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CHAPTER 21

PHYSICS TEXTBOOKS AND TEXTBOOK PHYSICS IN THE NINETEENTH AND TWENTIETH CENTURIES

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21.1 Textbooks: Past and Future

Textbooks are a classic yet elusive object in the history of science. They received significant attention in the early years of our discipline, and this interest has not diminished. However, it is still not entirely clear what science textbooks are or what status they have as historical objects. Historical studies of science textbooks are still scarce, and much of what we have is historiographically and methodologically limited. The history of physics is no exception in this respect, although a growing interest in the study of physics education has, in recent decades, resulted in a fundamental renovation of the discipline (Kaiser, 2005a and 2005b; Warwick, 2003a; Olesko, 1991 and 2006).

Textbooks might have been expected to become central sources for the writing of a truly international history of science. The study of scientific research in an international perspective has traditionally been described explicitly or implicitly as a matter of leading centres radiating towards passive peripheries (Gavroglu *et al.* 2008). In contrast, science education and textbooks are ubiquitous, for it seems implausible that any country which had a publishing industry would not have structures for the production of science textbooks. Although this is basically true, some national contexts have developed educational and textbook enterprises in science earlier than others, and have been better able to export their production.

In this chapter I focus on the French, German, American, and British cultures of textbook physics. I could have proceeded otherwise, since most countries have had a rich physics textbook tradition. If this possibility is often not brought out sufficiently, it is because textbooks and education have a secondary status in the historiography of science, and because the history of science canon is still nationally biased. Science textbooks have often been exclusively aligned with the training of scientific elites and the enforcement of scientific paradigms. This has done little to advance their study as a key area at the interface of history of science, history of education, and the history of the book, all of which could make a major contribution to more global histories. While research on textbooks has acquired a certain degree of maturity within science education (Choppin, 1992; Johnsen, 2001), such scholarly production has in general not received the attention of historians of science. Furthermore, historians of education have paid little attention to science textbooks, and they have tended to focus on primary education, while historians of science, with few exceptions, have only been interested in textbooks for higher education.[1] Finally, the history of the book is still finding its way into the study of science, and its interaction with the history of education in particular remains rare (Simon, 2011; Topham, 2000; Rudolph 2008; Rose, 2006; Secord, 2000).

Thomas S. Kuhn's *The Structure of Scientific Revolutions* (1962) has done more than any other work to draw attention to textbooks in the history of science, and research using textbooks as sources has hitherto tended to proceed along Kuhnian lines. Little effort has been made to place Kuhn's ideas in context, and to assess critically his agenda as a means of taking this field of research a step forward.[2] Kuhn's work was obviously a product of its time.[3] It reflects particular developments in physics, education, history and philosophy of science, and politics. In fact, textbooks have a low status in contemporary culture—something that illuminates the paradoxes of Kuhn's thought and of subsequent work (Bensaude-Vincent *et al.* 2003; Simon, 2011, 15–18; Brooke, 2000).

In this chapter I argue that the study of textbooks would benefit from greater reflexivity, showing how our views on textbooks have been shaped by events that have established particular hierarchies between scientific research and science education, and between universities and schools. By adopting this approach, as I maintain, we could avoid anachronism and oversimplification in a field that has great potential as a contribution to our understanding of the history of science. Textbooks have had a prominent role in the history of physics, and they can offer new perspectives that go beyond their traditional characterization as mere showcases of scientific paradigms. My chapter is divided into three sections. First, I examine the role that physics textbooks played in the early stages of the professionalization of the history of science.

Second, I offer a general overview of the genesis of textbook physics in the nineteenth century, highlighting major textbooks produced in France and the German states and making some reference to British and American textbooks. Finally, I discuss recent scholarship dealing with textbooks in the history of physics.

21.2 A Very Historico-Scientific History

In 1948, George Sarton issued a programmatic call for a history of physics based on 'The Study of Early Scientific Textbooks'. In referring to 'early textbooks', he meant those 'treatises' published especially before the nineteenth century, which constituted the core of the literature communicating science in particular periods. The aim was to trace 'scientific evolution' by examining the content of these books and tracing changes over time and space in successive editions and translations. Great emphasis was put into the analysis of logical structure, but style and illustration were also considered relevant.

Sarton did not think it necessary to define explicitly what a 'textbook' was, or whether a 'textbook' was any different from a 'treatise'. But he made some reference to educational contexts and, most importantly, drew a clear distinction between early textbooks and those produced from the second half of the nineteenth century onwards. He considered that modern textbooks were too abundant and, surprisingly (in the light of subsequent perspectives on the topic), that the lag between the emergence of new ideas and their integration into modern textbooks was too short to make them relevant to his aims (Sarton, 1948). I. Bernard Cohen, a close collaborator of Sarton, corroborated these remarks, but related his historical perceptions on old textbooks to his contemporary experience as a physics teacher and reader of modern textbooks in the discipline (Cohen, 1948). Although Sarton and Cohen admitted in passing that the authors of early textbooks could be dogmatic or resistant to scientific change, they considered that it was the duty of historians of science to avoid Whig interpretations. Textbook narratives should be considered in their own historical context, the context that shaped their structure and their expository functions and aims.

Between the 1930s and 1950s it was not unusual to find reviews of physics textbooks in *Isis*, by such scholars as Cohen (who succeeded Sarton as editor of the journal), Gerald Holton, and Victor Fritz Lenzen, who combined their history and philosophy of science writing with work in physics and teaching (Dauben *et al.* 2009; Heilbron, 1977; Nowotny, 1990). The books were selected for their particular focus on the history of physics and were characteristic of the literature of the field, which in that period was more scientific than historical (Cohen, 1943; Holton, 1956; Lenzen, 1937). In one of these reviews, Lenzen considered that the abundant historical contents of *Mechanics, Molecular Physics, Heat, and Sound*, a major college physics textbook by Robert Millikan, Duane Roller, and Earnest Charles Watson, made it a valuable contribution to the history of physics. Furthermore, he added, this textbook was a 'notable example of the humanization of science' (Lenzen, 1937).

Similar motivations led Cohen and Holton to participate in the General Education in Science programme developed at Harvard by James B. Conant after the Second World War. They did so along with Fletcher G. Watson, Leonard K. Nash, and Thomas S. Kuhn.[4] All of them had been trained in the physical sciences and were then finding their way as professionals in physics, education, or history and philosophy of science. Their interest in physics textbooks as historical sources ran in parallel with their perception of the need to produce textbooks in all these areas, in particular in the history of science as a means of consolidating the discipline (Bird, 2009; Dauben *et al.* 2009; Dennis, 1997; Jacobs, 2010; Murphy and Valsamis, 1997; Nowotny, 1990).

Cohen and Watson edited the textbook which served as a guide to the General Education in Science course. Holton published two major physics textbooks; one in collaboration with Duane Henry Dubose Roller. Roller, a Harvard PhD in history of science, teamed up with his father—a physicist and textbook author (see above)—in a number of history of science publications, including their contributions to the *Harvard Case Histories in Experimental Science*, edited by Conant and Nash, which soon made their mark on school textbooks by teachers such as Leopold E. Klopfer. Subsequently, he went on to establish a history of science department and a large associated library, which was the foundation for the 'Landmarks of Science' microform collection (Schofield, 1995). This initiative followed the broad lines of Sarton's programme, although it recognized the classic status of nineteenth-century physics textbooks by such authors as Johann Müller, Adolphe Quetelet, Adolphe Ganot, Jules Jamin, John Tyndall, and Adolph Wüllner.

Kuhn's first book, *The Copernican Revolution* (1957) was considered by some contemporaries as a textbook emerging from the General Education in Science programme (Fuller, 2000, n. 90, 219–20), which also had an important influence in his subsequent work, *The Structure of Scientific Revolutions*. However, the making of *Structure* cannot be understood without taking into account two major aspects. One was the climate for school reform in America, which surrounded Kuhn and which strikingly exemplifies the transformation of physics textbook production in the second half of the twentieth century. The other was the cultural pattern that led to the dismissal of textbooks as sources of knowledge—a perception that held sway for a long time and has continued to do so into our own day.

From the 1950s a favourable climate for the development of large-scale school reforms in the sciences started to develop in the USA. This included the reform of curricula, the production and distribution of new textbooks, and the development of teacher-training programmes. Most importantly, it supposed the empowerment of university scientists in the design of the school science curriculum (Rudolph, 2002).

In the nineteenth century, secondary education was the major focus of disciplinary development for the physical sciences. While the sciences had a limited place in university education, their presence was boosted by the development of secondary education within a large number of national contexts. University physicists had always played a significant role in the design of school curricula and the production of textbooks, but the intellectual boundaries between universities and secondary schools were not so well defined as they were later. Secondary-school teachers made a major contribution to the making of physics as a discipline, and the secondary-school curriculum often shaped university physics, not *vice versa* (Stichweh, 1984; Olesko 1991; Simon, 2011).

In the 1950s, American physicists were increasingly concerned about the decline in enrolments in physics courses—a trend that had been apparent since at least the late nineteenth century. This was in contrast with the growing political power of university physicists, based on their close involvement in the war effort (Kelly, 1955; National Research Council/American Institute of Physics, 1955; Rudolph, 2002). The school reforms proposed by physicists were supported by some influential psychologists and educationists. At Harvard, Jerome Bruner expressed his rejection of Conant's programme on the grounds of its non-specialized, amateurish nature. He supported instead the establishment of teaching programmes that would focus on the 'structure' of scientific subjects. Hence he favoured the presentation of subject matter focused less on coverage than on illuminating the relations between the fundamental principles defining a field of knowledge. For Bruner, learning the structure of physics involved learning the subject as physicists understood it. Accordingly, physicists had to take the lead in the development of a new school curriculum that would endorse their perspective on the subject (DeBoer, 1991; Fuller, 2000; Rudolph, 2002).

In the same period the educationist Joseph Schwab characterized nineteenth-century science education as 'embodied in authoritative lecture and textbook, inflexible laboratory instructions, and exercises presenting no problems of choice and application'. He contended that this fundamentally dogmatic approach had survived in American schools up to the twentieth century. According to Schwab, since scientific knowledge could no longer be considered as composed of stable truths, school science and science textbooks should not just present facts; they should also bring out principles of enquiry that constituted the fundamental structure of science (DeBoer, 1991; Schwab, 1958).

The work of Bruner and Schwab, among others, further reinforced the reform movement, which benefited from government funds, stimulated by Cold War competition and events of extraordinary political impact such as the Soviet Union's launch of *Sputnik* in 1957. In this context the Physical Science Study Committee (PSSC) and its ruling team of academic physicists presented themselves as performing a revolution in physics pedagogy aimed at replacing the old-school physics paradigm with a new one based on the principles of modern university physics. Its work included the design of new textbooks and the establishment of an aggressive programme aimed at promoting the adoption of its products in schools and acculturating teachers in their use. In this respect, they clearly aimed at displacing teachers and educators from a field in which they had had a fundamental role in the previous century (Brownson and Schwab, 1963; Rudolph, 2002).

The preparation of the PSSC programme was contemporaneous with Kuhn's writing of the first draft of *Structure*. Both projects arose from the same intellectual milieu, marked by a combined interest in physics and pedagogy and shaped by developments that shook American science and education (Marcum, 2005, 13–5). Kuhn's work matched perfectly the conceptual framework on science, education, and textbooks promoted by the PSSC school reform.[5]

During his time at Harvard, Kuhn had matured and presented his ideas in a series of lectures that constituted the embryo of his book. In 1951, in his first Lowell lecture, entitled 'Textbook Science and Creative Science', he already contended that the 'structure of knowledge in the textbook' masked 'the nature of the creative process' by which knowledge is gained (Marcum, 2005, 30–1). In 1961 Kuhn communicated to historians of science the ideas contained in his forthcoming book. For Kuhn, a special characteristic of science from the early nineteenth century onwards was that education was conducted through textbooks to an extent unknown in other fields of knowledge. Moreover, textbooks presented a surprising uniformity in conceptual structure and only differed in subject matter or pedagogical detail according to their level. Textbook science was the driving agent in the transmission of scientific knowledge through systematic education, and it involved indoctrination. Although this level of systematization was not present before the nineteenth century, there were works which could be considered 'classics', such as the treatises by Aristotle, Ptolemy, Newton, Franklin, Lavoisier, or Lyell, that played a similar role in representing 'universally received paradigms' (Kuhn, 1963).

The success of the PSSC programme was as great as that of Kuhn's classic work. But it was less successful than the programme's propagandists maintained. Although it had a major role in shaping the form that physics textbooks would take during the second half of the twentieth century, the PSSC had competitors among the wide range of approaches to pedagogy and physics that coexisted at the time. Furthermore, the problem of school physics curricula and textbooks was not really new, debates on this topic having taken place periodically during the nineteenth and twentieth centuries.[6]

In the late nineteenth century, the (American) National Education Association (NEA) had already debated the need to promote a closer connection between school and college curricula. Some of its members, such as Edwin H. Hall, professor of physics at Harvard, considered that in spite of the need to use a single standard textbook in physics courses, for their 'connective and comprehensive view of the subject', further emphasis should be given to laboratory training in order to encourage the development of skills of observation (DeBoer, 1991; Hall, 1909).

In the 1920s the physicist Robert Millikan complained that the situation had not changed. He urged that college scientists be made exclusively responsible for teacher training and school curriculum design. The same motivations had led him to publish in 1906 a physics textbook for high schools—a work that went through several editions before the end of the Second World War (Millikan, 1925; Millikan, and Gale, 1906). In his autobiography he recounted his encounter with physics textbooks at a young age, and the standard status of the English translation of Adolphe Ganot's *Traité élémentaire de physique expérimentale et appliquée* (1851) in American high schools and colleges at the time (Millikan, 1951). Ganot's *Traité* embodied precisely the kind of approach that was criticized by most physicists involved in education during the middle decades of the twentieth century. Its rise to standard status and subsequent fall offer an interesting window on the history of the making of textbook physics as a genre.

21.3 Textbook Physics: A Nineteenth-Century Genre?

In 1851, Joseph Lovering, professor of mathematics and natural philosophy at Harvard College, expressed his concern for the lack of appropriate physics textbooks in English ([Lovering], 1851). Lovering saw textbooks as a central tool in the teaching of physics and in its much-needed expansion in education and society in general. In his opinion, reading and recitation from a carefully chosen textbook, allied to lectures and experimental demonstrations, formed the core of a good education in physics. For Lovering, lectures were fundamental, since they allowed the introduction of the most recent developments in the field, which printed textbooks were often not able to incorporate quickly enough. But textbooks were central because they contributed to fix knowledge and to communicate it in a precise and accurate way.

According to Lovering, the major qualities of a good textbook were comprehensiveness, precision in the presentation of factual evidence, a clear and accurate writing style, and, no less important, a distinct type-face. The great challenge of the textbook author was at once to be accurate and to balance the difficult task of judging and selecting from the rapidly growing content of physical knowledge, and to find a pedagogical but engaging expository style. Lovering considered that a physics textbook should not confine itself to presenting the core principles of this field of knowledge, since these were at the time not numerous. More fundamental was the presentation of the 'history of discovery', the scientific instruments used in this process, and the factual evidence and experiments that illustrated the general laws obtained. But a good textbook should still portray the unity of nature and the interconnected character of the physical sciences.

In Lovering's opinion, the shortage of good physics textbooks in English was not due to a lack of major research, but to the type of publications through which British practitioners had communicated it. The monographs and articles composing the series of the *Cabinet Cyclopaedia*, the *Library of Useful Knowledge*, the *Penny Magazine*, and the *Encyclopaedia Metropolitana* had many qualities. But they lacked 'unity of thought', comprehensiveness, and up-to-dateness, and their subject arrangement, narrative, rhetoric, and expository focus made them inadequate vehicles for communicating physics to students, being often too academic or too 'popular'.

According to Lovering, the only proper physics textbooks available in English were also deficient. Examples included those by Golding Bird, lecturer at Guy's

Hospital, London, James William McGauley, professor for the Irish Board of National Education, and Denison Olmsted, professor of natural philosophy and astronomy at Yale College. This was in contrast with the rich French and German traditions of physics textbooks represented by a large number of exemplary authors such as the French Pouillet, Péclet, Pinault, Becquerel, Despretz, Regnault, and Lamé, and the Germans Müller and Peschel.

Indeed, in France and the German states, reforms leading to the establishment or refashioning of structures of secondary and higher education with broad national scope took place in the early nineteenth century, sooner than in other national contexts (Green, 1990). In the same period the making of physics as a discipline was boosted by its inclusion in the curricula of secondary education. These developments went hand in hand with the production of textbooks, which in many cases had a foundational role and were powerful tools for establishing, shaping, and standardizing pedagogy and physics.

In France, a network of secondary schools had come into existence soon after the Revolution (1795–1802). Their curricula were predominantly focused on the sciences, and in this context textbook authors such as Mathurin-Jacques Brisson (1723–1806) and Antoine Libes (1752–1830) linked the *ancien régime* tradition in physics and its public communication with the new Napoleonic framework of formal education. Their physics and pedagogy were closely connected to those of previous authors such as Jean-Antoine Nollet (1700–1770) and Joseph-Aignan Sigaud de Lafond (1730–1810), who in turn had appropriated the Dutch tradition of Newtonian physics, represented by Willem Jacob ’sGravesande (1688–1742) and Pieter van Musschenbroek (1692–1761). The focus on instruments and their description and use in experimental demonstrations characterized the works of French authors in this period (Fournier-Balpe, 1994; Heilbron, 1982).

The production of textbooks was considered a fundamental endeavour during the years of the Revolution and the subsequent Napoleonic regime.[7] Initially, however, it was not obvious to physics teachers that they should adopt texts which they had not written themselves. But, driven by political, commercial, professional, and pedagogical forces, textbooks increasingly moved to a central position. The Napoleonic reforms undertaken between 1806 and 1811 included the preparation of textbooks for every subject in the school curriculum in parallel with the publication of syllabuses.

The first science syllabuses were designed by a committee of university professors, which commissioned a physics textbook by the mineralogist René-Juste Haüy (1742–1822), who had taught this subject at the École Normale. Haüy’s *Traité de physique élémentaire* (1803) went through five editions and was translated into English and German. The official textbook recommendations were complemented with a translation of the *Lehrbuch der mechanischen Naturlehre* (1805) by the Berlin secondary-school teacher Ernst Gottfried Fischer. The translation was entrusted to Jean-Baptiste Biot (1774–1862), who also published two physics textbooks which were recommended in successive school curricula, to the preparation of which he contributed.

Biot's two textbooks appeared within a year of each other—a key event that helps to explain how textbook physics developed as a genre during the nineteenth century. His *Traité de physique expérimentale et mathématique* (1816) compressed in four volumes his vision of physics as a discipline. The book opened with a quotation from Newton's *Principia*, which communicated his intention of reducing all physical phenomena to simple laws based on mathematical analysis and experimental precision, following the works of Newton and Laplace, and his own researches. A year later, Biot published his *Précis élémentaire de physique expérimentale* (1817), prefaced this time by a quotation from Francis Bacon's *Novum Organum* and reduced to two volumes. In the preface he explained that he had resolved this time to present the facts in a purely experimental manner, devoid of any complex algebraic calculus, in order to address students interested in physics as a preparation for studies such as medicine or natural history. Medical students, constituted in fact the largest body of physics readers in France for most of the century. From the 1820s they were obliged to take the *baccalauréat-ès-sciences*, which was the same examination attempted by the small number of students wishing to go on to scientific or engineering studies.

Although Biot's shift of emphasis from Newton to Bacon had obvious pedagogical and commercial reasons, it also constituted a key aspect in the shaping of textbook physics in the nineteenth century, since the non-mathematical, experimental focus would characterize most textbooks of the period. Biot's textbooks circulated widely in France and abroad. His *Traité* was translated into German, Italian, and Spanish. And his two textbooks were used by John Farrar, Harvard's professor of mathematics and natural philosophy, to prepare his course on natural philosophy, which had a further edition in the 1840s, edited by Farrar's successor, Joseph Lovering.

Biot's work also inspired a new generation of French authors, who started to publish textbooks from the late 1820s. These authors were typically trained at the École Normale, the institution established to supply French secondary education with teachers.[8] They published the first edition of their textbooks at the beginning of their careers. The publication of a textbook was a useful strategy for developing pedagogical tools for the classroom, but it also had a major role in boosting scientific prestige and in career promotion. Most physics textbooks published in France during the first half of the nineteenth century can be seen as resulting from the intense competition in the fashioning of careers and the circulation of *normaliens* throughout the French educational structure.

In this period the French market for physics textbooks was dominated by five authors: Eugène Péclet (1793–1857), Claude Pouillet (1790–1868), César Despretz (1789–1863), Auguste Pinaud (1812–47), and Nicolas Deguin (1809–60). All were *normaliens* except Despretz. In general, their textbooks were originally designed for use in secondary schools, and their first editions coincided with the expansion of the number of students aspiring to the *baccalauréat-ès-sciences* as a qualification for entry to medical studies. The first editions of Péclet's, Pouillet's, and Despretz's textbooks were published in the 1820s, and those by Pinaud and Déguin shortly after 1837, when the *baccalauréat* requirement was re-established after a brief period of suspension.

From 1829 Péclet lectured in physics at the École centrale des arts et manufactures, newly established (in part by Péclet himself) with the aim of training engineers for senior managerial positions in industry. His textbook, whose first edition was published between 1823 and 1826, owed much to his early experience as a secondary-school teacher. It also presented both his research and his teaching at the École centrale, since he did not draw a clear boundary between his journal publications and textbook writing. Péclet's *Traité élémentaire de physique* went into its fourth edition in 1847, by which time he had risen to the rank of general inspector within the French educational system. However, his refusal to take an oath to the new political regime established after Louis-Napoléon Bonaparte's *coup d'état* of 1851 led him to resign from all his positions and from further textbook writing.

Pouillet too had a career that was cut short by his refusal to swear allegiance to the new political regime. If Péclet represented the connection with French private industry, Pouillet, as the director of the Conservatoire des arts et métiers had a close relation with the milieu of invention and machine and instrument-making. Between 1820 and 1829 he taught physics at one of the leading secondary schools in Paris. He also assisted Jean-Baptiste Biot and Louis-Joseph Gay-Lussac (1778–1850), and obtained a chair of physics at the Paris faculty of sciences. In addition, he held the physics chair at the Conservatoire, becoming the director there in 1832.

In 1827 Pouillet published his *Élémens de physique expérimentale et de météorologie*, in three volumes, which he based on his teaching at the faculty of sciences and dedicated to Biot. From his position at the Conservatoire, Pouillet was a pioneer in physics textbook illustration. The Conservatoire had been established in 1794 as a repository of knowledge about instruments and machines. Pouillet and the teachers of drawing at the Conservatoire were involved in the *Portefeuille industriel*—a compilation of drawings of the major inventions presented to the institution by law. These were used by Pouillet in his textbooks (and copied by many authors), keeping readers abreast of major innovations in instrument design. By 1856 Pouillet's *Élémens* had gone through seven editions, becoming the leading physics textbook in France, and generating translations into Italian, Spanish, and German. Pouillet's writing was directed at the intersection between secondary and higher education, but his three-volume textbook also constituted a comprehensive reference work for the use of researchers, in the fashion of Biot's first treatise. For this reason, in 1850 he published another textbook better suited to secondary-school pupils.

Pouillet's *Notions générales de physique et de météorologie* was cast as a more elementary introduction to the subject in one volume. The book pioneered in France the insertion of illustrations in the text, as well as the use of wood engraving, which allowed for a more accurate and attractive representation of physics instruments than had been possible with copper or zinc plates. So long as these older techniques were used, illustrations had to appear as folded plates at the end of books or in a separate volume. The new page layout had previously been used in British and German textbooks, such as those by Golding Bird and Johann Müller. But French expertise in instrument drawing, engraving, and low-cost printing could not be matched in other countries. This did much to promote the international success of French textbook physics during the second half of the nineteenth century. It also helped to reinforce a disciplinary account of physics focused on the description of scientific instruments.

Pouillet's work also had an important role in the production of a leading German textbook. The *Élémens* was freely translated and edited by Johann Müller (1809–1875) as *Lehrbuch der Experimentalphysik und der Meteorologie* (1839–43). Subsequently, Müller published the *Grundriss der Physik und Meteorologie* (1846)—an abridged version of his *Lehrbuch*, addressed to schools. In the early nineteenth century, French textbooks had a considerable impact on the German textbook tradition. Haüy's *Traité* was translated twice, by the mineralogists Johann Georg Ludolf Blumhof (1771–1825) and Christian Samuel Weiss (1780–1856), respectively. However, translations were in general not literal; instead they adapted the original texts to the different scientific and educational contexts for which they were intended. Weiss, for example, included new content which underlined the contrast between Haüy's Laplacian programme and that of German Romantic philosophy.

Biot's textbooks also occupied a major place in German translations from French originals. His *Traité* was translated by Gustav Theodor Fechner (1801–1887), who used this experience to complement his university training in science while preparing for a medical degree. Although he later turned to experimental psychology, his translations did much to help him secure his first university position in physics at Leipzig. The *Précis* was translated into German by the Berlin secondary-school teacher Friedrich Wolff (1766–1845).

The German states were fertile sources of physics textbooks in the eighteenth century. Important works included those by Johann Andreas Segner (1704–1777), Georg Christoph Lichtenberg (1742–1799), Johann C. P. Erxleben (1744–1777), Johann Peter Eberhard (1727–1779), Christian Gottlieb Krantzenstein (1723–1795), and Karl Wilhelm Gottlob Kastner (1783–1857), among others. Most textbooks were written in the middle of an author's career, as tools for their university or school-teaching. Between the late eighteenth century and the early nineteenth century, around a fifth of all physics professors in universities, technical schools, and academies seem to have written a textbook on their subject. An important though decreasing part of this production was penned by authors with medical training. Many textbooks were written in Latin, though from the 1780s Latin increasingly gave way to German. While the eighteenth-century tradition contributed to shape subsequent physics textbooks, few such works survived beyond this period, owing to the growth of a new educational framework in the early nineteenth century (Clark, 1997 and 1997b; Heilbron, 1982).

In the three decades following the Napoleonic invasion, profound educational reforms took place in the German states, resulting in a wide-ranging structure of secondary schools, technical and vocational schools, and teacher-training.[9] The traditional secondary school (*Gymnasium*) favoured the classical curriculum and monopolized access to the universities through the *Abitur* examination. However, during the middle decades of the century, different course programmes coexisted in these schools, and the sciences found an ever more prominent place. Moreover, new types of school with modern curricula including greater emphasis on science and technology were developed, such as the *Realschulen*, *Realgymnasien*, *Oberrealschulen*, and a set of trade schools that subsequently led to the creation of the German Polytechnic (Green, 1990; Müller, 1987).

Between the 1820s and the 1860s, Ernst Gottfried Fischer's *Lehrbuch der mechanischen Naturlehre* was one the books most used in German schools. It placed a relevant emphasis on the role of mechanical approaches in physics and on demonstration and measuring instruments, together with the use of mathematical methods. Other textbooks, such as F. Kries's *Lehrbuch der Naturlehre* and J. Heussi's *Die Experimentalphysik, methodisch Dargestellt,* were less popular or in certain cases did not find a significant market until the late 1840s. Early editions of Fischer's book were used in France and translated into English, Polish, Dutch and Italian, from Biot's French edition. But in the German states, Fischer's textbook had a major role in the mid-nineteenth century as an agent driving educational reforms which led to a more systematic provision of physics cabinets and laboratories in schools (Olesko, 1989, 110–2).

Some of the more successful German textbooks that appeared in the mid-century had a strong experimental focus; they were often produced by professors in technical and secondary schools, and they bridged the gap between school and university teaching.[10] Among them were Hans Anton Brettner (1799–1866), a *Gymnasium* professor of mathematics and physics, Gustav Wilhelm Eisenlohr (1811–1881), professor at the Kalsruhe Polytechnic, and Johann Müller, a secondary-school teacher at Darmstadt and Giessen, and, subsequently, professor of physics and technology at the University of Freiburg. Brettner's *Leitfaden für den Unterricht in der Physik* went through twenty editions between 1836 and 1882. Eisenlohr's *Lehrbuch der Physik* (1836) went into its eleventh edition forty years after its appearance. Müller's abridged textbook for schools, the *Grundriss*, had fourteen editions between 1846 and 1896, and it was translated into English, Dutch, Norwegian, and Danish. Its general course was complemented by a more thorough guide on the practice of lecture demonstrations and laboratory experiments prepared by Joseph Frick, a secondary-school teacher in Freiburg. Frick's *Physikalische Technik* (1850) went into successive editions through to 1909. Decades later, Frick's aims lived on in Adolphe Ferdinand Weinhold's *Vorschule der Experimental Physik* (five editions, 1872–1907). Müller's first textbook had also a very long publication history which fundamentally transformed it, though the book always preserved in its title page the trace of its origins (Müller-Pouillets *Lehrbuch der Physik*). With a growing number of contributors and editors, its five volumes had gone through eleven editions by the 1930s, becoming a standard reference work for students and researchers alike.

During the second half of the nineteenth century, instruction in physics in German universities was increasingly dispensed in seminars. Although the seminars were mainly aimed at training school-teachers, they implemented an educational regime based on the solving of problems and the development of skills in experimental research and mathematical analysis that went beyond the curricula contained in the original textbooks by Brettner, Eisenlohr, or Müller (Olesko 1991). This key turn is well illustrated by the reports on the appointment to the chair of physics at the University of Heidelberg in the 1850s. While the committee, chaired by Robert Bunsen, gave due weight to the success as textbook authors of such candidates as Eisenlohr and Müller, it considered that successful textbook writing and specialized research had become mutually exclusive. Hence the professsorship was given instead to the distinguished researcher Gustav Kirchhoff (1824–1887) (Jungnickel, and McCormmach, 1986, 188–9).

An exemplary product of this seminar culture was Friedrich Kohlrausch's *Leitfaden der praktischen Physik* (1870), based on his practical exercises for first-year students in the physico-mathematical seminar at Göttingen. Eleven editions of the book had appeared by the First World War, and a 24th edition was published in 1996. Under successive editorial teams, it was the most successful of a range of German practical physics textbooks that included, in the nineteenth century, Adolph Wüllner's *Lehrbuch der Experimentalphysik* (1862–1907) and Eilhard Wiedemann's *Physikalisches Praktikum* (1890–1924) and, in the twentieth century, Wilhelm H. Westphal's *Physikalisches Praktikum* (1938–1971) and Waldemar Ilberg's *Physikalisches Praktikum* (1967–2001) (Olesko, 2005).

German textbook physics spread internationally in the late nineteenth century and early twentieth century, but its interaction with the French tradition did not cease completely. Wüllner's book, for example, owed much to Jamin's *Cours de physique de l'École Polytechnique* (1858–1866). Jamin's textbook in four volumes went into its fourth edition in 1906 and was a respected work used in teaching and research all over Europe and the Americas. His textbook took over from Gabriel Lamé's course-book at the École Polytechnique, published in the late 1830s, and was contemporary with one by the *normalien* Émile Verdet based on lectures at the same institution (1868–69). With rather less success, in 1870 Jamin published a one-volume textbook for secondary-school students. His aim was to give a more central position than was the case in existing introductory textbooks to the unification of physics, following on from the acceptance of the mechanical equivalent of heat (Jamin, 1870).[11]

French textbook physics continued to exert an influence internationally in the second half of the nineteenth century. Its strength lay especially in one-volume treatises exploiting the connection between secondary education and university training through the *baccalauréat-ès-sciences*. Among these, Adolphe Ganot's *Traité élémentaire de physique expérimentale et appliquée* (1851) stands out for its global impact. The *Traité* grew from a fruitful interaction between medical and scientific training, instrument-making, and printing practices in mid-nineteenth-century Paris. It offered a comprehensive coverage of the material required by a private teacher preparing candidates for examinations. Ganot's pedagogical experience, combined with the dynamism of the French school context and the international projection of the French book trade, contributed to making the *Traité* an international best-seller. Ganot's *Traité* was in its 25th edition by 1913, was translated into twelve languages, and had a comparable number of editions in English and Spanish. Through its original editions or translations, it became an international standard in school and university teaching.

Ganot's textbook introduced important novelties such as a section of problems related to the main syllabus and to real examinations, and a new visual language in textbook physics. It also displayed the author's conception of physics as a discipline, and its illustrations of instruments and machinery were used for research purposes by leading practitioners such as Zénobe Gramme, William Thomson, and Sebastian de Ferranti. The work's visual dimension benefited from developments in printing and engraving generated by a long interaction between British and French print technicians. Its illustrations were used or copied in many other physics textbooks worldwide. Ganot's *Traité* served as an influential model for textbook physics, strongly focused on the description of instruments and experimental procedures, which survived into the early twentieth century.[12]

Ganot's textbook physics took root in a soil characterized by intense competition between authors. During the second half of the century other major introductory texts were published by former *normaliens*, such as those by Charles Drion and Émile Fernet (six editions, 1861–1877), Augustin Boutan and Joseph Charles d'Almeida (five editions, 1862–1884), Pierre Adolphe Daguin (four editions, 1855–1879), and Augustin Privat Deschanel (1868). Many of these works were translated into several languages. Among them, the English translation of Deschanel's textbook enjoyed great success (seventeen editions, 1870–1913), becoming, like Ganot's textbook, a standard work in Anglophone countries.

Three decades after Lovering's mid-century diagnosis, Silvanus P. Thompson offered a useful update. According to him, for decades British contributions had been limited to the textbooks published during the first half of the century by the medical doctors Neil Arnott and Golding Bird. In contrast, the French had at their disposal those by Verdet, Jamin, Daguin, Fernet, Boutan and d'Almeida, and Ganot, while German originals included those of Müller and Wüllner as well as numerous other authors. For a long time, the best textbooks on the British market were the translations of those by Ganot and Deschanel. The former, though, had become too encyclopaedic and conservative, despite the efforts of Edmund Atkinson (1831–1900), its translator and editor. The latter, on the other hand, had been improved in its English translation thanks to the editorial work of Joseph David Everett (1831–1904) (S. P. T., 1884).

The role of textbook editors was fundamental. The English editions of Ganot and Deschanel owed their success not only to the qualities of the original works but also to their adaptation by editors working in the rapidly expanding world of British schools and colleges. In contrast, textbooks such as Müller's, which was translated into English shortly after its publication, had a short life in Britain because of the lack of such connections.

Thompson's perception was partially inaccurate. In Britain and America, as in many other countries, there was a fertile tradition of textbook-writing in physics, albeit one that started later than in France and the German states and was generally unable to displace the texts of French and German origin. Moreover, the influence of French and German textbook physics in this British and American tradition is unmistakeable. But historians have tended to concentrate their research on late-nineteenth-century British and American physics, and consequently little work has been done on textbook physics in previous decades. The study of this period would certainly offer new ways of understanding the making of physics as a discipline in these national contexts.

Further research is still required, but the list of authors is long. On the British side, authors such as James Renwick, Dionysius Lardner, John Tyndall,[13] Charles Buckmaster, Richard Wormell, Robert Hunt, Jabez Hogg, John Charles Snowball, and Isaac Todhunter were successful in their national market and shaped the teaching of physics in connection with the development of systems of school and university examinations in the second half of the century (Newton, 1983, 1983b and 1983c; Simon, 2011). On the American side, the same can be said of authors such as J. L. Comstock, John Johnston, Denison Olmsted, Benjamin Silliman Jr., Leonard D. Gale, Richard Green Parker, Elias Loomis, George Payn Quackenbos, and Elroy McKendree Avery (Kremer, 2011; Shank, 1952).

Thompson, nonetheless, stressed the distinctiveness of the emerging style of British textbook physics, with its strong focus on the genuinely British principle of energy conservation. He highlighted the value of Balfour Stewart's *Lessons in Elementary Physics* (1870), which through its novel structure did much to spread an understanding of the principles in William Thomson and Peter Guthrie Tait's advanced *Treatise on Natural Philosophy* (1867) (S. P. T., 1884). Its success marks a turning point in British textbook physics, for it was translated into ten languages, including German and Spanish.

In addition, in the context of the expansion of laboratory instruction, British and American publishers did not rely exclusively on translations of German textbooks such as those by Kohlrausch (1873) and Weinhold (1875). They also produced influential textbooks of their own, including Frederick Guthrie's *Practical Physics* (1878) and Edward C. Pickering's *Elements of Physical Manipulation* (1873–1876) (Hentschel, 2002; Kremer, 2011; Simon, 2011).

Textbook physics emerged as a genre in the nineteenth century in the context of educational reforms that enlarged the publics for physics. Physics textbooks were both educational tools and vehicles for communicating knowledge of research physics. Introductory textbooks compressed all knowledge on physics in a single volume, and had a major role in the fashioning of physics as a discipline. Writing an introductory textbook was not a simple matter, nor was it a skill that all physicists possessed. Like research, it required practice and training.

The publication of advanced physics textbooks favoured the development of mathematical physics. But the core of nineteenth-century textbook physics was characterized by its focus on the description of scientific instruments and machines, and experimental practices. This emphasis responded to the need to promote an emerging discipline. But in addition, it was connected to a conception of physics that favoured knowledge about instrument design, experimental practices, and 'applied science' over mathematical and theoretical approaches.

Many nineteenth-century physics textbooks had a long and successful publishing history that continued into the early twentieth century and turned them into classics. However, their structure suffered, in general, from the disciplinary growth and mounting specialization of physics and from the death of their authors. Towards the *fin de siècle* a new style of textbook physics started to emerge. It coexisted for many decades with nineteenth-century patterns, but it became increasingly the work of physicists based in higher education or research institutions, as well as large editorial teams.

21.4 Textbook Physics versus Frontier Physics?

The PSSC project, developed from the 1950s in the US, is an excellent example of a new departure in the production of physics textbooks, one that involved large teams and was driven by academic physicists. This was a relatively new turn, since there were already textbooks produced collectively, such as Müller-Pouillet's *Lehrbuch der Physik*. Furthermore, nineteenth-century physics textbooks that became classics were able to maintain their dominant position because a succession of competent editors assumed responsibility for updating them regularly.

The intervention of academic physicists in school textbooks, as we have seen, was usual in the nineteenth century, but secondary education had its own logic, teachers, and authors. In different periods, academic physicists such as Jamin in France, Stewart in Britain, and Millikan in the US wrote textbooks for the secondary-school market, because they were dissatisfied with the type of physics communicated by most school authors. Like the PSSC members, they thought that textbooks had a major role in the definition of physics as a discipline—not only because they were central to the training of physicists, but also because their contents and approaches contributed to shape those of physics as a field of knowledge. The PSSC members were academic physicists who already had experience as authors of school and college textbooks, and of advanced physics textbooks which developed areas in modern physics such as relativity and quantum mechanics.

But, as John Rudolph has shown, the PSSC was notable for its political support and abundant resources and for its use of managerial techniques developed in large-scale scientific projects connected to the Second World War. This project seems to have raised the production of pedagogical materials for physics, in particular textbooks, to a new level. It was certainly not the first project to promote a radical reform of school curricula and of the structure and approach of textbook physics, but it was certainly one of the most striking examples of this in the twentieth century.[14]

The textbook series produced by the PSSC illustrate the fundamental schism between two traditions and functions—those of the 'treatise' and the 'textbook'—which previously had constituted a single genre. The PSSC textbooks no longer aimed at providing a comprehensive overview of the subject matter of physics. On the contrary, they omitted major areas of physics and concentrated instead on a more limited range of topics. But this was considered the best option in order to be able to focus on more fundamental aspects. It was essential to write a course that would accurately convey how academic physicists worked. This included an emphasis on the role of open inquiry—an essential quality not only of science but also of democratic ideals in American politics (in contrast with what American politicians regarded as Soviet absolutism) (Rudolph, 2002).

The PSSC course also left aside other elements that had been fundamental in textbook physics up to the mid-twentieth century, such as history and technology. The characteristic nineteenth-century focus on scientific instruments and industrial machinery had been preserved and further developed along with the increasingly pervasive presence of technology in twentieth-century society. But the PSSC sought to distinguish clearly between science and technology, with the aim (among others) of circumventing the governmental pressures to continue the technological enterprise boosted by the war projects (Easley Jr., 1959; Rudolph, 2002; White, 1960). Nineteenth-century textbook physics gave an important role to accounts based on the history of discovery and experiment. The PSSC rejected this historical approach, favouring instead a more conceptual presentation of physics that stressed its coherence and unity as a field of knowledge.[15]

In spite of its pedagogical impact, the PSSC was not the only successful textbook project in this period, and other textbooks favoured different approaches. For instance, the (Harvard) Project Physics Course, led from the 1960s by Gerald Holton, F. James Rutherford, and Fletcher G. Watson, prioritized the integration of the history of physics in its textbook series. Holton and Watson had been involved in the PSSC, and they used similar techniques in writing their textbooks. But they also remained true to their previous participation in the General Education in Science programme. Furthermore, they took special care to balance the forces involved in physics textbook design—physicists, teachers, and educators, a triad clearly represented by the three individuals directing the project (Holton, 1967; 1978).[16]

The PSSC reformers presented their programme as a revolution introducing a new paradigm in the teaching of high-school physics. Paradoxically, its course materials, with its textbooks at the core, were not considered easy to use. Teachers had to be trained in how to understand and exploit these textbooks, and the key issue was that without a body of teachers predisposed to empathize with the programme and its aims, its textbooks would be of limited value, as few teachers would accept them, change their pedagogical approach, and make effective use of the new materials (Donahue, 1993; Easley Jr., 1959).

The pattern is Kuhnian, if only because Kuhn and the PSSC reformers shared the same intellectual, cultural, and historical context; and the subsequent success of the PSSC programme endorses some of Kuhn's claims, especially in relation to the power of textbooks to drive the communication of scientific knowledge. It is remarkable that in this context the use of political and economic power by the PSSC in order to displace competing communities of practitioners (teachers and educators) partially undermined the democratic ideology underlying it. Furthermore, the progress of the programme was slow and incomplete. One reason was that the PSSC textbooks competed with many others. Certainly, they greatly influenced subsequent physics textbook production in Anglophone countries and beyond through translation. But in spite of its powerful funding and political support, the PSSC failed to win the battle for pedagogical supremacy.

Moreover, is it not paradoxical that in order to master the proper use of textbooks, school-teachers were subject to the same pattern of training as the one described by Kuhn for scientists and science? Or is it just that the PSSC physicists implemented in their programme measures that were standard in their cultural environment? Indeed, a leading aim of the PSSC was to introduce teachers to modern academic physics and acculturate them into behaving like academic physicists. They thought, like Kuhn, that textbook science was opposed to 'creative or frontier science'. Still, they intended to change textbook physics by making it converge with 'frontier physics', in parallel with the institutional takeover of secondary-school physics by university physics. But if we follow Kuhn, should we consider that academic physicists who were also textbook writers, such as those involved in the PSSC, were not performing creative work and that they were not creative contributors to the making of science? And is it possible to extrapolate from this case to a general discussion on the role of textbook writing in the making of science, including thorough historical evidence and historiographical arguments?

Most current research on physics pedagogy which deals with textbooks follows the lines of Kuhn's approach. Its main focus lies in understanding 'frontier science' and its shaping in academic circles. This is the case, for instance, with the work of Andrew Warwick and David Kaiser, which has been path-breaking in reshaping the study of pedagogy within the history of science. However, their study of training is constrained by its continuities with Kuhn's work, in relation to textbooks and their role (Warwick and Kaiser, 2005a).

In his study of the making of Cambridge mathematical physics, Warwick expresses respect for those educational works that he defines as classic treatises, such as Euclid's *Elements* and Newton's *Principia*. In contrast, he undervalues nineteenth-century textbooks. Warwick shows convincingly that Cambridge training in mathematical physics, based on preparation for examinations, had a capacity to define both pedagogy and physics that textbooks did not have. Textbooks on this analysis were in general partial and unable to absorb developments in the field. Warwick establishes that examinations and private teaching were the driving agents shaping the content and approaches of textbooks in this context, and not vice versa. Subsequently, these textbooks were agents in the diffusion of Cambridge mathematical physics in schools in Britain and the Empire (Warwick, 2003a).

In Warwick's account, textbooks play a secondary role, limited to the passive communication of developments in physics taking place somewhere else. His study offers a fine account of the Cambridge context of higher education. Most importantly, it reminds us of the coexistence of different pedagogical tools, such as examinations, curricula, pedagogical regimes, and textbooks in the shaping of science and education. However, the exemplary character of his study is limited by the specificity of Cambridge, and by his partial focus on a particular context of education. Thus, he dismisses other equally important contexts of knowledge production, such as the school system developing in nineteenth-century England due to a wide range of examination systems with national scope, including the Oxford and Cambridge Locals. In this, Warwick has a conception of the making of scientific knowledge which in the study of science education reproduces the top-to-bottom approach that has been widely criticized in research on science popularization (Simon, 2009 and 2011; Hiltgarner, 1990; Secord, 2004).[17]

In his study of the production and use of Feynman's diagrams in post-war physics, David Kaiser offers a much more sophisticated conceptualization of textbooks—one that in several ways goes beyond Kuhn. This is especially true with regard to the concept of textbooks as rigid repositories of paradigms. Most historians of physics are still interested in textbooks only as sources that show what knowledge was standard in a particular period, and they tend to consider that in times of 'normal science' all textbooks offer the same basic paradigmatic picture. For those who adopt this approach, analysing textbook narratives over time is only a way of locating changes of paradigm.[18]

While Kaiser follows this approach to a certain extent, he is more interested in illuminating the relations between physics and local pedagogical contexts. In his work he has shown that textbooks dealing with Feynman diagrams in post-war America offered a wide variety of perspectives.[19] He considers that Kuhn exaggerated the central role that textbooks play in the training of scientists—observing that other tools such as pedagogical regimes, problem-solving, and lecture notes could often have a more decisive role in this context. Kaiser demonstrates that the writing of advanced textbooks was a creative task. But he also shows that although the circulation of textbooks had an important role in the spread of Feynman's diagrams and their uses, textbooks did not replace other coexisting modes of knowledge communication (Kaiser, 2005a, 253–79).

Subsequently, Kaiser has provided a rich overview of American textbooks of quantum mechanics, including comparisons with other national contexts. He has observed that a process of textbook standardization took place simultaneously with the maturing of this subdiscipline, but also in connection with local pedagogical practices. In the interwar years, quantum-mechanics textbooks displayed a diversity of approaches, especially with regard to philosophical convictions and points of interpretation. However, by the early 1950s, they offered a far more homogeneous perspective, which abandoned philosophical inquiry in favour of a pragmatic approach focused on the solving of more practical and quantitative problems. Although the field had indeed matured in these decades, this homogenization cannot be understood except in the context of changing student enrolments (Kaiser, 2007 and forthcoming).

Josep Simon's study of the production, circulation, and appropriation of Ganot's textbook physics in nineteenth-century France and Britain has points in common with Kaiser's approach, in that it demonstrates the creativity of textbook writing and its important role in the fashioning of scientific disciplines. However, Simon's work puts textbooks at the centre of analysis; it proposes a strong position with regard to education (not only pedagogy) as a powerful driving force in the making of scientific knowledge, attaches greater significance to students and readers, and places the locus of the disciplinary genesis of physics at the frontier between secondary and higher education.

The thrust of Simon's work lies in his proposal for a new way of writing the history of physics through an interdisciplinary analysis of school textbook physics. In bringing textbooks to centre stage, he uses approaches drawn from the history of the book that connect the material production of textbooks with the shaping of the knowledge they contain. Furthermore, he argues that the main reason why secondary-school textbooks, such as those by Adolphe Ganot, can be considered as classic or canonical lies in the number and diversity of their various readerships in different cultural, national, and social spheres, and the active role of readers in providing texts with meaning. He uses historical evidence to transcend the boundaries between the making and communicating of scientific knowledge, and in this way he presents nineteenth-century authors of introductory textbooks as contributing to the making of physics as a discipline (Simon, 2011).

In contrast, the main aim of both Kaiser and Warwick has been to investigate the making of frontier science, through the Kuhnian question of how students in higher education become part of a disciplinary community and come to assimilate the 'paradigms' of their discipline. Their concept of pedagogy as knowledge communication is unidirectional, since they consider that only a selective number of students and readers could appropriate the knowledge acquired in their training, and endow it with original meanings. As a result, their analysis of textbook pedagogy becomes a complementary tool enriching our understanding of scientific research practices. But it ignores the opportunity of going a step further in considering the transformative power of textbooks and their uses on scientific knowledge.

The reworking of Kuhn's approach to pedagogy and textbooks by Kaiser and Warwick has many virtues, however. It matches pretty well how physics was fashioned in post-war American higher education, the very context from which Kuhn's work emerged. But it fails to provide a larger explanatory framework for understanding textbook physics in the long run, and beyond academic circles in leading centres of research. On the other hand, Simon's strong thesis on the making of physics as a discipline through school textbooks still needs to be tested by further case-studies going beyond the nineteenth century and dealing with other local and national contexts.

The complexities and contradictions of this field of study are clearly expounded in a valuable volume on textbooks of quantum physics edited by Jaume Navarro and Massimiliano Badino. The book provides a rich panorama of such textbooks in the first three decades of the twentieth century and sufficient evidence to demonstrate the creative character of textbook writing and the interaction between research and pedagogical practices. This is a much-needed set of case-studies which includes examples of major textbooks by authors such as Arnold Sommerfeld, Max Born, Paul Drude, Wolfgang Pauli, and Paul Dirac, with others by less well represented actors in the history of this fundamental field of modern physics (Navarro and Badino, 2013).[20]

Michael Eckert's analysis of Sommerfeld's *Atombau und Spektrallinien* shows elegantly how the interaction between different spheres of science communication (popular lecturing, university seminars, colloquia and doctoral supervision) can converge in textbook writing, it demonstrates the role of textbooks in building scientific reputation and also their collective dimension as works of research schools (Eckert, 2013). Clayton A. Gearhart's work on Fritz Reiche's *Die Quantentheorie* is particularly interesting for its illustration of the close ties between journal science and textbook science (Gearhart, 2013). Don Howard's study of Pascual Jordan's *Anschauliche Quantentheorie* suggests convincingly the connection of textbook writing with politics—an aspect that is also mentioned in other chapters in the volume (Howard, 2013). Helge Kragh introduces Dirac's *Principles of Quantum Mechanics* as a notable example of textbook writing with the aim of endowing a developing field of knowledge with new conceptual foundations (Kragh, 2013).

All contributions make good use of sources such as reviews, university calendars, biographical memoirs, and private correspondence, in addition to textbooks themselves. But, in general, they fall short in exploiting the potential of tools available to historians of science books, such as the analysis of literary replication of the kind practiced by James Secord, the active role of printers, booksellers, and readers emphasized by Jonathan Topham and Adrian Johns, and the conceptualization of scientific practice proposed by historians interested in the study of science communication (Secord, 2000; Topham, 2000 and 2009; Johns, 1998; Simon, 2009).[21] A key question is obviously how studies focusing on the analysis of textbooks might be able to make an original contribution to leading trends in the history of science. To fully exploit this possibility, it is reasonable to think that a wider range of approaches should be used, combining conventional perspectives in the history of science with others developed in different disciplines, such as history of education, science education and book history.

21.5 Conclusions

Textbooks have traditionally been standard sources in the history of physics, but in general they have remained marginal in the formulation of large historical questions and the construction of original historical arguments. Kuhn's work helped to draw attention to textbooks and to give them a status as objects of historical study. In their tendency to consider this type of publication as uncreative and dogmatic, Kuhn's ideas were not new. However, he treated textbooks as central agents in the integration of students into the institutionalized and conceptual framework of science. Kuhn's approach has been useful in highlighting the power of textbooks in communicating science and providing a compact characterization of scientific disciplines. Moreover, it has done much to advance the study of physics textbooks produced around the period in which the *Structure of Scientific Revolutions* was conceived, especially those produced close to the cutting edge of academic research. Kuhn's view is partial, however, and it reproduces hierarchies in the organization and public perception of science and education that are tied to particular political, cultural, and social contexts.

It would be naïve to think that the fundamental characteristics of textbooks do not change over time and space, just as physics, education, and print and book trade cultures do. In fact, it is this plurality and temporality that makes them excellent sources on which to base historical questions. Textbooks are different from other types of book because their successive editions are connected to changes in scientific disciplines, educational structures, and pedagogy. They are at the interface between a wide range of forces that converge in education and shape political, social, and economical contexts. They are subject to translations into different languages, which are often active appropriations of their contents and form within different cultures of science and pedagogy. This cross-cultural characteristic and the longevity of certain textbook enterprises have transformed some physics textbooks into scientific, educational, and cultural canons. In this sense, they merit the same attention as works traditionally considered as classics in physics.

If textbooks can contribute to new ways of writing the history of physics, they have to be studied in their own right just like other sources, such as journal papers, laboratory notes, or even popular books, which currently have a higher status in the historiography of physics. Although Kuhn's approach to textbooks squared well with the educational reforms in physics education taking place in mid-twentieth century America and the rise of academic physics as a social and political force, it is inadequate for dealing with other equally fundamental contexts, such as that of school physics. Different questions emerge when one focuses on school textbooks, instead of concentrating exclusively on academic research. The geographical scope and readerships of textbook physics are quantitatively far greater than those of other sources used in the history of physics. This does not mask the fact that there are hierarchies, with contributions that are qualitatively more important than others in the making and development of physics as a discipline. But, in the light of historical evidence, there should be no doubt that, overall, textbook physics is simply physics.

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NOTES

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2. Notable exceptions to these general trends are, for instance, Bensaude-Vincent *et al.* (2003), García-Belmar *et al.* (2005), and Kohlstedt (2010).
3. This is clearly illustrated by a Focus section on textbooks published in *Isis*. See Vicedo (2012).
4. See Duschl (2005) and Isaac (2011). Also Midwinter and Janssen (2013) and Fuller (2000). Midwinter and Janssen (2013).
5. The 'General education' programmes were then widely regarded as a good niche in which to shelter the emergence of history of science as an academic discipline in the USA.
6. The PSSC and Kuhn play convenient pivotal roles in this narrative for their power to illustrate the arguments deployed in this overview essay. They are no doubt important in textbook history, but there is undoubtedly a vast historical and historiographical universe beyond them.
7. However, see also the differences between Kuhn's and Schwab's thought in Siegel (1978).
8. In the following, the account on French textbook physics is based on Simon (2011).
9. The École Normale soon became a major centre for research as well. Its students constituted an elite who after graduating typically acquired experience as teachers in provincial schools, and the most successful subsequently secured positions in large schools or science faculties in Paris or major capital cities. In this period, the gap between secondary and university education was narrow, and research was also conducted in secondary schools. See Zwerling (1990) and Balpe (1997).
10. The available secondary literature on German education is quite heavily biased towards Prussia. However, it is not within the scope of this essay to deal with comparative distinctions between different German states.

11. Lind (1992) and Jungnickel and McCormmach (1986) are rich sources on German physics textbooks, and I have mainly drawn on them in this part of my essay. But I have also performed my own bibliographical research and analysis of primary sources.
12. Like Jamin, Wüllner also published a second textbook intended for schools (Oldham, 2008, 210–248).
13. This close connection between textbooks, scientific instruments, and illustration seems standard, but there are few thorough studies of the relationship. See Simon (2011); Turner (2005) and (2006).
14. While Tyndall's work as a popularizer has been studied, there are no accounts of his role as teacher and textbook author in the school-driven Science and Art Department.
15. Information about other physics textbooks produced and used in the USA can be found in Holbrow (1999).
16. The substitution of inductivist historical accounts with hypothetico-deductive accounts, in the name of pedagogical efficiency, is also evident in such cases as the English translation of Adolphe Ganot's textbook physics, and in Landau and Lifshitz's *Course of Theoretical Physics* (Hall, 2005 and 2008).
17. See also Heilbron (1987), Siegel (1979), and Turner (1984).
18. Nonetheless, Warwick (2003b) offers an interesting analysis of textbook production and appropriation by readers in his study of Maxwell's *Treatise on Electricity and Magnetism*.
19. A good example of this type of standard approach is found, for instance, in the work of Stephen G. Brush. See Brush (1970), (1976), and (2005). The same approach has characterized the work of historically minded philosophers of science. In spite of his critical rethinking of Kuhnian themes, the work of Hasok Chang illustrates this trend (Chang, 2004). Historians of chemistry have shown a greater interest in rethinking textbooks as sources for research (Lundgren and Bensaude-Vincent 2000; Bensaude-Vincent *et al.* 2003).
20. Along similar lines, although lacking the historical sophistication of Kaiser and his use of sources such as lecture notes, Stanley Goldberg has provided a useful overview of American physics textbooks dealing with relativity (Goldberg, 1984, 275–305). Analogously, Dominique Pestre has surveyed university physics textbooks in interwar France and compared them with their American, German and British peers (Pestre, 1992, 31–65). On physics textbooks in Soviet Russia, see Hall (1999), 559–764.
21. At the time I submitted this essay, I had been able to read only eight of the twelve papers in the volume. Although some of the papers deal with less well known textbooks, all the authors selected were included in Kuhn *et al.* (1967).