) with new ingredients. These authors had dominated the French physics textbook market since the late 1820s. Through translation they also contributed to shape physics in many other countries as well. Ganot took the lead from the 1850s and although he had strong competitors, his *Traité* was during the second half of the century the major standard work used to introduce students to physics in secondary education and in the early stages of university degrees in science.

In spite of this, so far, Ganot's work has not received much attention. Historians and philosophers of science have in general ruled out the use of textbooks as sources. Conventional views about textbooks have been prejudiced by an inaccurate separation and hierarchization of teaching and research. Ganot was not involved in research like for instance Pouillet, Péclet and Despretz. He was mainly a teacher who kept very well informed, especially on scientific instrument design. As far as we know, he only used scientific instruments for pedagogical illustrations, although he was also involved in the design of some industrial applications in

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relation to lighting and steam machines. During his career, Ganot registered at least four patents in France [8].

Teaching and textbooks – as major educational products and tools – have been considered as uncreative, dogmatic and mere simplifications of research and research papers. However, these views have been increasingly criticized. Recent scholarship is showing that often research and teaching come together, and that teaching and textbook writing are highly creative practices having a major role in shaping science [9–14]. This is the approach taken in this paper.

Accordingly, we argue that scientific disciplines such as physics and subjects such as electrostatics are not only shaped by research and researchers but also by other actors such as teachers and textbook authors. Thus we intend to use the case of Adolphe Ganot's *Traité* in order to build a richer picture of the shaping of physics as a discipline in the nineteenth century and to provide in this context a historical definition of electrostatics which hopefully will be intellectually-engaging for the modern reader.

In the following narrative, we begin by presenting a brief panorama of physics and its constitution as a discipline in the nineteenth century by analysing its structure, the relevance of its unification projects and the diversity of actors intervening in the process. Subsequently, we devote two sections to the study of electrostatics through Ganot's textbook account. Finally, we suggest several aspects which can contribute to make Ganot's book interesting for contemporary readers involved in the practice of electrostatics.

2. Physics and its discipline(s)

In 1825, the mathematician and science writer Louis-Benjamin Francoeur (1773–1849), expressed the heterogeneity of the field of research designated then as 'physics' or 'natural philosophy':

> "Of all elementary treatises which aim to be used in the teaching of the sciences, the most difficult to do is certainly a work of physics: the reason is that in this branch of knowledge are classed several different sciences which are distinct sciences having often nothing in common between them."[15] *(all translations are by the authors)*

Indeed, during the first half of the nineteenth century, 'physics' was composed by several areas of research studying different phenomena in nature. Accordingly, physics textbooks were composed by separate parts – often designated as "books" – devoted to the study of the properties of matter (solids, liquids, and gases), light, sound, heat, magnetism and electricity, respectively. The study of electricity was often divided in two separate books devoted to static or frictional, and dynamical electricity. These overall divisions were based on the eighteenth-century use of the concept of imponderable fluids. Each of the aforementioned phenomena was accounted for by the interaction of a particular imponderable fluid with matter.

The historiography of physics has placed the unification of these fields as the central phenomenon leading to the constitution of physics as a discipline in the late nineteenth century [16,17]. Different programs were put forward in this period with this intention. In the early nineteenth-century, the French Laplacian programme intended to unify physics by proposing that molecular forces with a common origin governed the action of the different imponderable fluids. This program was subsequently rejected and substituted in succession, first by theories giving central explanatory power to the correlation, conversion and conservation of forces in Britain, and later by the conservation of energy proposed in Britain and Germany, and in electricity and magnetism by Maxwell's field theories. As expressed by Rudolf Stichweh, this element of discontinuity in the historicization of physics is an attractive solution, as it allows presenting "physics" as an "invention", thus making the contingency of its origin a central object of discussion [18]. In fact, available general histories of physics have especially focused on the conservation of energy and conventionally linked the different unification programmes to the culmination of a process of disciplinary formation around that concept.

However, in the light of case studies such as that of Ganot's *Traité* and other physics textbooks, this strategy is problematic, as it has resulted in a periodization of the development of physics as a discipline implying a simplistic national division. The development of physics is supposed to have been carried forward by French, German and British scientists, in successive periods and mostly through separate initiatives. Furthermore, it is generally suggested that the different theoretical frameworks put forward in different moments of this process were immediately accepted everywhere. The reality is much more complex, and the analysis of textbooks reveals this rich complexity.

During the long editorial life of the *Traité*, Ganot only declared in the fourteenth edition of 1870, that "the hypothesis of imponderable fluids, abandoned everywhere, has been replaced by that of a unique fluid", in his textbook [19]. The reader might be surprised by the lateness of this declaration and by the fact that Ganot still used the term "fluid", instead of talking about forces and their correlation, or even about the conservation of energy – taking into account that this doctrine had from 1867 been vigorously promoted in Britain by William Thomson and Peter Guthrie Tait. In fact, Ganot never rewrote his textbook in terms of this principle, which was at the core of the making of physics at the end of the century. In spite of this, he did provide accounts of the different researches that where leading towards a unification of the interpretation of natural phenomena by physicists, such as Fresnel's wave theory and Joule's dynamical theory of heat. Moreover, from the mid-1860s, in the introductory chapter of his *Traité*, Ganot accepted that all physical phenomena could be subdued to a mechanical cause and to the vibrations of 'ether', a unique substance filling the universe [20]. It is significant to pinpoint that although the English edition of Ganot's *Traité* did introduce a section on the new principle of energy conservation as soon as 1868, as for the French case, it did not imply a significant change of the structure of the book and its conceptual and narrative arrangement [7].

Ganot's conception of physics was led by other priorities. For him, the theoretical frameworks successively proposed to unify the study of natural phenomena, were mere hypothesis, which in many senses were unnecessary to explain the latter. On the contrary, the accurate description of scientific apparatus, experimental sets, and experimental procedures, and their exposition in a clear and precise way had a fundamental role in Ganot's physics. Indeed, pedagogical concerns were essential in Ganot's writing and his theoretical choices were often led by pedagogical instrumentalism. As has been pointed out by scholars like Frederick L. Holmes and James Secord the communication of science is an integral part of its making [21–23]. The following sections are devoted to expose Ganot's approach to physics, through the analysis of his book on static electricity.

3. A tale of two electricities

The book on static electricity started like the other books composing Ganot's *Traité* with a historical record of research in this field, followed by a short empirical definition of the behaviour of static electricity and an exposition of the theoretical framework in use.

At this point, Ganot expressed again his characteristic approach to theory. Two theories of electricity were in use since the late eighteenth century. Benjamin Franklin's theory supposed there was a unique imponderable fluid, whose relative absence or presence accounted for the effects of electricity. On the other hand, Robert Symmer argued that there were instead two fluids which combined, and eventually could even neutralize each other. Historians of physics have considered that Franklin's theory was in general adopted in Britain, while Symmer's theory gained favour in the Continent [24]. Indeed, after exposing both theories, Ganot revealed his preference for Symmer's in accordance to what he considered the most accepted contemporary views on the matter. But, Edmund Atkinson – the translator of Ganot's *Traité* in England – did not consider necessary to change Ganot's choice, and his translation also promoted Symmer's theory among English readers [25].

Ganot and his translator agreed in another question: Franklin's and Symmer's theories were in fact mere hypotheses. Ganot thus chose the latter, in considering that it was more suitable to explain and to communicate to students the phenomena of electricity. Beyond pedagogical benefit, theoretical disquisitions were not particularly useful, and Ganot saw often them with scepticism: "Moreover, it is worth to pinpoint how vague is this denomination of fluid applied to the causes of caloric, light, magnetism and electricity. What is in fact a fluid? What is its nature? No physicist has provided information on this matter" [1].

On the other hand, the book on static electricity was one of the more stable through successive editions of the *Traité*. During three decades as editor of the book, Ganot preserved most of its original contents, and additions were rare. This was in clear contrast with the book on dynamical electricity, which increased with new matter at every edition, exposing the vibrant context of industrial development taking place in this field, during this period. On the contrary, the major aim of the book on static electricity was establishing the fundamentals of electricity, exposed through experiments and examples relevant in terms of research and pedagogy. In spite of this there was also some space for novelties and applications, as we show in the next section.

4. Instruments, experiment and pedagogical practice

Ganot's account of static electricity started by an empirical introduction to the field, exposing the most simple effects of development of electricity by friction and the characteristics of conductors, non-conductors and insulating bodies. After briefly exposing the different theories of electricity, he described different techniques to produce electricity by friction, and provided an account of Coulomb's formulation of the laws of electrical attraction and repulsion, in the context of his experiments with his torsion balance. Subsequently, the *Traité* analysed the distribution of electricity on insulated bodies, its loss, and the phenomenon of electrostatic induction as described by Faraday. The rest of the book was fundamentally devoted to electrical machines and their use, condensers and electrical discharge, and the physiological, luminous, calorific, mechanical and chemical effects of static electricity.

Most of the instruments and experimental illustrations displayed by Ganot in his textbook were classical, in the sense that they had already a long history, having been introduced between the late eighteenth century and early nineteenth century. To this category belonged the different sets of insulated conductors used in many experimental demonstrations, the classical electrical machine designed by Ramsden, electrophores, Leyden bottles, Aepinus's condenser, and Volta's electroscope and pistol (Ref. [27] p. 504). The book included some new instruments related to Faraday's researches. However, through the years, the major number of additions was new electrical machines, stressing the fundamental role in Ganot's electrostatics of techniques of charge generation. In addition, some of these additions such as Nairne's electrical machine and Armstrong's hydroelectrical machine responded to contemporary developments in applications of static electricity to medicine and industry. Thus, Ganot showed that dynamical electricity was not the only object of these fruitful interactions, although its developments in this direction were comparatively much more numerous.

Ganot's writing and selection of experiments and instruments were both due to his aim of attaining pedagogical clearness and precision, and to make the *Traité*, an updated vademecum of the most relevant research carried forward in physics, including electricity. As stressed by a reviewer of physics works, the function of a major textbook was to communicate "a large number of researches [...] which have not come out from scientific journals and academic compilations", rendering thus an important service both to *savants* by making their work known, and to students by providing them with a more complete idea of science [26].

Ganot's textbook account of static electricity was not at all characterized by dogmatic consensus – a feature conventionally assigned to textbooks. On the contrary, as already mentioned, he included side by side the rival theories of electricity of Franklin and Symmer. He also gave account, for instance, of Snow Harris's objections to Coulomb's laws, based on his own experiments. In both cases, Ganot's decisions to discriminate one or the other option were fundamentally based on pedagogical concerns, but also related to his perceptions as a physicist of the directions the field was taking. With these decisions, he contributed himself to the development of the discipline.

5. Historical contingency and the present of electrostatics

Historical contingency marks the place of Ganot and his *Traité élémentaire de physique* in the study and practices of static electricity. The peculiarities of Ganot's professional profile in mid nineteenth-century Paris had indeed an important impact in the constitution of the *Traité*. In spite of this, its original local context of production and use ended up expanding, covering the world-wide scale, and transforming the book in a canon. Moving from geographical space to time, this section intends to establish a dialogue between the contemporary researcher in electrostatics, Ganot's physics and the historian. Our aim: claiming the mutual benefits of such interaction.

Adolphe Ganot and contemporary researchers are obviously grounded in very different historical contexts. Today, research in electrostatic has major developments in risk prevention and industrial applications – the major driving forces defining the field. In Ganot's time, the *Traité* shows us that, while industrial applications were important and had important developments in the field of dynamical electricity, static electricity was rather conceived as a general introduction to the topic, and its industrial applications were minor. The few applications appearing in Ganot's electrostatics book are quite diverse and belonging to fields which perhaps we would not expect to appear in a general treatise of physics, such as medicine or steam power. But this is particularly related to Ganot's career as a physicist, and the importance of the interaction of these two fields in the emergence of physics as a discipline.

Today, electrostatics can be roughly divided into two main aspects: charge generation and charge dissipation. From a safety point of view, charge dissipation is the most important phenomenon of electrostatics whereas controlled charge generation is present in many applications (electro spraying, electrets, adhesion, separation, etc.). In contrast, Ganot's static electricity is mainly focused on charge generation which is the way to analyse its properties and work with it. Charge dissipation appears as a secondary phenomenon, less understood and illustrated with fewer examples.

On the opposite, Ganot's approach to electrostatic is strongly based on experimental illustration with basic methods. The exposition of electrostatics in Ganot's *Traité* is a logical progression of experimental facts illustrating the most elementary principles of electrostatics. Instead, in current textbooks and teaching of electrostatics, a mathematical model directly derived from Maxwell's

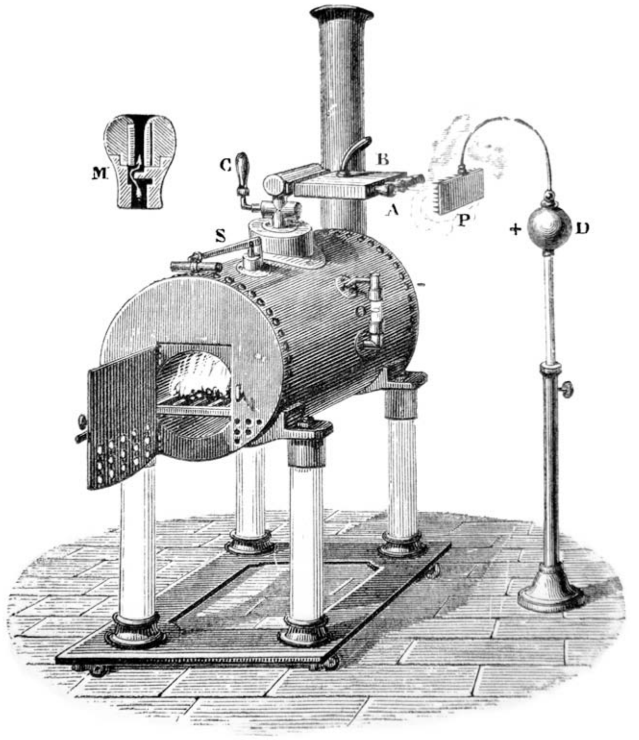

Fig. 1. Pedagogical model of Armstrong machine [28].

equations is often the articulating framework. Hence, electrostatics is usually reduced to calculations rather than experimental manipulations.

Ganot tackled the problem of triboelectric charging but again he produced a basic and mainly empiricist account due to his epistemological approach but also to the characteristics of the 19th-century context of industrial applications.

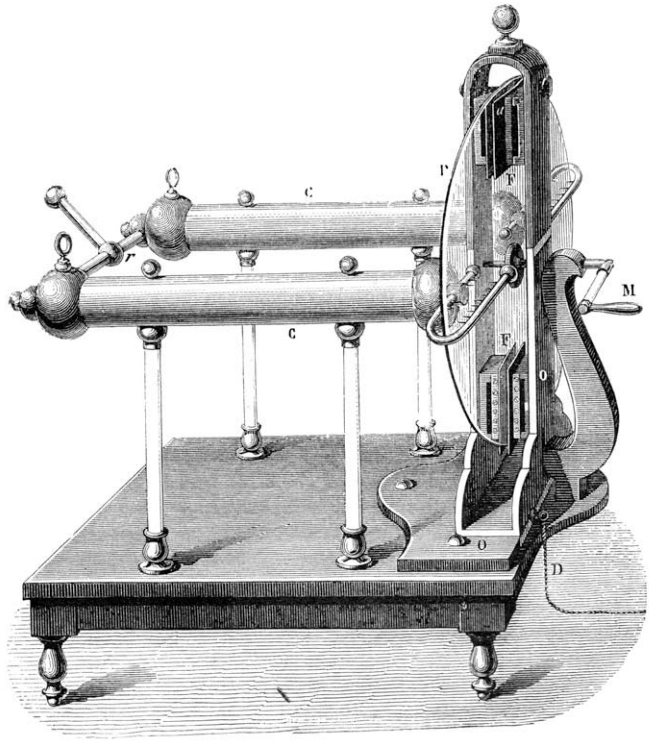

Fig. 2. Ramsden electric machine reproduced by Ganot [28].

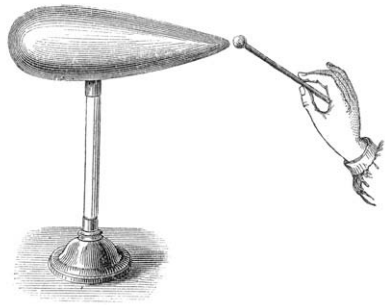

Fig. 3. Measurement of electric field enhancement in a tip [28].

Today, triboelectric charging accounts for an important part of research, especially in relation to risk prevention in our industrial societies. A major difference is the current extensive use of polymers and organic materials. Of course, the list of solid materials generating electrostatic charge is longer nowadays. Besides, organic liquids such as oils or fuels are also easily charged and, at the same time, generate potentially explosive atmospheres. Electrostatic charging with gases has been widely studied to reduce the electrification of cars and planes as well.

Ganot focused instead in a shorter range of materials, such as amber, wax, resin, gutta-percha, sulphur, glass, silk, ebonite. They were used for demonstrations or in the manufacture of electric machines to produce static electricity. In fact, materials play a secondary role; their interest mainly lying in their use as sources of static electricity.

A major point in Ganot's introduction to the study of static electricity is the description of the nature of electricity. A fundamental question was the attribution of a sign to static electricity. From an experimental point of view, in the context of 19th-century electrostatic instrumentation, it was not obvious to give a positive or negative sign to electricity in an unambiguous way, since only mechanical attractions and repulsions were observed. Moreover, static electricity was classified into vitreous or resinous, using the behaviour of these two materials as a reference. In fact, the categories of positive and negative electricity were used and adopted by Ganot for pedagogical convenience. But, in addition, he aimed at an instrumental consensus allowing him to reconcile Franklin's and Symmer's ideas in a scientific field still lacking a stable theoretical framework.

Interestingly, Ganot's account of empirical research recognized powders such as flour, talcum powder and coal powder as easily

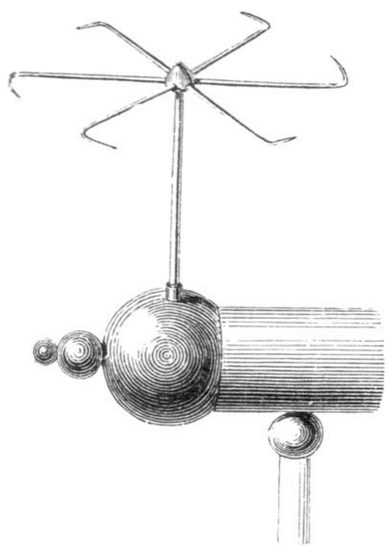

Fig. 4. Electric whirl or vane mounted on Ramsden machine [28].

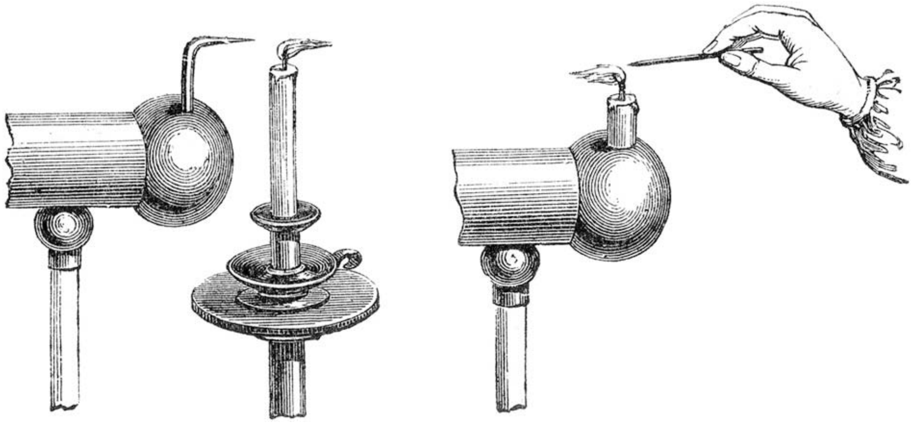

Fig. 5. Experimental demonstration of what today is known as electric wind [28].

chargeable. Although coal and flour were of common use, no electrostatic accidents handling these powders were reported. However, the generation of electrostatic charge by human walking on floors was known and briefly mentioned. Ganot did only report on an electrostatic accident on humans, a particular case related to the electrification of steam flow in a steam machine. Investigated by Armstrong, this is an example of an early identification of an accident exclusively due to industrial presence of electrostatics (excluding lightning which is of a wider nature). Subsequently, it was incorporated into the list of pedagogical illustrations of physics courses such as Ganot's (Fig. 1).

As pinpointed at the beginning of this section, the second major aspect of current industrial electrostatics – charge dissipation – is a question of important technological concern. It has been widely studied and many technological solutions have been developed. In historical perspective, charge dissipation does not constitute a major problem leading research at a large scale in Ganot's *Traité*. Still, it appeared as a fundamental phenomenon related to the strength of static electricity. An important part of charge dissipation is related to electric machines (Fig. 2) which suffered from static electricity dissipation, limiting their performance. The dissipation of static charge to ground was also well known and limited by insulating materials. To store the electrostatic charge, long glass insulators were used to isolate metal electrodes. Neutralization of static charge by air was also mentioned although it was attributed to humidity. Probably, absorption of humidity by insulators was responsible for charge dissipation. However, neutralization of charge by ionization was well known by means of the effect of points or tips. Not only, electric field enhancement was experimentally measured (Fig. 3) but also charge neutralization by tips placed close to a charged surface was noticed. This was at the same time a demonstration made with the electric machine and a manifestation of its limitations.

A paradigmatic different demonstration was the electric whirl or vane which created movement from the electric discharges produced in the tips (Fig. 4). The electric wind was known and demonstrated by the deviation of a flame in front of a charged tip (Fig. 5). Finally, surface neutralization by brushes was used in frictional electric machines to collect the surface static charge. Both, neutralization by ionization in tips (passive or connected to a high voltage source) or by brushes are today applied in industry to ensure charge dissipation.

6. Conclusions

This case-study of electrostatics in Ganot's *Traité* allows us to point out several significant aspects in relation to the study of electrostatics in historical and contemporary perspective. The rise of Ganot's *Traité* to canonical status in 19th-century Europe offers the opportunity of defining physics in its development as a discipline.

Ganot's *Traité* offers us an approach to electrostatics which prioritizes experimental accounts against theoretical frameworks. Moreover, Ganot's electrostatics was strongly guided by pedagogical instrumentalism coupled with the compromise of exposing updated research through a logical narrative. This way of knowing and making science has not found the place in the historiography of physics that – in our opinion – it deserves.

Rethinking the history of electrostatics is not only a historiographical exercise. In our opinion, it offers the opportunity of establishing a fruitful dialogue between historians and scientists. The comparative analysis of Ganot's 19th-century exposition of electrostatics and general current practices in electrostatics brings useful elements of reflection both for researchers of past and present science.

Despite the lack of extended industrial applications, Ganot's *Traité* brings an excellent methodological approach to investigation on electrostatics. The *Traité* described step by step the nature of electrostatics from an experimental point of view. Conversely, in current practice, the teaching of electrostatics (if not insufficient) is very often based on theoretical considerations leaving a poor comprehension of electrostatics manipulation. The experimental approach requires an advanced knowledge on electrostatics handling. If we compare today's complex electrostatic environment with Ganot's context, it is very surprising to find that the experimental approach to handle electrostatic charge is lacking in current textbooks whereas electrostatics is now a real practical concern.

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