Hist. Sci., l (2012)

SECONDARY MATTERS: TEXTBOOKS AND THE MAKING OF PHYSICS IN NINETEENTH-CENTURY FRANCE AND ENGLAND

Josep Simon
Université Paris Ouest

> Concerning national education in England, it is like with all the other institutions in this country: at first sight it does not appear as a system, as the logical development of an idea, of a preconceived plan, but as the odd product of several forces which are diverse and often opposed; it is in appearance a purely fortuitous set of traditions, of more or less reasoned uses, local improvements, audacious or timid innovations, all together abandoned to individual initiative, in a complete abstention of public authority. It is a city built without any given alignment, where houses are randomly placed and capriciously moulded.
>
> Jacques Demogeot and Henri Montucci, 1868[1]

> A very good indication of the progress the teaching of science is making in our schools and elsewhere is the rapidity with which edition after edition of Ganot's Physics is called for and published.
>
> Anon., *Leeds Mercury*, 1875[2]

In 1866, in the context of educational reforms in France, Jacques Demogeot and Henri Montucci were commissioned by the French government a report on British secondary and higher education. Commissioners were also sent to other countries, including Germany, Belgium and Holland, following a common practice in nineteenth-century educational reforms which heavily drew on international comparisons for the preparation of national policies. Demogeot and Montucci published their report subsequently as a book, which was also widely read in Britain.[3] Their opening paragraph, included at the heading of this paper, seems to indicate a major incongruence between French and British education.

The two national case studies presented in this paper have conventionally been considered as representing essentially antagonistic models of educational development. This thought, which precedes Demogeot and Montucci and is still deeply grounded in contemporary French and English culture, has shaped scholarship on the development of science education in these countries. While French historians have stressed the role of national structures of formal education and state intervention, historians of English science have tended to focus on the role of voluntarism, informal education, autodidacticism and market forces.[4]

However, Demogeot and Montucci's perspective was biased by their (otherwise reasonable) aim of finding in England objects and patterns which could be compared with their experience in the French educational terrain.[5] Being both teachers in a major *lycée* in Paris, the objects they found more likely to develop comparisons with were the English public schools. Their focus on public schools was in fact in accordance with that of the British government, which shortly before Demogeot and Montucci's visit to England, had commissioned a report on this type of educational

0073-2753/12/5003-0339/$10.00

establishment (the Clarendon Commission report), which also made frequent comparative reference to French *lycées*.[6]

In spite of their unpromising opening, the two French professors developed a detailed account of English education, based both on their readings and their visits to schools. Their focus was traditional public schools. Only one third of their report on the English context was devoted to other types of schools. As we will see, for this reason, it gave less prominence to science than to the teaching of other subjects. Still, it established significant parallelisms between science education in French *lycées* and in a range of new schools which in the previous decades had been developing in England.

Indeed, in the second quotation opening this paper we find that, in spite of the potential antagonisms between French and English education, a certain level of congruence had to exist in the teaching of science in both countries. Ganot's Physics was the translation into English of a textbook by Adolphe Ganot, a French private teacher whose work as a textbook author had been favoured by the boost in science education promoted by government reforms in France since the 1850s. By 1875 the English edition of Ganot's *physique* was already an extremely successful publishing enterprise, whose sixth edition was appearing that year. Ganot's Physics was a standard textbook across England, whose fortunes were equated with those of English science education as a whole.

But how was it possible for a French physics textbook to be so successful in England if the educational cultures of France and England were presumably so different? Perhaps the differences revealed by the standard pictures of these two national contexts (which have shaped their historical relation and popular culture, but also scholarship) are not that accurate or significant? This paper intends to explore this question by using textbooks as cross-national objects which shall help us to characterize better than hitherto science education in France and England with a case study on nineteenth-century physics.

It is commonly assumed that the textbook emerged as a well defined genre, in the nineteenth-century. Paradoxically, defining the 'textbook' has proved much more difficult for historians.[7] A simple definition is that a textbook is a book specifically conceived for instructional purposes. But textbooks are not immutable objects. Their defining qualities have changed over time and they are affected by the ways in which they are used. However, it was arguably in the nineteenth century, that the centrality given to the use of standard books in pedagogical practice was more generally widespread, promoted by educational reforms and the publishing industry.[8] A major reason for the rise of the textbook was its instrumentality in the development of national structures of education, in particular, the nineteenth-century implementation of secondary education. These two phenomena coincided in time with the expansion of science teaching. In this paper I suggest that the major forces behind the establishment of physics as a discipline were secondary to medical education, and school examinations, and that textbooks had a major role in this process.

Textbooks served the purposes of educationists and politicians in the establishment of science education in a national context. They contributed to shape the pedagogical practice of physics teachers and the learning experience of physics students. They enabled physics teachers and researchers to progress in their professional careers, and to shape and to promote their discipline. Textbooks also constituted an important business for authors, publishers, printers and booksellers. The textbook was shaped by the ability of these actors in designing a new product appealing to a large number of customers. The success of the textbook in the marketplace was in part due to their skill in integrating in a single product different teaching tools which had previously shaped pedagogical experience. Syllabi, student and teacher notebooks, teaching collections, blackboards and examinations survived the rise of the textbook, but they all converged in the textbook's pedagogical centrality.

This paper is structured in two parts which analyse the emergence of the physics textbook in France and England, respectively. Each part is divided in two sections. First, I study the development of an expanded demand for physics textbooks. Second, I examine physics textbook production, its authors, and the interaction between textbook production and teaching. Finally, I compare the French and English cases and consider textbook physics in cross-national perspective.

THE RISE OF TEXTBOOK PHYSICS IN FRANCE

During the years following the Revolution, Joseph Lakanal expounded the foundational character of textbooks in French educational organization by declaring to the Convention that "the columns that must support the building of public instruction are the *livres élémentaires*".[9] This principle and the national network of schools created in this period were inspirational for the subsequent Napoleonic reforms. But the imperial system of education was aimed at training the administrative elites of Bonaparte's regime, leaving aside the post-revolutionary stress on science. Nonetheless, a national network of schools and faculties was established, which subsequently had a major role in the promotion of science teaching and textbook production.

The emergence of the textbook as a major tool in French educational organization and practice was not trivial. Decades earlier, the pedagogical function of textbooks did not appear to be clear to physics teachers. Their remarks express the ongoing emergence of the textbook as a genre. Joseph Izarn, a teacher of physics and chemistry in post-revolutionary France, considered that textbooks provided a means of progressing for students, and a resource for inexperienced teachers. But he questioned the idea of a standard textbook to be used by all teachers, for which teacher "would have liked dictating the notebooks of someone else?" For Izarn the only difference was that a textbook allowed students to save time (the time of transcribing the teachers' oral discourse). Other contemporary textbook authors held similar views. Their testimonies make clear that textbooks were a novelty then and that they were progressively emerging as central tools in science education.[10] These teachers operated in a restricted marketplace for physics textbooks, in comparison to its important expansion during the following decades. The French textbook marketplace expanded in parallel to the expansion of secondary education, the increasing importance of physics in the school curriculum, the rise of status of science examinations and the growth of the publics of physics.

The adoption of officially approved textbooks in Napoleonic schools was considered fundamental to secure state political control over education and the standardization and homogenization of school subjects and pedagogical methods. The promotion and control of textbook production was administrated by the Conseil de l'instruction publique, the highest political body for educational matters. Its composition had thus a prominent role in the institutional and commercial success of certain textbooks over others.[11]

The French marketplace for physics textbooks was strongly shaped by the weight of this subject in the school curriculum. Its promotion resulted from political tension within the Conseil, between the supporters of the École polytechnique and mathematical tradition, and those aiming to promote the faculties of sciences and medicine and the experimental outlook. From the 1820s, the increasing influence of the latter resulted in the introduction of science subjects in the access examination for medical studies and, subsequently, the expansion of science teaching in secondary education. During most of the century, medical studies and secondary education were the major agents in the promotion of physics textbook production. These two educational contexts were connected by an examination: the *baccalauréat*.

This examination had two branches: the *baccalauréat ès-lettres* based on the traditional school curriculum was the better attended during the first half of the century. The *baccalauréat ès-sciences* — focused instead on science — could only be taken after the latter and was only required by those wanting to teach the sciences; therefore, it was attended by a low number of students. The introduction of the scientific *baccalauréat* as a requirement for medical school candidates expanded its publics to what was the largest pool of science students for most of the century. The crucial boost to this examination and to physics teaching came in the early 1850s with the *bifurcation* reform, raising the science curriculum to the same level as the classical. This reform coincided with the instauration of the Second Empire in France, as a result of political upheavals starting in the 1848 workers revolution, which were exploited by Louis-Napoleon Bonaparte — the first emperor's nephew — to proclaim himself emperor with the support of the bourgeoisie.[12] In parallel, the Falloux law allowed for freedom of teaching and textbook choice, contributing to the expansion of the private sector of education and the production of physics textbooks by private teachers.[13]

In fact, during the first half of the century, the state control of textbooks struggled to cope with the increasing dynamism of the publishing market and did not operate effectively.[14] Still, being a member of the Conseil could facilitate the adoption of textbooks written by its members or by authors connected with them.[15] The textbook market was thus subjected to the hierarchies of the French educational structure. While the École polytechnique had during the first decades of the century dominated the educational sphere, another elite institution — the École normale — increasingly controlled secondary education. The graduates of this school — established to supply secondary education with teachers — monopolized the best school positions and dominated the textbook market. The *normaliens* produced textbooks in order to organize their teaching, but also as a merit that would contribute to the furthering of their professional careers. Major publishers who knew how to exploit the *normalien* professional and social prestige published their textbooks.

Only a few authors of physics textbooks were able to compete with the *normalien* rule. Paradoxically, their success came from their peripheral position in the French educational system. If competition against the *normaliens* proved almost impossible within the state educational system, the mid-century opening to private initiative in education gave opportunities to a certain number of private teachers and textbook authors. Among these the most representative were Adolphe Ganot (1804–87) and Edmond-Jean-Joseph Langlebert (1820–1900). Their success was based both on their focus on the preparation of the *baccalauréat ès-sciences* and their targeting of medical students. Their pedagogical methods and their textbooks soon spread beyond their context of creation, being adopted in state schools as well.

By the mid 1860s, the *bifurcation* scheme was turned down and many private schools that had appeared under its umbrella disappeared. A single course integrating the classical curriculum with a significant (but lower than hitherto) amount of science teaching substituted the two branches established by this reform.[16] However, the pedagogical methods developed in private schools such as those of Ganot and Langlebert were incorporated into state education, and their textbooks continued to compete with those of the *normaliens*.

The approach to teaching and textbook writing changed over time. During the first third of the century, authors often considered their lectures and textbooks both as pedagogical tools and as treatises encapsulating their major results as researchers.[17] By mid-century, textbook authors had increasingly specialized in teaching and pedagogical writing, and the textbook market had expanded, providing space for a wider range of authors. Thus many textbook authors were not involved in scientific research, but in investigating the most appropriate ways to communicate science to students. In parallel, the connection between textbook writing and teaching was partially blurred: supported by the development of the publishing market, authors with teaching experience started to produce textbooks which did not reproduce their actual lessons, but were products designed to target specific readerships. Nevertheless, specialization did not transform textbook authors into mere messengers of scientific researchers, nor into simply inventive writers. Their job required a good understanding of contemporary physics, of the design and working of physics instruments, and expertise in their manipulation in the classroom.

While the first authors of physics textbooks saw physics as subordinate to mathematics, by the 1830s most textbooks advocated an experimental approach, which made the practice of physics closer to chemistry. The use of mathematics was restricted in most textbooks with the clear intention of attracting new students, thus expanding the sphere of action of physics as a discipline. In addition, textbook writers became increasingly interested in the uses of physics in industry. Their strategies to promote their discipline were in fact often linked to persuading industrialists of the need for providing their workers with a scientific formal education.

SECONDARY EDUCATION, THE *BACCALAURÉAT ÈS-SCIENCES* AND THE EXPANSION OF THE READERSHIPS OF PHYSICS

The establishment of secondary education took place in France through the Napoleonic reforms undertaken between 1806 and 1811, after commissioning preparatory reports on foreign universities. The plan for the new imperial university acted on five major grounds: a network of faculties of letters, sciences, medicine and pharmacy, and of secondary schools was established or reinvigorated, in addition to a set of special institutions — the *Écoles du Gouvernement* — forming the French higher elite of military and civil servants;[18] the Conseil supérieur de l'instruction publique, was constituted by a combination of university and government members; the *baccalauréat* was established; the Conseil appointed commissions in charge of the design of the school curriculum, and of the preparation of textbooks; and, the École normale was established in order to provide secondary school teachers.

The design of school syllabi by the Conseil was devised in parallel to the preparation of textbooks for every school subject. The first science syllabi were prepared by a commission for mathematics teaching closely linked to the École polytechnique, which commissioned a physics textbook to René-Juste Haüy (1742–1822), previously in charge of teaching this subject at the École normale (originally founded in 1794).[19] Jean-Baptiste Biot (1774–1862) was designated as Haüy's substitute in case the latter could not take the appointment. During the first decades of the century, Biot — *polytechnicien* and professor of astronomical physics at the Paris faculty of science — published two physics textbooks, which — together with Haüy's treatise — were recommended by the Conseil in successive school curricula, in the preparation of which Biot intervened.[20] During the first decades of the century, mathematics and professors related to the milieu of the École polytechnique had an important role in defining the teaching of physics in secondary education.

The extension of the French network of secondary schools secured a larger readership for physics textbooks. The imperial university established secondary schools in the capital city of each of the eighty-three *départements* into which France was politically divided, as well as in other important towns that were able to provide the necessary funds and infrastructure for their organization. The university administration divided the French geography in sixteen *académies*, administrated by their faculties of science and letters, located in the *académie* head towns.[21] However, the composition of the school network was heterogeneous, and the introduction of the sciences had to struggle with the defenders of the classical curriculum.

As the core of secondary education was based on Latin and mathematics, the sciences were only introduced in the last two years of the school curriculum. These included physics, chemistry and natural history, subsumed under the general designation of *sciences physiques*.[22] At the provincial schools, physics was often assigned to mathematics teachers, who would often exclusively concentrate on mathematics.[23] Moreover, *sciences physiques* chairs were ranked as second class — in contrast to the first class mathematics chairs — being thus associated with a lower salary.

Furthermore, not all secondary schools offered the same level of studies, due to differences in the availability of resources. Only certain schools (*lycées*), located at the *académie* heads, offered the complete secondary education course lasting six years. By contrast, second rate schools (*collèges communaux*), only provided the first four years of education. The salaries of teachers in provincial schools were between a half and three quarters lower than in Paris.[24] In spite of the high rate of centralization and state intervention, provincial schools and faculties were highly dependent on the availability of municipal funds and the contribution of local industrialists.[25]

The administration of the *baccalauréat* constituted the major duty of the faculties of sciences as very few students took a licence or a doctorate.[26] This examination closely determined the secondary school curriculum. The *baccalauréat ès-lettres* linked secondary school studies with higher education, being a requisite to enter the École polytechnique and any faculty, from theology and law to medicine and sciences.[27] Although French secondary education was rather cheap and socially comprehensive, it was still a minority option.[28] During the second half of the century, enrolments comprised only between 2.5% and 4% of the age group, a poor proportion compared to attendance in primary education.[29] Only around 0.8% of the students took the *baccalauréat ès-lettres*.[30] As the *baccalauréat ès-sciences* could only be taken after the latter, and was originally required for science teachers, it had an even poorer rate of attendance.[31]

A further difficulty in establishing regular instruction in physics was the lack of sufficient resources in the provincial school libraries, cabinets and laboratories. Teachers required these tools not only for their teaching but also to conduct their own research and to prepare for examinations allowing them to progress in their professional careers. While taking their first job in a provincial school, many teachers prepared for the *agrégation* examination — driving the assignment of teaching jobs — for the licence or the doctorate, or they prepared textbooks. The Conseil considered all these options as merits contributing to potential transfers to better schools, an upgrade to a faculty of sciences or even a position in the state educational administration.[32]

The careers of physics teachers and textbook authors were decisively promoted, from the 1820s, by the rise in status of the *baccalauréat ès-sciences*, first prompted by the interaction of the sciences with medical education. In 1821, the science *baccalauréat*, was enforced by the Conseil as a prerequisite for medical studies, significantly boosting the establishment of physics in the school curriculum.[33] The start of the rise in status of the *sciences physiques* in relation to mathematics in secondary education paralleled that of the faculties of sciences against the École polytechnique in the organization of scientific education. It also promoted the production of textbooks addressed to medical students and to *baccalauréat ès-sciences* candidates. An important part of these textbooks were related to private schools established with the aim of preparing students for this examination and making a substantial financial profit from this expanded clientele.

In the 1840s the *baccalauréat ès-sciences* was also for the first time made compulsory for admission to the *Écoles du Gouvernement*. In this period, *sciences physiques* chairs were transferred from the second to the first class, and thus their salary was made equal to that of mathematics chairs.[34] The definitive expansion of science teaching and the *baccalauréat ès-sciences* began in 1852, with the *bifurcation* reform. As a consequence, student numbers for the science *baccalauréat ès-sciences* equalled for the first time those of the classical.[35] The number of hours assigned to physics in the secondary school curriculum doubled, and consequently there was a significant increase in the number of teachers, strengthening the identity of this professional collective.[36]

The rise of the *baccalauréat ès-sciences* was the result of the confrontation between two different approaches to education and to physics, played on the battlefield of the Conseil de l'instruction publique. The position of mathematics and the École polytechnique was represented by Siméon-Denis Poisson (1781–1840) who endorsed the mathematical character of physics, and thus coupled the teaching of these two subjects. The position of physics as experimental science and the faculty of sciences was represented by Louis-Jacques Thénard (1777–1857), who stressed its links with chemistry. Thénard's efforts were decisively continued by his assistant Jean-Baptiste Dumas (1800–84), who succeeded him in all his positions, and represented through his chemistry professorships the link between the French faculties of medicine and sciences, and the experimental approach to physics. Dumas was the major actor in the design and implementation of the *bifurcation*.[37]

Several factors converged in the successful promotion of this educational scheme: On the one hand, the rise of the faculty of sciences against the École polytechnique. On the other, the related strategy of promotion of the sciences by the members of this faculty and of the École normale, as a way to strengthen their position in French society.[38] The reform had arisen from a report commissioned in 1846 by the government to a commission led by Dumas. His report stressed five major aspects. First, the necessity of replacing the single secondary education syllabus by three independent, although connected, courses: the classical, the scientific and the special, with a *baccalauréat*, for each of them. Second, the need to recover the state hegemony over secondary education against private preparatory schools, through the replication of the latter's pedagogical organization and techniques. Third, the benefits of including scientific subjects in the classical syllabus and in its sanctioning examination (the *baccalauréat ès-lettres*). Fourth, the urge of advancing the time of appearance of the sciences in the school curriculum. And fifth, the indispensability of implementing pedagogical practices and material resources, organizing the teaching of science through demonstration, experimental manipulation, and observation, and illustrated by its major applications. England was cited as a leading example of the latter, and Germany as a country starting to follow that trend.[39]

Dumas's report highlighted the strong competition that state schools had at this time from private preparatory schools, and the admiration of their pedagogical methods. Furthermore, it stressed the will of the *sciences physiques* practitioner to extend his public to the literary student and to the future industrial worker. His plan pressed for the introduction of science subjects in the classical curriculum, and the creation of a secondary education branch ('special', 'industrial' or 'professional'), intended to train the future workers of industry and commerce. Furthermore, scientific education should include illustrations of the 'applications' of science, as — Dumas suggested — foreign industrial competitors were doing. Although incubated during the previous decade, the *bifurcation* was implemented only a year after the Great Exhibition, and similar arguments were critical to debates on middle-class education promoted then in England. These, however, used France and Germany as the models to follow in the organization of science teaching and research.[40]

Most of Dumas's suggestions were implemented during the 1850s, but the establishment of the 'special' branch of secondary education did not occur until 1866, shortly after the abolition of the *bifurcation*.[41] The end of the *bifurcation* had an impact on science teaching, but not a dramatic one. The *bifurcation* had an enduring influence in the school and faculty curriculum, and by the end of the period it had led to the strengthening of the state school system by the integration of pedagogical techniques originally conceived in private schools. It was also decisive for the great expansion of the French science textbook market, and for the success of French physics textbook production not only in France but also abroad. The development of a 'special' branch of secondary education contributed also to keep the dynamism of the French market in physics teaching and textbook production.

THE REALM OF THE *NORMALIEN* AND THE RISE OF THE PHYSICS TEXTBOOK AUTHOR

Progressing in the French educational system and succeeding in textbook writing was not a simple matter. The *agrégation* and the best *lycée* positions were practically covered by students graduating from the *École normale*. In parallel, with few exceptions, *normalien* authors monopolized the physics textbook market. This was a direct consequence of the design of French education. The École normale had been devised after the Revolution as the elite institution in charge of supplying teachers, and for this reason, the foundational physics textbook of imperial secondary education had been commissioned to Haüy.[42] In spite of the pressures of the textbook market and its subsequent liberalization, the *normaliens* permanently occupied privileged positions as textbook authors. Nonetheless, they had to fight in order to secure a prominent place for the sciences in secondary education.

After graduating, the *normaliens* had to take the licence, and the last year at the École was effectively used to prepare for the *agrégation*. The number of positions available for the *sciences physiques agrégation* was small for the number of Normale graduates: twenty-five between 1821 and 1830, and two-hundred-and-sixty between 1830 and 1849, while the number of *normaliens* was around one-hundred and two-hundred-and-fifty, respectively. As a result, before 1832, one third of the *agrégés* were *normaliens*, and in the following decades they got hold of three-quarters of the positions available.[43] They formed a collective with a strong *esprit de corps* and a middle and working class social background — in contrast to the highest social provenance of the *polytechniciens* — and they exerted a collective enterprise to take as far as possible the *normalien* rule in French society.[44]

Physics had an increasing weight in the science section of the École normale, connected to its increasing importance in the secondary school curriculum, and many *normaliens* taught physics in French secondary schools before specializing in other branches of the *sciences physiques*. Chemistry had a comparable importance, and was particularly boosted from the 1850s through the work as École normale teachers of Louis Pasteur and Henri Sainte-Claire Deville. Conversely, the Normale had always a strong competition from the École polytechnique in the provision of mathematics teachers.

Pasteur himself represents very well the pattern of *normaliens* careers. He studied at the Normale, after successfully passing the *baccalauréat ès-sciences* — with the help of special preparation in a private school in Paris.[45] After graduation, he went against the advice of his father, who considered that he should take the mathematics *agrégation*, because of its highest prestige and its associated job perspectives. But in 1846 Pasteur decided to take the *sciences physiques agrégation*, and got his first appointment as a secondary school physics teacher. Subsequently, he moved between different provincial schools and faculties of sciences and specialized in chemistry, progressing towards the award of a position in Paris as director of the Normale science section.[46]

The science *normaliens* were very active in the writing of textbooks, produced typically in the early stage of their professional careers. Not all of them produced textbooks, but the most successful in general did, and this served their careers. Textbooks were a fundamental tool to develop their teaching method in taking their first position in a provincial *lycée*. In addition, they served their ambitions of career promotion. The French ministry of public instruction conceded a great value to the preparation of textbooks, serving the government needs of control and national homogenisation of education. In this context, the extensive French network of secondary schools and faculties of sciences constituted a dynamic and competitive professional context which shaped the quality of the production of textbooks and pedagogical experience in France.

In this competitive context, the mobility of science teachers was high and had an important role in the promotion of textbook production and use. Before 1850, a third of the *sciences physiques* teachers in French secondary schools remained for less than five years in the same position. Furthermore, a competitive selection took place, as around two fifths of the science teachers had careers in state education lasting less than ten years. In contrast, ambitious teachers, after holding several positions, could end their career in a prestigious *lycée*, in a faculty of sciences or in the state administration. In the meantime, they wrote textbooks helping their pedagogical work and professional promotion. Alternatively, in the course of their professional itinerancy, they could recommend the use of particular textbooks, due to their use of them in previous professional destinations or their personal acquaintance with their authors.

During the nineteenth century, a third of the *sciences physiques* teachers moved two or three times before settling down. In certain cases, teachers moved four or five times before being able to get a position in Paris, the most prized location in terms of professional and social prestige, salary and access to the possibilities of a future career in higher education or administration.[47] The capital of the highly centralized French state offered many opportunities not available in the provinces, including access to science lectures at the faculty of sciences and other institutions such as the Conservatoire des Arts et Métiers, and to public and private laboratories necessary to conduct research and to prepare for examinations. Furthermore, the *agrégation* could only be taken in Paris.[48] The most successful *normaliens* used their textbook writing to climb to higher positions in Paris, and vice versa, by their transfer to the capital they ensured an enduring success for their textbooks. The major French physics textbooks published during the first half of the nineteenth century were thus products of the strong competition and circulation of *normaliens* across the French educational structure.

In this period, the physics textbook marketplace 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.[49] Their textbooks were originally designed for use in secondary schools, and their first editions coincided with the expansion of the *baccalauréat ès-sciences* publics due to its requirement for admission 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 Deguin shortly after 1837, when the *baccalauréat* requirement was re-established. This first group of authors represents the rise to prominence of the *normaliens* in the French scientific elite, concentrated in Paris. The second group serves to qualify the traditional picture of French education and science as a highly centralized system, for they were the first in a series of major physics textbook authors established in a provincial town.

Péclet's career led him, after graduation at the École normale, from his first position as physics and chemistry teacher at the *lycée* of Marseille in 1816, to his appointment as physics lecturer at the Normale, three years later, and, from 1828, at the École centrale des arts et manufactures. The latter was founded after conversations led by Dumas and Péclet with French industrialists. It was privately funded — in contrast with the other French engineering schools — and had a fundamental role in providing engineers for high managerial positions in French industry.[50] Péclet's physics textbook appeared first as a result of his teaching at Marseille.[51] After his appointment at the École centrale, he transferred the publication of his textbooks to Paris.

Péclet and his Parisian publisher renamed his *Cours de physique* (an explicit reference to its origin in his lessons) as the more ambitious *Traité élémentaire de physique*, indicating that the author had fulfilled the challenge of producing a comprehensive account of physics — a treatise — for the use of secondary school students.[52] The *Traité* — in two volumes — was sold at twelve francs, representing around a tenth of the monthly salary of a provincial secondary school teacher.[53] In Paris, Péclet could supervise the printing of successive editions of his textbook and benefit from the national and international distribution offered by Parisian booksellers. From 1832, his textbooks were published by Hachette, which soon became the leading French firm in the secondary school textbook market.[54] In parallel, Péclet also published treatises dealing more specifically with his research on the applications of physics to lightning and steam, connected to his lessons at the Centrale.[55] However, his lessons also circulated as notes distributed to the students.[56] During the first half of the century, the circulation of notes written by students or teachers — sometimes reproduced through new techniques such as lithography and stereography — was common, and the rise of the textbook did not manage to render this practice obsolete.[57] Péclet's physics textbook also displayed his research and teaching at the École centrale, as he did not establish a clear boundary between his teaching and research, and between his journal publications and his textbook writing.

The ministry of public instruction prized Péclet's work as a teacher, researcher and textbook author by giving him positions in the educational administration, as inspector of the Paris *académie* in 1838, and general inspector of the *Université* in 1840.[58] In 1847, he published the fourth edition of his physics textbook. It was the last, for after the 1851 *coup d'état* of Louis-Napoleon Bonaparte, in refusing to take the oath — as a civil servant — to the new political regime, he retired from all his positions and ceased to engage in textbook writing for state schools.[59] Political upheavals had thus an important impact on the textbook market and could afflict especially those teaching in state schools and occupying high positions.

For the same reasons, the political changes that inaugurated the Second Empire in France also marked the end of the successful career of Claude Pouillet. After graduating at the Normale, he taught physics between 1820 and 1829 at one of the major secondary schools in Paris. In parallel, he assisted Jean-Baptiste Biot and Louis-Joseph Gay-Lussac (1778–1850) at the Paris faculty of sciences, and in 1833 he obtained a physics chair in this faculty. In this period, he also held the physics chair at the Conservatoire des Arts et Métiers and, two years later, he became its director. In 1827, Pouillet published his *Éléments de physique expérimentale et de météorologie*, based on his teaching at the faculty of sciences.[60] The publication of Pouillet's textbook marks a key moment in the emergence of the textbook and the textbook author in nineteenth-century France.

Pouillet's lessons at the faculty of sciences — like those of Gay Lussac — were stenographed by Augustin Grosselin (1800–78), one of the most active French practitioners in this craft in this period. Grosselin used this technique to transfer the oral speech of Pouillet through an abridged system of signs.[61] Subsequently, he published the lessons, acknowledging Pouillet's authorship, but preserving for himself the financial benefits of the edition. Although this practice was quite widespread, Pouillet and his publisher considered that Grosselin's initiative interfered with their own textbook business.[62] As a result, they went to court, and the stenographer was condemned to pay substantial compensation to the author.[63] The textbook author and the textbook publisher were thus careful to stop any unauthorized intrusion into the intellectual and profitable business of rendering classroom teaching into print. This was thus an important moment in the rise of the textbook to the centre of pedagogy and the publishing trade.

From his position as director of the Conservatoire des Arts et Métiers — the reference institution for instrument and machine design in France — Pouillet was also a pioneer in physics textbook illustration. Many of his textbook illustrations were used by other contemporary authors such as Péclet.[64] Most of them were extracted from the *Portefeuille industriel*, a project involving Pouillet and the teachers of drawing at the Conservatoire. The Conservatoire had been established in 1794 as a repository of knowledge on instruments and machines, and the *Portefeuille* was a project aimed at storing drawings of the major inventions presented by law to the Conservatoire. Pouillet's textbook could thus keep abreast of the major innovations in instrument design through its illustrations. By 1856 his book had seven editions, it was translated into several languages, and it became the major physics textbook in France until the 1850s. Like for Péclet, Pouillet's textbook writing addressed the intersection of secondary and higher education and it targeted those readerships who wanted a general introduction to physics, those interested in the applications of physics to the industrial arts, and those involved in research. In 1850, he produced his *Notions générales de physique et de météorologie*, an abridged version of his textbook intended to be a more elementary (and cheaper) introduction to the subject.[65]

Pouillet's first textbook was an expensive four-volume treatise priced at double that of Péclet's two-volume book, but his second textbook was instead a smaller volume with a lower price. This second book pioneered in France the insertion of illustrations in text and the use of wood instead of copper engraving, allowing for more accurate and attractive representations of physics instruments. The publisher of his textbooks was Béchet jeune, one of the major medical publishers during the first half of the century. But in the early 1850s, Pouillet's books were — like those of Péclet — published by Hachette whose strategy was clear: controlling the secondary school marketplace for physics textbooks, by incorporating major authors to his list.

During the first half of the century, Pouillet's successful career was an inspiring model to many students at the École normale. Like Péclet, Pouillet's work as a researcher was acknowledged by his admission to the Académie des Sciences and the award of the *Légion d'honneur*. The same year, he actively engaged in politics by entering the French Chamber of Deputies. In 1845 he became a member of the Conseil de l'instruction publique, a position that surely enforced further the successful circulation of his textbooks. But his refusal to accept the new political regime forced him to retire in the 1850s.

Forced to abandon their positions, their teaching and research facilities, and losing their connections in the upper echelons of the educational administration, Pouillet and Péclet ceased writing textbooks. Already aged and having the prestige of long and successful careers, they did not consider engaging in alternative ventures such as private education. However, for young teachers afflicted by similar political problems, private teaching could be a solution. This was the case of Eugène Catalan, a promising mathematician assisting in teaching at the École polytechnique. After losing his position, he became associated with Joseph-Edmond Langlebert, developing private teaching and textbook writing for medical students preparing for the *baccalauréat ès-sciences*.

Ganot and Langlebert were the major private teachers in this field. As private entrepreneurs who were not directly linked to state education, their teaching and textbook writing was not affected by the political change. On the contrary, their work benefited from the implementation of the *bifurcation*, which was decisive for the success of their textbooks. Thus, the *bifurcation* and the retirement of elite physicists and textbook authors such as Pouillet and Péclet did contribute to the opening of the market to authors such as Ganot and Langlebert who occupied a marginal position in the French scientific and political map.[66]

But, even if weakened for a certain period, the *normalien* rule continued to be in force during the rest of the century, as a new generation of Normale graduates took positions in the French educational system. In the 1860s, the *normaliens* Charles Drion (1827–62) and Émile Fernet (1829–1905), Augustin Boutan (1820–1900) and Joseph Charles d'Almeida (1822–80), Augustin Privat Deschanel (1821–83), and Pierre Adolphe Daguin (1814–84) produced some of the most successful physics textbooks of the second half of the century. Their careers developed according to the patterns outlined at the beginning of this section. But, fortunately for authors such as Ganot and Langlebert who published the first editions of their textbooks at the beginning of the 1850s, the new elite of *normalien* authors did not publish immediately after taking their first teaching position — as was common in the first half of the century. The widest range of textbooks made available in the previous decades, probably made publication less urgent and more difficult. Thus, the new *normaliens* were involved in teaching for around a decade before publishing their textbooks.

Drion and Fernet's physics textbook had six editions between 1861 and 1877, and was translated into several languages.[67] It was published by Victor Masson, the leading French medical publisher (competing with Jean-Baptiste Baillière) during the second half of the century. From the 1870s, Fernet produced other physics textbooks adapted to different readerships. The success of Fernet's textbook writing had an important role in his appointment to the position of inspector of the Paris *académie* in 1877.[68] Privat Deschanel published his first textbook of physics in 1855, and subsequently produced textbooks on mechanics and chemistry and a handbook for the *baccalauréat ès-sciences*. His major textbook was his *Traité élémentaire de physique* published by Hachette in 1868, after almost twenty years of teaching experience in Paris. It had only one edition but was translated into Spanish and English. In Britain its translation was, together with that of Ganot's textbooks, one of the most successful textbooks during the second half of the century.[69] Privat Deschanel was also appointed in 1868, inspector of the Paris *académie*. Boutan and Almeida's *Cours élémentaire de physique* appeared in 1862 and its fifth edition was published in 1884.[70] Almeida was one of the founders of the Société de physique (1873), arising from meetings in Henri Sainte-Claire Deville's chemistry laboratory, at the École normale.[71] This society intended to promote physics by gathering all physics teachers — independently of their position or status — and any men with interests in physics among the industrial, engineering, military and medical professions.[72]

On the other hand, Daguin's textbooks represented the strength of Toulouse as a provincial centre for physics teaching and textbook production, thus preserving the status attained in previous decades by the work of Auguste Pinaud, professor of physics at the faculty of sciences and Nicolas Deguin professor of physics at the Toulouse *lycée*.[73] In spite of this, Toulouse authors and publishers had to seek the support of major science publishers in Paris in order to distribute their works nationally.[74]

The role of the publisher Louis Hachette was fundamental in the physics textbook marketplace. Hachette represented an early example of a new type of French publisher, which became more common only during the second half of the century. He was not apprenticed in the trade, but had been previously educated at the university. Moreover, he was trained as a teacher before learning the job of the bookseller. Hachette studied at the École normale but could not graduate because of the temporary closure of the School in 1821 for political reasons. A year later, he took the *agrégation* examination, but did not succeed.[75] Hachette then endeavoured to study law.

His social interaction in the influential milieu of the law faculty was essential for the development of his business as bookseller. He obtained a bookseller *brévet* in 1826 — paradoxically a year of crisis for the French book trade. His social connections helped him to obtain in 1834 a state commission producing a boost to the firm, and official recommendation for his textbooks, which included among others those by the *normaliens* Péclet, Pouillet, Pinaud and Privat Deschanel.[76] Hachette took care in preserving good connections with the university milieu and especially with the *École normale* and its graduates. In addition, the firm maintained close relations with educational administrators and copies of Hachette's books were regularly sent to inspectors in every *département* in France.[77]

The *normalien* rule over the secondary school physics textbook marketplace was shaken only by some authors educated at the École polytechnique, and especially by a few authors who taught in private schools in Paris, such as Ganot and Langlebert. This was possible because of the importance of the *baccalauréat ès-sciences* for medical students, the *bifurcation*, and the Falloux law. The political and pedagogical importance assigned to textbook production in France, and the early development of a secondary education system at national level shaped the wealth of French physics textbook production. Although this production was highly concentrated in Paris, the provincial network of schools and faculties constituted a dynamic system of pedagogical training, which enriched the experience and skills of French textbook authors. The French government had a fundamental role in the development of the textbook marketplace, but the private initiative of authors and publishers was also important. The competitive dynamism of the French textbook marketplace made its strength, and led to the export of French textbooks and their translation into other European languages such as English.

In contrast, the development of secondary education in England from the 1850s was not accompanied by a general plan of textbook production, and thus the availability of a wide range of physics textbooks in France came to have a fundamental role in the early introduction of physics in English secondary schools. In spite of this, the English textbook market was not exclusively led by private initiative but was driven by a wide range of learning institutions aiming to promote science and middle class education.

THE RISE OF TEXTBOOK PHYSICS IN ENGLAND

In 1851, Josep Lovering, professor of mathematics and natural philosophy at Harvard College,[78] expressed in an anonymous review his concern for the lack of adequate physics textbooks in America and Great Britain, as opposed to the wealth of textbooks available in France and Germany.[79] American and British men of science were, according to him, readers of the major French and German physics treatises but — with a few exceptions — they had sadly been unable to write similar textbooks in English. Translation of some of the best French works into English was incipient, but not the production of original textbooks. While there was relevant British writing on physics, it had been spread in publications such as the *Cabinet cyclopaedia*, the *Library of useful knowledge*, the *Penny magazine* and the *Encyclopaedia metropolitana*, which were "of too popular a character" and lacked the compact structure, "unity of thought" and pedagogical approach required by textbooks. Lovering also considered that available textbooks, written by medical doctors, were insufficient. This situation was even more surprising, taking into account the important place that — in his opinion — physics should have, and the associate need of teaching it in Britain and America.[80]

Some of the publications alluded to by this privileged reviewer had played, since the 1830s, a major role in the communication of science to 'popular' audiences. The political and educational mission of the Society for the Diffusion of Useful Knowledge — who produced the *Penny magazine* and the *Library of useful knowledge* and inspired the *Cabinet cyclopaedia* — had been coupled to the establishment of a network of mechanics' institutes, aimed at teaching the sciences to the same working class audiences to which these publications were addressed.[81] But, by the late 1850s, the foundational agenda of this movement had lost strength, and its impulse was moving towards the provision of education for the middle-classes.

Following enquiries by the members of the Clarendon commission about the availability of science textbooks in England for use in schools, the comparative anatomist and palaeontologist Richard Owen stressed in 1862 the lack of such works because "the demand has not arisen, and, therefore, there is not the supply", and furthermore that "they are more difficult [to write] than is generally thought. Good elementary books on science are very rare".[82]

By the 1870s, a reviewer in the *Leeds mercury* lamented again the superiority of France and Germany compared to England in the production of physics textbooks, providing an acute explanation for this state of affairs:

> The country had a low but productive number of men of science whose researches placed England high in the international scientific movement. However, due to its limited space of scientific education, the potential readerships of physics textbooks had been restricted and thus textbook production was not required. The recent expansion of scientific education had finally provided the required demand and, in this context, the production of English physics textbooks had — no wonder — been supplemented by the importation and translation of works having already a high reputation and circulation in France.[83]

The lack of physics textbooks by able teachers who could recreate their lessons could be explained by the lack of a secondary school curriculum that included physics among its subjects in a sufficiently large number of schools. In fact, there were physics textbooks by English authors, but — according to many contemporary writers — they were insufficient or were not adapted to the needs of a major but novel emerging readership: secondary school students.

During the 1860s and 1870s, the translation into English of French textbooks by authors such as Adolphe Ganot and Privat Deschanel certainly held a prominent position in the British textbook market. Their translators, Edmund Atkinson (1831–1900) and Joseph David Everett (1831–1904) rendered these books into English after having looked for a suitable textbook for their teaching, when they took positions as physics college teachers.[84] Their intention was to provide students with appropriate textbooks, displaying thus the pedagogical centrality of the textbook in classroom practice.

The increasing number of science students in England created the expectation for a potentially large clientele for such textbooks, with obvious financial benefits for authors and publishers. This market was particularly boosted by the establishment by different educational institutions of examination systems promoting the study of science at a national level. Thus, textbooks were translated for pedagogical, institutional and financial reasons. In addition, textbook production enhanced the prestige of authors and strengthened their professional careers. The success of the English editions of Ganot's and Privat Deschanel's books provided Atkinson and Everett with the professional acknowledgement and respect of their colleagues. It also contributed to shaping the constitution of physics as a discipline, as a community of practitioners devoted to research — but also — to teaching and textbook writing.

The introduction of the sciences in secondary education started to become widespread in England from the 1860s, although in the two previous decades there were significant foundational moves that led to the establishment of schools for the middle classes. English science education came to be principally driven by three systems of examinations and associated school networks: The London Matriculation examination, the Oxford and Cambridge Locals, and the Science and Art Department. The establishment of examination schemes at the national level contributed to the standardization of the readerships for science and to the creation of an increasing body of science teachers, which had a major role in the professionalization of science. Initially these teachers had to rely often on textbooks produced abroad, especially in France. But, by the 1870s, the number of physics textbooks by English authors increased significantly, competing in the market with translations of French textbooks.

The development of science education took place through several processes that contributed to the reaction against the classical curriculum imparted by public and grammar schools and the universities of Oxford and Cambridge.[85] The reaction of the English middle classes against the exclusivity of the English educational system and the inadequacy of the classical curriculum for the commercial and industrial professions resulted, from the 1840s, in the establishment of private schools with modern curricula. In the 1830s, the constitution of the University of London with its strong focus in medicine and science and the national range of its matriculation examination contributed to the expansion of science teaching in schools and the translation and publication of textbooks. In parallel, physics teaching and textbook production had a prominent place in English medical education. Moreover, the establishment of competitive examinations for access to military academies contributed to the development of a new type of public school with modern sections teaching the sciences. Edmund Atkinson's translation of Ganot's *Physique* took place at the eve of his career as a physics teacher in one of these schools.

The reaction of Oxford and Cambridge to the emergence of schools with modern curricula and the school network constituted by the University of London, contributed to the introduction of the sciences in their university degrees and the creation of an Oxbridge system of national school examinations including science subjects. Public debate on the need for introducing the sciences into the school curriculum reached its climax after the Great Exhibition. This was a perfect occasion exploited by the English scientific elite to promote their emerging profession, playing on arguments of national pride and industrial fitness that placed the expansion of science teaching at national level as the solution to a supposed loss of power of Britain in the international context. As a result, in 1853 the Science and Art Department (DSA) was created, contributing to the training of science teachers and to an enormous expansion of the number of science classes across the country. The implementation of the DSA scheme supposed an additional boost to the physics textbook market.

The three examination systems established in England since the late 1850s produced examination syllabi and all — except the London scheme — had an associated list of recommended textbooks. The English state did not intervene in the making of these lists as in the French case. Their making was rather the business of a select number of examiners and teachers who often occupied positions in the administrative boards of more than one examination system, and who were in close relation with London publishers, often as authors of several textbooks. The London, Oxbridge and DSA examinations decisively contributed to the expansion of the school publics for science and for physics textbooks. Nonetheless, by the late 1860s, enrolments in English secondary education were still around a quarter of those in France.[86]

SECONDARY EDUCATION AND THE READERSHIPS OF PHYSICS IN ENGLAND

In the early nineteenth-century English primary and secondary education was provided by grammar and public schools regulated by Acts of Parliament. Their geographical distribution was heterogeneous since they had been created by private foundations. Contemporary censuses established that there were in England around 30,000 pupils in circa 900 grammar schools. Among these, a special set — the public schools — had attained a status making them privileged feeders of the universities of Oxford and Cambridge. Most public school pupils however, did not follow subsequent university studies. In all of them the curriculum was based on Latin and elementary mathematics and initiatives to reform it were restricted by their foundational Acts.[87]

During the first half of the century, the major physics textbooks published in

England were written by medical practitioners. From the late 1820s, the use of natural philosophy in medical practice was promoted and enforced through examination by the English medical boards, and lectures on this subject were provided in the major teaching hospitals in England. A large number of medical schools were founded in London and leading provincial cities, and medical studies led the way in vocational education, attracting the largest body of English students taking physics courses in this period. From 1858 medical degrees were the first to be systematized and standardized at a national level through the establishment of a nationally unified system of education.[88] The establishment of this system and the presence of physics in its curriculum were fundamental to the promotion of physics textbook production.[89]

The development of physics teaching and textbook production was taken a step further by the establishment of University College London (1826) — modelled on Scottish and German universities — and its rival King's College (1831) — founded as an ecclesiastical reaction to the secular character of the latter. Both were characterized by their particular stress on science and medicine, and aimed at developing medical schools, thus expanding the use of the sciences in medical practice.[90] The background of their students was middle class, in contrast to the more aristocratic profile of students attending the old universities.[91] While Oxford and Cambridge were directly fed by students from the elitist public schools, the London colleges did not have a school network securing sufficient attendance to their courses. Moreover, students often used the London experience merely as a preparation to enter Oxford and Cambridge. For this reason, the two London colleges soon established schools associated to them.[92] Furthermore, in 1836, they joined forces to form the University of London, and a matriculation examination including science questions was established.[93] The London examination for the M.B. included proofs in the sciences and, from the 1860s, medical and science students sat for the same papers in the first stage of their university education.

The London examinations had an important role in articulating the teaching of science in England. They directed the curriculum and performance of a certain number of schools, as they provided a certificate which became sought-after by students aiming to follow a career in science or to crown their school education with a title.[94] In parallel, provincial colleges such as Owens College — established in 1851 — shared the London focus on science and its political origins, and it often worked as a provincial examination body for the University of London. Unlike other institutions, London did not include official textbook recommendations. Nonetheless, its examinations prompted the emergence of a dynamic context of private teaching and textbook production.[95]

Furthermore, during the 1840s and 1850s, as a result of the changes demanded by the English industrial and commercial middle class in the school classical curriculum, a certain number of grammar schools emerged with their curriculum renovated, and new schools were established. As pointed out by Margaret Archer and Robert Anderson, in not being able to produce a complete reform of the old schools and universities, the strategy of this movement was to create an educational system parallel to the traditional one supported by the aristocracy and the Anglican Church.[96]

The new schools had private foundations which were instituted by teachers, groups of parents or entrepreneurs, and religious communities. A private school census in 1851 established that there were in England around 5,000 "Superior" schools and around 7,000 "Middling" schools, being half of the total private schools in the country.[97] A considerable number of these gave an important place to the sciences in their curriculum. Although the school science movement had an important role in the subsequent institutionalization of science, it has been a marginal concern both for historians of science and historians of education.[98] Our knowledge on this context is still sketchy, but a few examples can be illustrative of the extent of the provision of science in formal education in England.

References to science teaching in schools are often found in relation to the early career of major figures in Victorian science. However, scholars have often failed to realize that these early experiences had in fact a major role in the subsequent establishment of scientific disciplines. Examples of these are Queenwood College, Hampshire, in which John Tyndall, Edward Frankland and Edmund Atkinson, among others, started their teaching careers; Bootham school, York, a Quaker foundation in which Silvanus P. Thompson was educated and where he taught; Clapham proprietary school, South London, directed by Charles Pritchard, a Cambridge wrangler and distinguished astronomer; the science school at Chester directed by Arthur Rigg — another wrangler — in which William Crookes had one of his first jobs; and the school directed by Antony Nesbit and his son, the chemist John Collis Nesbit, first in Manchester and then in London.[99]

In addition to the establishment of new schools, the science school movement could also count on collaboration with mechanics institutes. In these establishments, attendance to science courses was mixed in terms of social class — at least in institutes located in large towns — although working class and lower middle class was the general profile.[100] From the late 1830s, affluent mechanics' institutes such as Liverpool and Manchester, established secondary schools within their premises. The mechanics' institute movement was a useful ally, as it had already established national or regional networks, large libraries and teaching collections, and an early experience in science teaching and textbook production. From the 1860s, these institutes often coupled their educational action to the work of the Science and Art Department, by joining its examination scheme.

New educative initiatives were not restricted to the northern nonconformist middle classes and the political philanthropy of the mechanics' institute movement. New universities colleges such as Durham (1832) and Queen's College, Birmingham (1843) were Anglican foundations. Moreover, the sciences were also taught in Anglican schools such as Liverpool College, and in certain grammar schools that effectively reformed their curriculum to the requirements of their clientele, such as Edward VI, Birmingham, and the Manchester grammar school.[101]

However, an important number of the schools established in this period had an ephemeral life, due in great measure to the lack of well-defined educational and vocational targets, and their integration into a solid and extensive educational network. For these reasons, their teachers rarely produced new physics textbooks. In contrast, in the 1840s and 1850s, a group of large proprietary schools was founded, which would play a major role in science teaching during the following decades as they raised their status to be recognized as new public schools. Their emergence was especially due to their development of large modern sections teaching science subjects in preparation for entrance to military and civil service academies. The major schools of this kind were Cheltenham, Marlborough and Wellington. At Cheltenham, Edmund Atkinson translated Ganot's *Traité* into English, a few years after starting his career as a physics teacher and, subsequently, he linked his successive editions of the book to his pedagogical practice as professor of experimental science at the Royal Military College, Sandhurst. In contrast, among the old public schools, only Rugby introduced science courses, while the rest kept for a long time their curricula in the classical ideal.

As a reaction to these developments, Oxford and Cambridge created a system of examinations for provincial schools aimed at fighting against their potential loss of influence. The Oxford and Cambridge Local examinations were instituted in 1858, as an extension of the universities to the "outside world" represented by middle-class schools. This examination was also used as a certificate of achievement in leaving school but did not constitute a way in to university.[102] In the late 1840s Oxford and Cambridge had already been under pressure to include the sciences in their curricula. In this context, Robert Walker — the Oxford professor of experimental philosophy — had pinpointed the problematic lack of appropriate textbooks and the need for proper teaching laboratories and instrument collections.[103] The organization of the Locals required new syllabi and textbooks, and in this context, the Clarendon Press and its schoolbook committee remarked upon the need for launching a programme to provide new textbooks.[104]

The science school movement was definitely boosted with the creation in 1853 of the Science and Art Department (DSA), and the launch of its program in 1859. The DSA promoted the establishment of scientific disciplines through three connected actions: the training of science teachers, the expansion of science teaching through an award system based on examinations, and the support to the establishment of scientific collections in schools. The DSA scheme targeted both the working and the middle class and did not focus on the industrial applications of science but on the first elements of science subjects such as physics.[105]

The Science and Art Department combined a clear will of state intervention with the political culture of *laissez-faire*. State intervention featured prominently in contemporary debates, which used France as a model for the establishment of a standardized national system of school science education. It also translated the strategies of British scientists to increase their professional and political status. The argument was also justified by the contrasting state intervention in the organization of English primary education and Irish secondary education, and it paralleled the democratic challenge of the private grammar school managing boards by elected municipal authorities.[106]

The DSA's strategy was based on a moderate intervention. Its major tool — an examination system — was articulated through a reward scheme paying teachers by student results. However, teachers joining this scheme had to be accredited by taking training courses designed by DSA examiners. A system of school inspectors was instituted, but had to rely on part-time personnel. From the 1870s, the pedagogical and disciplinary action of the DSA was also communicated through the writing of textbooks by its lecturers and some teachers trained in its scheme.

In the early 1860s, thirty science classes, constituting a body of around 2,500 pupils, had joined the DSA scheme. Their distribution was national, covering mainly England but also certain Scottish and Irish schools. In the late 1860s, the DSA examinations were attended by 25,000 students belonging to more than two hundred schools, constituting thus the largest body of science students in England.[107]

The DSA programme of science teacher training was the most ambitious of its kind in England. Influential members in the British scientific elite such as John Tyndall, Edward Frankland and Thomas H. Huxley used this scheme as a way to create a body of science teachers, tied by a strong *esprit de corps*, contributing to the promotion of the rise in status of the sciences in England. Similar interests led to the creation of the Physical Society in 1870, in which teachers like the DSA lecturer Frederick Guthrie, and chemists like William Crookes and Edmund Atkinson himself had a major role.[108]

In 1861, the DSA had provided teaching certificates to more than one-hundred science teachers. In the late 1860s, around three hundred science teachers had been qualified by this institution.[109] If the DSA had a fundamental role in the training of school teachers, perhaps comparable in this period to that of the École normale in France, the provision of college science teachers followed in general other patterns. The prestige of DSA certificates did not outstrip that of university colleges. Hence, the educational profile of English science teachers was more diverse than that of their French counterparts. Many English science teachers therefore had degrees from London, Oxford or Cambridge, and in certain cases they had previously been educated at Owens College.

THE ENGLISH PHYSICS TEXTBOOK MARKETPLACE AND ITS AUTHORS

In the early nineteenth century, Haüy's treatise — the foundational physics textbook of the French secondary school system — was translated into English by Olinthus Gregory of the Royal Military College, Woolwich, a few years after its appearance in France.[110] In this period, the English marketplace offered a wide range of natural philosophy books addressed to various readerships, including military academies, schools, domestic education, polite conversation and fashionable leisure. The English science textbook production was particularly rich in books addressed to readerships involved in home education and fashionable leisure. Since the 1830s, English publishers led the way in the making of cheap science books for popular audiences, in conjunction with the mechanics' institution movement. However, while the English textbook market was self-sufficient, and even a powerful exporter in this field, it lagged behind the production of countries such as France and Germany in science textbooks for formal education. As expressed by Joseph Lovering, and illustrated in the previous sections, the literatures and contexts of popularization and formal education had some common features, but were clearly distinct. British popular science books were often considered insufficient and unable to be adapted to the new educational context.

However, during the following decades, the English physics textbook market was expanded by the development of systematic teaching of natural philosophy for medical students and secondary school students. The major authors in this market were the medical doctors Neil Arnott and Golding Bird, and Dionysius Lardner, an active lecturer in the mechanics' institute movement and the first professor of natural philosophy at University College London. In spite of the medical orientation of Arnott's and Bird's books, the scarcity of textbooks in this subject made them relevant to all readers who wished to read an introduction to physics.[111]

Arnott's *Elements of physics, or natural philosophy, general and medical*, was published in 1827 by Longmans in association with the medical publishers George and Thomas Underwood. It had a fourth edition in 1838, was reprinted in 1864, and was translated into several languages. With his book, Arnott aimed to promote the use of physics among medical practitioners, and he argued for the importance of this subject in the map of knowledge, even above the traditional stress on mathematics.[112] Arnott's emphasis was emulated by Golding Bird, whose *Elements of natural philosophy* appeared in 1839 with the medical publisher John Churchill and had two more editions until 1851. Bird's textbook was addressed to students in medicine and chemistry, especially those engaged in the examinations run by the English and Scottish medical boards, and it was based on his lectures at Guy's Hospital. His textbook marked the development of physics teaching for medical students: while acknowledging his debt to Arnott's pioneering effort, Bird argued for the need of a textbook like his, adapted to the late 1830s educational context of English medical schools. He also declared that, in the writing of his book, he had been greatly helped by the availability of major physics textbooks in German and especially in French, including those by Biot, Pouillet, and Haüy.[113] During the second half of the century, this important tradition of fruitful interaction between science and medicine in the textbook marketplace was followed by the medical doctor Jabez Hogg and the science teacher George Rodwell — who in addition to his school teaching also lectured at Guy's Hospital.[114]

This interaction was also present in the establishment of University College London. It was in this context that the most important mid-nineteenth-century physics textbook addressed to schools was published by an English author: Dionysius Lardner. During his tenure of the professorship of natural philosophy and astronomy (1827–31), Lardner was actively engaged in all the scenes of science lecturing and writing in London and the provinces. In addition to his college duties he lectured at the Royal Institution and other London institutions and he toured the provincial mechanics' institutes. His science writing was closely associated to his lecturing and to the Society for the Diffusion of Useful Knowledge, for which he wrote several treatises on natural philosophical subjects, including applications to industry. After resigning from his London professorship due to disagreements with its organizing body, Lardner continued his activities as a full-time private entrepreneur in the educational market.[115] Since the late 1820s he had found a fruitful association in the publishing firm Longmans, as the editor of the *Cabinet cyclopaedia*, a collection of textbooks by major scientific authors, seizing the dynamic context of lecturing and publishing associated with the mechanics' institute movement.

Lardner contributed to the *Cyclopaedia* as the author of *Natural philosophy and astronomy* (1831). His textbook intended to provide an introduction to natural philosophy for those attending mechanics' institute lectures, but also to promote physical science among the liberal professions and those steeped in classical education — considering that familiarity with science was fundamental to the running of a modern society and to the success of England through industry and manufacture.[116] Lardner's book had numerous editions during the 1830s and between 1851 and 1853 it was reshaped as his *Handbook of natural philosophy and astronomy*, published in four volumes.

This textbook displayed the mixed features of the transition from the educational framework of the mechanics' institutes to that of systematic science teaching in schools. It was published by Taylor, Walton and Maberly, publishers to University College London, aiming to exploit the growth of science teaching associated with the London matriculation examination. Nonetheless, it addressed a comprehensive readership including "the Medical and Law student, the Engineer, and Artisan" which, in addition to "School education" and "University students", accounted for the mid-century expansion of the readerships of science in England. In 1857, Lardner produced an abridged version of his *Handbook* addressed "to supply the want felt by a large number of teachers in public and private schools of a Class Book for Junior Students".[117]

In producing his *Handbook*, Lardner was already an extremely experienced textbook writer. However, he was not directly involved in secondary school teaching and had not previously produced textbooks with these readerships in mind. For this reason, he resorted to the French experience on physics textbook production. Lardner had moved in 1840 to Paris, after a moral scandal which made him fall in disgrace in London society.[118] He was well aware of the French textbook production, and in Paris had continued his work as textbook writer for London publishers. His *Handbook* was in fact an unacknowledged free translation of Pouillet's *Notions* — a volume that had appeared in Paris the year before.[119] By this strategy, Lardner was able to produce a textbook, which was extremely successful in satisfying the needs of the emerging English secondary school market. It had three editions between 1851 and 1859, and new editions after Lardner's death, prepared by able editors linked to University College and science teaching.

Some volumes of the *Handbook* were edited by Thomas Olver Harding, towards the end of his stay as a science student at the University of London, and subsequently, as a science master at Marlborough College. In 1866 George Carey Foster edited a new edition of Lardner's volume on electricity, magnetism and acoustics, only one year after taking the professorship of experimental physics at University College London.[120] Subsequently, Foster acted as co-editor of the London Science Class-Books, a collection of science textbooks for the London examination published by Longmans. Lardner's editors found profitable their work as a way of supporting their teaching, of enhancing their scientific reputation, and as a financial complement to their salaries. But the lack of a unique editor with sufficient experience and scientific prestige, willing to concentrate for decades on the preparation of successive updated editions, prevented Lardner's successful book from winning the competition against new textbooks that appeared in the 1860s and 1870s. Nonetheless, Lardner's *Handbook* was still published in the late 1870s and its editions had considerably large print runs.[121] This was possible due to the interest and work of his publishers.

The growing interest of English publishers in the production and distribution of textbooks was clear in the controversy involving in the 1840s and 1850s the major London publishers against the British government's educational policies in Ireland. In Ireland the British government followed a model much more similar to that of France. A special commission in charge of the design and distribution of textbooks was established, and textbooks were produced at the government's expense. The firms of Longmans and John Murray led the publishers' protest against this state intervention, which deprived their business with an important market. As a result, the government committed to forbid the sale in England of the Irish official textbooks.[122]

Longmans had already shown its commercial intuition in seizing early the emergence of the physics textbook market. Between 1845 and 1846 they had published an English translation of Carl Friedrich Peschel's *Lehrbuch der physik*, only one year after its appearance in Germany. For some reviewers this was one of the most valuable advanced physics textbooks available then to the English reader. Another equally important work was the English translation of Johann Müller's *Grundriss der physik und meteorologie*, published in London by the Franco-British publisher Hippolyte Baillière.[123] Müller's book was in fact a shorter version for schools of the author's previous *Pouillet's lehrbuch der physik und meteorologie* (1842–44), based — as indicated by its title — on Pouillet's *Élémens de physique expérimentale et de météorologie*.[124]

But the most successful translation of French textbook physics in England was that of Ganot's *Traité élémentaire de physique expérimentale et appliquée* (1851). This translation was encouraged by Hippolyte Baillière, a French publisher which had a major role in appropriating French educational and scientific culture in Britain. Baillière was an entrepreneurial publisher in medicine and science belonging to arguably the most important international network in this type of trade operating in London during the nineteenth century.[125] In 1861, he commissioned Edmund Atkinson to do the translation of Ganot's *Traité élémentaire de physique expérimentale et appliquée*, which had already had nine editions in France and had been translated into several languages. Ganot's textbook became a successful commercial investment for Baillière in a few years, and — after his death — for Longmans who purchased the book for its publishing list.[126]

The need for translations was a sign of the lack of British textbook authors able to respond to the intense changes in the English educational market, creating a demand that English publishers were eager to satisfy with the supply of new books. Many of the physics books published in England during the first half of the century had successful publication histories, lasting beyond their authors' death and often continuing until the last decades of the century. However, as we have seen, contemporaries considered that these books were not adequate for the needs of the new type of education for the middle classes established during the second half of the century. The dependence of English physics students and teachers on foreign writers started to be overcome from the 1860s, and especially the 1870s. In this period, English secondary education had clearly emerged as a dynamic marketplace for the textbook, with different examination bodies including physics in their syllabi, stable networks of schools teaching it, and a larger number of experienced lecturers and teachers who considered textbooks central to their pedagogical practice and who were able to engage in their writing, and a wider range of publishing houses strongly involved in textbook production.

The two major authors leading the emergence of the English physics textbook in this period were John Tyndall and Balfour Stewart. In the 1860s Tyndall had accumulated experience as a surveyor, school teacher, journal writer, researcher, and lecturer. Since 1853, he had become one of the most influential personalities of the English scientific elite as professor of natural philosophy at the Royal Institution. In the same period he was offered membership of the Royal Society for his research work. At the Royal Institution Tyndall lectured to fashionable audiences[127] but, in addition, between 1859 and 1868, he was physics professor at the teacher training school of the Science and Art Department, and its examiner on physics subjects until 1876.

A large proportion of Tyndall's lectures at the Royal Institution were published by Longmans; they had a large number of editions and were translated into several languages including French. His *Heat considered as a mode of motion*, published in 1863, was among their most successful books, having eleven editions during the nineteenth century. Tyndall's publications combined his target of the English social elites at the Royal Institution, with his work in research, and his training of teachers from working and middle class backgrounds at the DSA. His published lectures on heat, sound, light and electricity were permanently recommended textbooks in the preparation of the Science and Art Department examinations. His scientific prestige and position at the DSA no doubt promoted the recommendation of his textbooks.

Balfour Stewart had briefly lectured on mechanics and mathematics at the University of Edinburgh, where he conducted research on heat, and he was the director of Kew Observatory (1859–71), before being appointed in 1870 professor of natural philosophy at Owens College. His first textbook dealt with the rapidly changing research field of heat. *An elementary treatise on heat* (1866) was published by the Clarendon Press in its "Series of School Books and Manuals", as part of the Oxford University concern for the increasing demand for science textbooks. This textbook had six editions during the century and was, like Tyndall's textbooks, recommended for the DSA examinations.

On his arrival at Owens College, Stewart articulated his pedagogical practice through the publication of his *Lessons in elementary physics* (1870), inaugurating Macmillan's series of "Science Primers". It ran through nine editions during the nineteenth century and was translated into several languages, including German. During the 1870s, Stewart was examiner in physics for the University of London examinations, which had in Owens College a close collaborator. In subsequent decades he published a textbook on practical physics for Macmillan and was one of the editors of their Science Primer series (together with Thomas Huxley and Henry Roscoe).[128] Macmillan was a major publishing firm rapidly emerging in the central decades of the century, whose success especially lay in its focus on the science textbook marketplace.[129]

As the examples of Tyndall and Longmans, and Stewart and Macmillan illustrate, connections with the science examinations established in England were a fundamental requirement for the commercial success of a textbook. From the 1870s, the consolidation of the DSA, London and Oxbridge examinations attracted thus the commercial and professional interest of a wide range of English authors and publishers of physics textbooks. Longmans exerted an important control on textbook publication for the preparation of the London Matriculation examination, through the successful translation in 1872 of Ganot's second textbook (the *Cours*), appropriated by Atkinson and his publisher in order to address the preparation of this examination. Furthermore, Longmans published a series of "London School Books" to which Frederick Guthrie — Tyndall's fellow lecturer at the DSA — contributed an important textbook on practical physics. On the other hand, Macmillan produced, in addition to Balfour Stewart's "Science Primers" a large number of "Class books for colleges and schools" especially aimed at the Cambridge Locals. For this purpose he recruited Cambridge lecturers and writers such as John Charles Snowball (fl. 1830–44) and subsequently Isaac Todhunter (1820–84).[130] Longmans and Macmillan dominated the secondary school textbook market, but the market was larger and often involved joint publication with several publishers.

The success of emerging English secondary education and physics textbook production is clearly illustrated by the professional and social success of John Charles Buckmaster and Richard Wormell: two examples of teachers and textbook authors born in working-class environments who, trained in the schemes of the DSA and the London University, respectively, contributed to the science movement while gaining professional careers and middle-class status.

Buckmaster, a carpenter and joiner active in the Anti-Corn League, was one of the first students to come out of the Science and Art Department, in 1859, with a science teacher certificate. In 1863, he published with Longmans a leaflet presenting and publicizing the work of the DSA. A year later Buckmaster published his *Elements of experimental physics* with the same publisher, addressing students and teachers preparing for the DSA examinations. In his *Physics*, he stressed that he followed Tyndall's syllabus, but also that he had used the works of Ganot, Müller and Faraday to prepare his textbook.[131] In this period, he was in charge of evening classes at the Royal Polytechnic institution and was examiner to the College of Preceptors.[132] The former was since the late 1830s a major centre for science lecturing and instrument making display. As an institution serving multiple purposes it combined a focus on informal education with entertainment and a close interaction with the emerging context of formal education.[133] The College of Preceptors had been founded in

1846 with the intention of standardizing teaching in schools through a scheme of teacher training. Although these types of initiative were partially unsuccessful until the establishment of the DSA, the College was an important centre of pedagogical training until the end of the century, and it influenced a certain number of schools associated with it.[134] Buckmaster's work as a textbook author was clearly aimed at reproducing the DSA pedagogical and scientific rationale in the institutions in which he was involved as a teacher. His work was subsequently rewarded by the DSA by awarding him with a lectureship.[135]

Wormell's work shared many features with that of Buckmaster, but he was educated at the University of London. He was a mason and bricklayer, before becoming an elementary teacher and developing an interest in mathematics. While teaching at Westminster he was awarded an external London B.A., and later he earned a London M.A and D.Sc. In 1866, he was appointed headmaster of the new Central Foundation School, which subsequently served as a base for the establishment of the City and Guilds Finsbury Technical College — the first institution in England explicitly designed to impart formal education in applied science. Wormell was responsible for the creation of workshops in the school and the supply of scientific apparatus and machines from private donations. Furthermore, he published with different publishers around twenty textbooks on mathematics and physical sciences among which *An elementary course of hydrostatics and sound* (1870) and *A course of natural philosophy* (1871). Both were published in new series devoted to science textbooks for use in secondary education, inaugurated by London publishers such as Groombridge & Sons. Although these publishers did not have the commercial power of Longmans and Macmillan, they clearly saw the benefits of the emergence of the secondary school textbook market, and contributed to its development. Some of Wormell's textbooks addressed candidates to the London Matriculation examination; others combined different targets such as the DSA examinations and those of the College of Preceptors.

CONCLUSIONS

The emergence of the physics textbook in France and England was linked to the expansion of the readerships of science through the development of secondary education. The central decades of the century were the crucial moment for the introduction of systematic physics teaching in secondary schools in both countries, and medical studies were the major ally in this development. The writing of physics textbooks was promoted by state, commercial, pedagogical and scientific forces. While the state was the major agent in France since the foundation of its secondary education system, private initiative was also important. In this context, private teachers and entrepreneurial publishers contributed to shape the French physics textbook market. Through their initiatives, French physics textbooks were exported to England. By mid-century, France had a competitive market of physics teaching and textbook production based on the pedagogical experience accumulated by its teachers and authors. Accordingly, French textbook production proved useful for the development of physics teaching in English schools. Thus the English market depended on the French textbook production during its first decades of development. Subsequently, the development of science teaching in English schools and the experience accumulated by English science teachers made possible the growth of a genuine English production. But the early appropriation of French textbooks through translation found a place in the British market which had an enduring effect on British education and textbook physics writing.

While the French science textbook market was structured by the strength of a unique examination sanctioning secondary education and giving access to scientific, medical and engineering careers, the development of science education in England displayed greater diversity. Like in France, it was shaped by the strategies of science practitioners to establish their disciplines, but it was articulated through three major examination schemes. The analogies and differences between the DSA and the École normale are significant in this context. Both of them intended to expand the practice of science by training teachers and producing textbooks, and they were established by governments. Both promoted a strong competition and *esprit de corps* among their members.

However, the DSA was more open to a competition independent of educational and social hierarchies and was based upon commercial success. In this context, the work of publishers was even more relevant because of their major role in the recruitment of authors, commissioning of translations and original works, and creation of school science series. While the major French authors of physics textbooks had profiles defined by their belonging to the *normalien* collective, English authors had a more diverse background, related to the different institutions teaching science and their associated examinations, and ranging between medicine, chemistry, mathematics and applied science. Nonetheless, the important intervention of the French state in educational matters was softened by mid-century, leaving room for significant exceptions, such as the textbook enterprises of private teachers like Adolphe Ganot which were extremely successful in France and abroad.

The emergence of textbook physics was due both in France and England to the establishment of a demand: the expansion of the readerships of physics caused by the development of national structures of education; and the establishment of an offer: the configuration of a pool of teachers, writers and publishers with the skill and experience necessary to produce books fit to occupy a central place in teaching and learning. The marketplace for physics textbooks was configured by forces driving the exchange of pedagogical knowledge, scientific, professional and social prestige, and money. The production of physics textbooks thus came to define the professional careers of educationists, teachers, scientists and publishers. Through their major role in the establishment of physics as a school discipline, textbooks were also determinant in the shaping of physics as a distinct scientific discipline.

ACKNOWLEDGEMENTS

I would like to thank Jon Topham for fruitful discussions on the nature of nineteenth-century British science book production. The preparation of this paper was possible thanks to a Marie Curie Postdoctoral contract.

REFERENCES

1. J. Demogeot, and H. Montucci, *De l'enseignement secondaire en Angleterre et en Écosse: Rapport adressé a son Exc. le Ministre de l'Instruction Publique* (Paris, 1868), 1.
2. Anon., "Ganot's physics", *The Leeds mercury* 20 October 1875.
3. See for instance, Anon., "Review of *Report on the system of education for the middle and upper classes in France, Italy, Germany and Switzerland* by M. Arnold and *Rapport sur l'enseignement secondaire en Angleterre et en Écosse* by Demogeot and Montucci", *The quarterly review*, cxxv (1868), 473–90; J. M. Wilson, *Elementary geometry. Books I. II. III.* (London and Cambridge, 1869), p. ix.
4. This state of affairs is also connected to the comparatively low status of 'education' in current British history of science, in contrast to the wealth of studies on science popularization (which often avoid confronting the role of formal education in nineteenth-century British science and its fruitful interactions with popularization). See B. Belhoste, "Les caractères généraux de l'enseignement secondaire scientifique de la fin de l'Ancien Régime à la Première Guerre Mondiale", *Histoire de l'éducation*, lvi (1989), 3–45; B. Belhoste, C. Balpe and T. Laporte, *Les sciences dans l'enseignement secondaire français: Textes officiels* (Paris, 1995); W. H. Brock, "Science education", in R. Olby, G. N. Cantor, J. R. R. Christie and M. J. S. Hodge (eds), *Companion to the history of modern science* (London, 1990), 946–59; A. Fyfe and B. Lightman, *Science in the marketplace: Nineteenth-century sites and experiences* (Chicago, 2007); J. Secord, "Science", in L. Howsam, C. Stray, A. Jenkins, J. A. Secord and A. Vaninskaya (eds), "What the Victorians learned: Perspectives on nineteenth-century schoolbooks", *Journal of Victorian culture*, xxii (2007), 272–6.
5. On the pros and cons of Demogeot and Montucci's report, see R. D. Anderson, "French views of the English public schools: Some nineteenth-century episodes", *History of education*, ii (1973), 159–71.
6. G. W. Frederick (Earl of Clarendon) *et al.*, *Report of Her Majesty's commissioners appointed to inquire into the revenues and management of certain colleges and schools, and the studies pursued and instruction given therein; with an appendix and evidence. Vol. I. Report* (London, 1864).
7. A. Choppin, *Les manuels scolaires: Histoire et actualité* (Paris, 1992), 6–18; C. Stray, "Paradigms regained: Towards a historical sociology of the textbook", *Journal of curriculum studies*, xxvi (1994), 1–29, pp. 1–4; E. B. Johnsen, *Textbooks in the kaleidoscope: A critical survey of literature and research on educational texts* (Tønsberg, 2001), ch. 1; B. Bensaude-Vincent, A. García Belmar and J. R. Bertomeu Sánchez, *L'émergence d'une science des manuels: Les livres de chimie en France (1789–1852)* (Paris, 2003), 1–11.
8. A. T. Grafton, "Textbooks and the disciplines", in E. Campi, S. De Angelis, A. S. Goeing and A. T. Grafton (eds), *Scholarly knowledge: Textbooks in early modern Europe* (Geneva, 2008), 11–36; Stray, "Paradigms regained" (ref. 7); J. Issitt, "Reflections on the study of textbooks", *History of education*, xxxiii (2004), 683–96; B. Bensaude-Vincent, "Textbooks on the map of science studies", *Science & education*, xv (2006), 667–70.
9. This term was commonly used to refer to textbooks for primary education, while 'livres classiques' referred to secondary school textbooks. In practice, these terms were often combined and the adjective 'élémentaire' was part of many titles of secondary school textbooks. F. Buisson, "Livres scolaires, 1º Les livres élémentaires de la Première République, IV", in *Nouveau dictionnaire de pédagogie et d'instruction primaire* (Paris, 1911).
10. Bensaude-Vincent, García Belmar and Bertomeu, *L'émérgence* (ref. 7), 56–59.
11. There is a huge amount of literature on the organization of nineteenth-century French education which I have used to produce the following narrative. I recommend especially R. D. Anderson, *Education in France, 1848–1870* (Oxford, 1975); Belhoste, Balpe and Laporte, *Les sciences dans*

l'enseignement (ref. 4); R. Fox and G. Weisz (eds), *The organization of science and technology in France, 1808–1914* (Cambridge, 1980); N. Hulin, *L'enseignement secondaire scientifique en France d'un siècle à l'autre, 1802–1980* (Lyon, 2007); C. S. Zwerling, *The emergence of the Ecole Normale Supérieure as a center of scientific education in nineteenth-century France* (New York and London, 1990); Bensaude-Vincent, García Belmar and Bertomeu Sánchez, *L'émergence* (ref. 7). For a more complete bibliography see J. Simon, *Communicating physics: The production, circulation and appropriation of Ganot's textbooks in France and England, 1851–1887* (London, 2011).

12. P. Mainardi, *Art and politics of the Second Empire: The universal expositions of 1855 and 1867* (New Haven, 1987).
13. This law was a tool designed by conservative governments to encourage the Catholic Church to regain control over education. Eventually, it also favoured private entrepreneurs like Adolphe Ganot. A. Prost, *Histoire de l'enseignement en France, 1800–1967* (Paris, 1968), 172–7.
14. Bensaude-Vincent, García Belmar and Bertomeu, *L'émérgence* (ref. 7), 47–82.
15. See for instance C. Kounelis, "Atomism in France: Chemical textbooks and dictionaries, 1810–1835", in A. Lundgren and B. Bensaude-Vincent (eds), *Communicating chemistry: Textbooks and their audiences, 1789–1939* (Canton, Mass., 2000), 207–32.
16. Belhoste, Balpe and Laporte (eds), *Les sciences dans l'enseignement* (ref. 4), 388–407.
17. C. Fournier-Balpe, "Histoire de l'enseignement de la physique dans l'enseignement secondaire en France au XIXe siècle" (PhD thesis dissertation, Université Paris XI, 1994), 167–9; Bensaude-Vincent, García Belmar and Bertomeu, *L'émérgence* (ref. 7), 88–91, 96–99.
18. Among these were the École polytechnique (first step in engineering education), the École d'artillerie et du génie in Metz (artillery officers and military engineers), the École des ponts et chaussées (civil engineers), the École vétérinaire (veterinary surgeons), and the École normale supérieure (school teachers).
19. A. Haüy, *Traité élémentaire de physique* (Paris, 1806); N. Hulin, "René-Just Haüy: Des leçons de l'an III au Traité élémentaire de physique", *Revue d'histoire des sciences*, l (1997), 243–63.
20. J.-B. Biot, *Traité de physique expérimentale et mathématique* (Paris, 1816); J.-B. Biot, *Précis élémentaire de physique expérimentale* (Paris, 1817).
21. At the beginning of the century there were faculties of sciences, medicine or pharmacy only in Paris, Besançon, Caen, Dijon, Lyon, Montpellier (medicine and pharmacy), Toulouse, Strasbourg (medicine and pharmacy) and Grenoble. In the following decades new faculties of sciences were created in Aix, Bordeaux, Clermont, Douai, Montpellier, Nancy, Poitiers, Rennes and Strasbourg, constituting a national network of sixteen faculties of sciences. Belhoste, Balpe and Laporte (eds), *Les sciences dans l'enseignement* (ref. 4), 66–67, 77–78; Fox and Weisz, *The organization of science* (ref. 11), 1–7.
22. Belhoste, Balpe and Laporte (eds), *Les sciences dans l'enseignement* (ref. 4), 77–78, 113–15, 121, 127, 129.
23. C. Balpe, "L'enseignement des sciences physiques: Naissance d'un corps professoral (fin XVIIIe – fin XIXe siècle)", *Histoire de l'éducation*, lxxiii (1997), 49–85, p. 68.
24. In 1842 the salary of a provincial teacher ranged between 1,200 to 2,000 francs. In 1865 the salary in a Parisian *lycée* was 2,500 francs and the lowest salary in the province was 1,200 francs. Balpe "L'enseignement des sciences physiques" (ref. 23), 70. See also Prost, *Histoire de l'enseignement* (ref. 13).
25. Zwerling, *The emergence of the Ecole Normale* (ref. 11), 91, 170, 194, 198.
26. In fact, early in the century, several provincial faculties had to close due to the lack of students. Subsequently, they were reopened. Fox and Weisz, *The organization of science* (ref. 11), n. 3, p. 2.
27. The *baccalauréat ès-lettres* was not compulsory to enter the École polytechnique but highly

recommended. G. Weisz, *The emergence of modern universities in France, 1863–1914* (Princeton, 1983), 27–28.

28. Day school fees were cheap, but boarding school fees were considerable (although still lower than the English ones) costing between a half and a third of the annual salary of a secondary school teacher, and around the annual salary of a primary school teacher. Prost, *Histoire de l'enseignement* (ref. 13).
29. In 1820, 50,000 students received secondary education; in 1887, the number had increased to 150,000, while the number of primary school students was five and a half million. Thus, only 3% of the primary school students subsequently attended secondary education. A. Green, *Education and state formation: The rise of education systems in England, France and the USA* (Basingstoke and London, 1990), 17–18; Fournier-Balpe, *Histoire de l'enseignement de la physique* (ref. 17), n. 3, p. 86.
30. *Ibid.*, 18.
31. In 1812, only 24 *bachelier ès-sciences* against 1632 *bachelier ès-lettres* diplomas were awarded. Belhoste, Balpe and Laporte (eds), *Les sciences dans l'enseignement* (ref. 4), n. 1, p. 82.
32. Balpe "L'enseignement des sciences physiques" (ref. 23).
33. The measure was suspended in 1831 (due in part to students protests), but was restored in 1837. Medicine and engineering were at the time the major job profiles available for science students. J.-C. Caron, *Générations romantiques, les étudiants de Paris et le Quartier latin, 1814–1851* (Paris, 1991), 29; Belhoste, Balpe and Laporte (eds), *Les sciences dans l'enseignement* (ref. 4), 139.
34. Balpe, "L'enseignement des sciences physiques" (ref. 23), n.1, p. 70.
35. In 1842, the number of candidates attending the *baccalauréat ès-sciences* was still one sixth of that of the *baccalauréat ès-lettres*. It had however multiplied by ten its relative rate of attendance, as in 1812 the former was sixty-eight times lower than the latter. In the 1850s and early 1860s, both examinations had approximately the same number of candidates, of around 4000 candidates each. P. Gerbod, *La condition universitaire en France au XIXe siècle: Etude d'un groupe socio-professionnel. Professeurs et administrateurs de l'enseignement secondaire public de 1842 à 1880* (Paris, 1965), 357, 384.
36. Fournier-Balpe, *Histoire de l'enseignement de la physique* (ref. 17), 88.
37. See Anderson, *Education in France* (ref. 11), 61–72.
38. Zwerling, *The emergence of the Ecole Normale* (ref. 11), 219–28.
39. J. B. Dumas, "Rapport sur l'état actuel de l'enseignement scientifique dans les collèges, les écoles intermédiaires et les écoles primaires, adressé à M. le ministre de l'Instruction publique, grand-maître de l'Université de France, par la faculté des sciences de Paris (extraits)", in Belhoste, Balpe and Laporte (eds), *Les sciences dans l'enseignement* (ref. 4), 207–23.
40. G. Gooday, "Lies, damned lies and declinism: Lyon Playfair, the Paris 1867 exhibition and the contested rhetorics of scientific education and industrial performance", in I. Inkster, C. Griffin, J. Hill and J. Rowbotham (eds), *The Golden Age: Essays in British social and economical history, 1850–1870* (Aldershot, 2000), 105–20.
41. Belhoste, Balpe and Laporte (eds), *Les sciences dans l'enseignement* (ref. 4), 413–42; T. Charmasson, A.-M. Lelorrain and Y. Ripa (eds), *L'enseignement technique de la Révolution à nos jours: Textes officiels avec introduction, notes et annexes* (Paris, 1987), 21–55.
42. Hulin, "René-Just Haüy" (ref. 19).
43. V. Karady, "Educational qualifications and university careers in science in 19th-century France", in Fox and Weisz (eds), *The organization of science* (ref. 11), 95–126, pp. 96, 105, 124.
44. Zwerling, *The emergence of the Ecole Normale* (ref. 11), 111, 245, 295–300.
45. R. Vallery-Radot, *The life of Pasteur* (Garden City and New York, 1928), 10.
46. Balpe, "L'enseignement des sciences physiques" (ref. 23), 62, 70; A. Chervel, "Lauréats des concours

d'agrégation de 1821 à 1900", *INRP* (http://www.inrp.fr/she/chervel_laureats1.htm).

47. *Ibid.,* 77–80.
48. N. Hulin-Jung, "L'enseignement scientifique sous le Second Empire: la 'bifurcation'; la formation des professeurs de l'enseignement secondaire" (PhD thesis dissertation, E.H.E.S.S, 1986), 301.
49. Despretz is an atypical case, and for this reason, I will not treat in detail here his contribution. His physics textbook had six editions between 1825 and 1840. His research broadly interacted with physics, chemistry and medicine and he worked at a Parisian *lycée*, the faculty of sciences, and the École polytechnique. See F. Hoefer, *Nouvelle biographie générale* (Paris, 1852–66); G. Vapereau, *Dictionnaire universel des contemporains* (Paris, 1893).
50. J. M. Edmondson, *From mécanicien to ingénieur: Technical education and the machine building industry in nineteenth-century France* (New York, 1987).
51. E. Péclet, *Cours de physique* (Marseille, 1823–25).
52. E. Péclet, *Traité élémentaire de physique* (Paris, 1830).
53. Balpe, "L'enseignement des sciences physiques" (ref. 23), 70.
54. On Hachette, see J. Y. Mollier, *Louis Hachette (1800–1864): Le fondateur d'un empire* (Paris, 1999); and *L'argent et les lettres: Histoire du capitalisme d'edition, 1880–1920* (Paris, 1988).
55. E. Péclet, *Traité de l'éclairage* (Paris, 1827); and *Traité de la chaleur et de ses applications aux arts et aux manufactures* (Paris, 1828).
56. E. Péclet, *École centrale des manufactures. Cours de physique appliquée. Professeur: M. Péclet. Lithographies distribuées aux élèves pour leur instruction: Année scolaire 1833–1834 [1836–1837]* (Paris, n.d.).
57. For examples of these practices see B. Bensaude-Vincent, "From teaching to writing: Lecture notes and textbooks at the French *École Polytechnique*", in Lundgren and Bensaude-Vincent (eds), *Communicating chemistry* (ref. 15), 273–94; A. Garcia-Belmar, "The didactic uses of experiment: Louis Jacques Thenard's lectures at the Collège de France", in J. R. Bertomeu and A. Nieto-Galan (eds), *Science, medicine and crime: Mateu Orfila (1787–1853) and his times* (Canton, 2006), 25–53.
58. L. C. Dezobry, *Dictionnaire général de biographie et d'histoire* (Paris, 1869).
59. Péclet's *Traité de la chaleur* had two new editions after the 1850s, probably reprints. His other textbooks did not have further editions. É. Fourquet, *Les hommes célèbres et les personalités marquantes de Franche-Comté: Du IVe siècle à nos jours* (Besançon, 1929).
60. Pouillet, *Élémens de physique expérimentale et de météorologie* (Paris, 1827).
61. F. Buisson, "Grosselin", in Buisson, *Nouveau dictionnaire* (ref. 9).
62. Jean-Pierre Brès, "Review of *Vocabulaire sténographique* by A. Grosselin", *Revue Encyclopédique*, xxiii (1824), 442–4; D. Gardey, "Mechanizing writing and photographing the word: Utopias, office work and histories of gender and technology", *History and technology*, xvii (2001), 319–52.
63. Anon., "Nouvelles politiques", *L'ami de la religion et du roi, journal ecclésiastique, politique et littéraire*, 1467 (1828), 91–93, p. 92.
64. F. Khantine-Langlois, "Les multiples manuels: Une source pour retrouver la description et l'usage des appareils anciens", in F. Gires (ed.), *Cabinet de physique du lycée Guez de Balzac d'Angoulême* (n.p., 2006), 19–23, p. 19.
65. C.-M.-S. Pouillet, *Notions générales de physique et de météorologie à l'usage de la jeunesse* (Paris, 1850).
66. See Simon, *Communicating physics* (ref. 11), 58–76.
67. C. Drion, and É. Fernet, *Traité de physique élémentaire* (Paris, 1861).
68. O. Lorenz, and D. Jordell, *Catalogue général de la librairie française: Continuation de l'ouvrage d'Otto Lorenz* (Paris, 1908–9). I. Havelange, F. Huguet and B. Lebedeff, *Les inspecteurs généraux de l'Instruction publique: Dictionnaire biographique 1802–1914* (Paris, 1986).

69. A. Privat Deschanel, *Traité élémentaire de physique* (Paris, 1868); A. Dantès, *Dictionnaire biographique et bibliographique* (Paris, 1875); O. Lorenz, *Catalogue général de la librairie française depuis 1840* (Paris, 1877); Vapereau, *Dictionnaire universel* (ref. 49).
70. A. Boutan, and J. C. d'Almeida, *Cours élémentaire de physique, suivi de problèmes* (Paris, 1861).
71. On Almeida see D. Mitchell, "Gabriel Lippmann and late-nineteenth century French macrophysics" (D.Phil. thesis dissertation, University of Oxford, 2010), ch. 1.
72. Zwerling, *The emergence of the Ecole Normale* (ref. 11), 125, 160–1.
73. This status was preserved until the late nineteenth century. M. J. Nye, "The scientific periphery in France: The faculty of science at Toulouse (1880–1930)", *Minerva*, xiii (1975), 374–403.
74. Daguin's treatise was published by Edouard Privat in Toulouse, in association with Dézobry & E. Magdeleine in Paris. From the 1840s Deguin's book was exclusively published by Bélin-Mandar in Paris. Pinaud's textbook was published by Privat et Bon in Toulouse in association with Hachette in Paris. P.-A. Daguin, *Traité élémentaire de physique théorique et expérimentale avec les applications à la météorologie et aux arts industriels* (Toulouse, 1860–61); Deguin, *Cours élémentaire de physique* (Toulouse, 1839); A. Pinaud, *Programme d'un cours élémentaire de physique* (Toulouse, 1839).
75. J. Mistler, *La Librairie Hachette de 1826 à nos jours* (Paris, 1964), 15–29.
76. Mollier, *L'argent et les lettres* (ref. 54), 172–97.
77. O. Martin and H. J. Martin, "Le monde des éditeurs", in H. J. Martin (ed.), *Histoire de l'édition française*, iii (Paris, 1985), 159–215, pp. 184–96.
78. B. O. Peirce, "Biographical memoir of Joseph Lovering, 1813–1892", in (ed.), *National Academy of Sciences: Biographical memoirs, part of volume VI* (Washington, 1909), 329–44.
79. By authors such as Pouillet, Péclet, Lamé and Despretz.
80. [J. Lovering], "Elementary works on physical science", *The North American review*, lxxii (1851), 358–95.
81. J. Topham, "Publishing 'popular science' in early nineteenth-century Britain", in Fyfe and Lightman (eds), *Science in the marketplace* (ref. 4), 135–68, p. 135.
82. Frederick *et al.*, *Report of Her Majesty's commissioners* (ref. 5), 392
83. Anon., "Christmas books and annuals: Ganot's elementary treatise on physics", *The Leeds mercury*, 7 December 1871, 6.
84. As the publication dates and prefaces of their books testify. See E. Atkinson, "Preface to the first edition", in A. Ganot (ed.), *Elementary treatise on physics experimental and applied* (London, 1863); A. Privat Deschanel, *Elementary treatise on natural philosophy* (London, Glasgow and Edinburgh, 1870–72).
85. Oxford and Cambridge had science teaching but in general not counting for their degrees and thus being highly voluntarist.
86. Green, *Education and state formation* (ref. 29), 19.
87. J. Roach, *A history of secondary education in England, 1800–1870* (London and New York, 1986), 55–59, 20, 25–26; R. D. Anderson, *Universities and elites in Britain since 1800* (Cambridge, 1995), 44.
88. Anderson, *Universities and elites* (ref. 87), 6
89. Unfortunately, it is difficult to say more, for, in general, historians of physics have ignored the relevance of medical education for physics, and historians of medicine have kept silent about physics teaching in the English medical schools. An exception is A. L. Mansell, "Examinations and medical education: The preliminary sciences in the examinations of London University and the English Conjoint Board, 1861–1911", in R. McLeod (ed.), *Days of judgement: Science examinations and the organization of knowledge in late Victorian England* (Driffield, 1982), 87–107.
90. Anderson, *Universities and elites* (ref. 87), 5.

91. *Ibid.,* 48–49.
92. *Ibid.,* 7.
93. *Ibid.,* 5; W. Dodds, *A Complete guide to matriculation at the University of London* (Manchester, London [ca. 1869]), 3.
94. C. M. Heward, "Education, examinations and the artisans: The Department of Science and Art in Birmingham, 1853–1902", in McLeod (ed.), *Days of judgement* (ref. 89), 45–64, p. 54.
95. Dodds, *A complete guide* (ref. 93), 4–5.
96. Anderson, *Universities and elites* (ref. 87), 7–8; M. Vaughan and M. S. Archer, *Social conflict and educational change in England and France, 1789–1848* (Cambridge, 1971), 45–59.
97. Roach, *A history of secondary education* (ref. 87), 5.
98. Partial exceptions are M. E. Bryant, *The London experience of secondary education* (London, 1986); Roach, *A history of secondary education* (ref. 87), and *Secondary education in England, 1870–1902* (London, 1991).
99. Queenwood College has received particular attention in connection with John Tyndall and Edward Frankland in this school. However, it is still an isolated case in a panoramic view which has not been built yet. Roach, *A history of secondary education* (ref. 87), 130–2; W. H. Brock, "Queenwood College revisited", in *Science for all: Studies in the history of Victorian science and education* (Ashgate, 1996), 1–23; D. Thompson, "Queenwood College, Hampshire", *Annals of science*, xi (1955), 246–54.
100. J. Laurent, "Science, society and politics in late nineteenth-century England: A further look at Mechanics' Institutes", *Social studies of science*, xiv (1984), 585–619; S. Shapin and B. Barnes, "Science, nature, control: Interpreting Mechanics' Institutes", *Social studies of science*, vii (1977), 31–74.
101. Anderson, *Universities and elites* (ref. 87), 5–6; Roach, *A history of secondary education* (ref. 87), 112–14, 120–32, 175–9.
102. T. D. Acland, *New Oxford examinations for the title of Associate in Arts and certificates for the year 1858* (London, Oxford and Cambridge, 1858), pp. xxiii–xxiv; W. H. Brock, "School science examinations: Sacrifice or stimulus?" in McLeod (ed.), *Days of judgement* (ref. 89), 169–88, pp. 170–3.
103. J. Morrell and A. Thackray, *Gentlemen of science: Early years of the British Association for the Advancement of Science* (Oxford, 1981), 23–28, 386–96; R. Fox, "The context and practices of Oxford Physics, 1839–77", in R. Fox and G. Gooday (eds), *Physics in Oxford, 1839–1939: Laboratories, learning and college life* (Oxford, 2005), 24–79, pp. 31–32.
104. D. P. Newton, "A French influence on nineteenth- and twentieth-century physics teaching in English secondary schools", *History of education*, xii (1983), 191–201, p. 193.
105. H. Butterworth, "The Science and Art Department examinations: Origins and achievements", in McLeod (ed.), *Days of judgement* (ref. 89), 27–44; Heward, "Education, examinations and the artisans: The Department of Science and Art in Birmingham, 1853–1902", in *ibid.* (ref. 89), 45–64; G. Gooday, "Precision measurement and the genesis of physics laboratories in Victorian Britain" (PhD thesis dissertation, University of Kent, 1989), 50–54; Science and Art Department, *Directory (revised March 1861) with regulations for establishing and conducting science schools and classes* (London, 1861), 42–47, and *Directory (revised September 1863) with regulations for establishing and conducting science schools and classes* (London, 1863), 49–51.
106. Roach, *A history of secondary education* (ref. 87), 95–97, 110; Gooday, "Lies, damned lies" (ref. 40).
107. See ref. 105.
108. Gooday, "Precision measurement" (ref. 105), ch. 8.
109. Science and Art Department, *Directory (revised March 1861)* (ref. 105), 42–47, and *Directory (revised September 1863)* (ref. 105), 61–69.

110. A. Haüy, *An elementary treatise on natural philosophy* (London, 1807).
111. [Lovering], "Elementary works on physical science" (ref. 80).
112. N. Arnott, *Elements of physics, or natural philosophy, general and medical: Explained independently of technical mathematics* (London, 1827), Introduction.
113. G. Bird, *Elements of natural philosophy; being an experimental introduction to the study of the physical sciences* (London, 1839), Preface.
114. J. Hogg, *Elements of experimental and natural philosophy* (London, 1853); G. F. Rodwell, *Notes of a course of nineteen lectures on natural philosophy delivered at Guy's hospital during the session 1872–73* (London, 1873).
115. J. N. Hays, "Lardner, Dionysius (1793—1859)", in *Oxford dictionary of national biography* (Oxford, 2004).
116. J. N. Hays, "The rise and fall of Dionysius Lardner", *Annals of science*, xxxviii (1981), 527–42.
117. D. Lardner, *Natural philosophy for schools* (London, 1857), p. v.
118. See ref. 116.
119. A review of Lardner's textbook referred to the connection with Pouillet's "Elémens de physique", but a closer examination shows that he followed instead Pouillet's *Notions*. Anon., "Review of *Handbook of natural philosophy* by Dionysius Lardner", *Nature*, x (1874), 102; D. Lardner, *Hand-book of natural philosophy and astronomy* (London, 1851–53).
120. G. J. N. Gooday and C. A. Hempstead, "Foster, George Carey (1835—1919)", *Oxford dictionary of national biography* (Oxford, 2004).
121. According to the title pages of the book, print runs were of the order of 7,000 copies.
122. J. Feather, *A history of British publishing* (London, 1988), 144, 165; A. Weedon, *Victorian publishing: The economics of book production for a mass market, 1836–1916* (Aldershot, 2003), 125.
123. [Lovering], "Elementary works on physical science" (ref. 80).
124. G. Lind, *Physik im Lehrbuch, 1700–1850: Zur Geschichte der Physik und ihrer Didaktik in Deutschland* (Berlin, 1992), 235, 381.
125. J. Simon, "The Baillières: The Franco-British book trade and the transit of knowledge", in R. Fox and B. Joly (eds), *Franco-British interactions in science since the seventeenth century* (London, 2010), 243–62.
126. See Simon, *Communicating physics* (ref. 11).
127. J. Howard, "'Physics and fashion': John Tyndall and his audiences in mid-Victorian Britain", *Studies in the history and philosophy of science*, xxxv (2004), 729–58, pp. 732–3.
128. P. J. Hartog and G. J. N. Gooday, "Stewart, Balfour (1828–1887)", in *Oxford dictionary of national biography* (Oxford, 2004).
129. R. T. Van Arsdel, "Macmillan family (per. c.1840–1986)", in *ibid.*
130. Snowball's textbooks were purchased by Macmillan after his death. F. Boase, *Modern English biography* (Truro, 1892–1921).
131. J. C. Buckmaster, *The elements of experimental physics: Acoustics, light and heat, magnetism and electricity* (London, 1864), Preface.
132. See J. C. Buckmaster, *The elements of magnetism and electricity* (London, 1875); J. C. Buckmaster, *The elements of sound, light and heat* (London, 1879).
133. See J. H. Pepper, *Cyclopaedia of science simplified* (London, 1869); B. Lightman, "Lecturing in the spatial economy of science", in Fyfe and Lightman (eds), *Science in the marketplace* (ref. 4), 97–132.
134. Bryant, *The London experience* (ref. 98), 161–3.
135. J. F. Kirk, *A supplement to Allibone's Critical dictionary of English literature and English and American authors* (Philadelphia and London, 1891).