Spaces and Collections in the History of Science

The Laboratorio Chimico Overture

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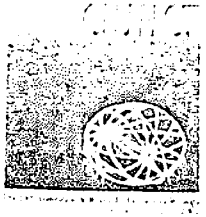
Museum of Science of the University of Lisbon

2009

Published by
the Museum of Science of the University of Lisbon

Volume organized with the support of:



Sponsors:

Sociedade Portuguesa de Química

FCT
Fundação para a Ciência e a Tecnologia

Design: Maria Helena Veloso
Printed by: Ciência Gráfica, Lisbon
Cover photos: P. Cintra (Museum of Science Archives)

For Fernando Bragança Gil (1927 - 2009)

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The making of Spanish secondary schools

The idea of national 'secondary education' was developed and implemented in Europe and the Americas during the nineteenth century. Although it followed different paths, it was led by different forces, and it offered a diversity of organisational structures in different countries, the creation of secondary school systems was a general phenomenon in this period.[2] In Spain, the first modern secondary schools were created during the 1830s and 1840s. The most important development took place around 1845, through the intervention of the state, after a reform promoted by Pedro Pidal, *Ministro de Gobernación* (Home Secretary), and his officer Antonio Gil de Zárate. New legislation established the creation of a national secondary school network aiming at providing general education for the middle classes, who were considered to be those leading the country and thus having an extensive effect on the improvement of the whole society. In addition, general education was expected to provide an efficient preparation for higher education in the faculties of medicine, law, pharmacy and theology. The so-called Pidal's plan promoted the establishment of secondary schools in almost every provincial capital, and in a certain number of other towns that were able to meet the required budget and arrangements for the provision of premises and teaching staff.[3]

By the middle of the nineteenth-century, 52 *institutos* (secondary schools) had been created: eleven were associated with universities (Madrid, Barcelona, Granada, Oviedo, Salamanca, Santiago, Seville, Valencia, Valladolid and Zaragoza), from which teachers, classrooms and scientific collections were often initially borrowed. However,

most of the schools were managed by provincial administrations targeting the sons of the provincial middle classes.[4] They were established in buildings confiscated from religious orders by the liberal government, in old schools (sometimes previously administered by the expelled Jesuit order), or in the buildings of former universities. The economic basis of the new institutions was complex: the main resources were registration fees and irregular funding provided by the municipal, provincial or national authorities. Many schools also enjoyed income from lands or buildings confiscated from the Church.[5] In addition to these new institutions, there were many private schools, commonly religious. These competed for the increasing number of middle-class students, and occasionally even succeeded in defying the legislation and substituting new secondary schools, becoming the only establishment of this kind in certain areas.[6]

The number of students enrolled in secondary education differed depending on the school. By the middle of the nineteenth century, most of the provincial secondary schools had enrolments of 90 to 120 students, although some centres (Palencia, Caceres and Murcia) had 150 and even 200 students (Huesca, Orense and Burgos). Other centres (Albacete, Badajoz, La Laguna, Ciudad Real) had lower enrolments (between 40 and 60 or even less), in some cases due to the proximity of a university or an influential religious school. By then, the total number of students who attended secondary schools was between 11,000 and 12,000, increasing very slowly to 18,000 by the end of the nineteenth century. This number remained stable until the early 1930s, when the educational reforms introduced by the Second Republic dramatically increased the number of secondary schools and their students.[7] The sociological portrait of the students has not been studied in detail but they were definitively masculine and most came from middle-class families.[8]

The curriculum of the new secondary schools was established by several government plans during the nineteenth century. The sciences had an important driving agency in the development of the modern curricula, but always in tension with the traditional classical curriculum. In turn, secondary education played a fundamental role in the configuration as disciplines of sciences such as physics and chemistry.[9] At the beginning of the twentieth century, many liberal projects allocated a large space to scientific subjects such as chemistry applied to the arts, experimental physics, mathematics and natural history. However, subsequent reforms limited their importance, instead promoting a more humanistic approach, in which classical languages (mostly Latin), grammar and literature, and ethics and religion played a major role. An influential commentator, Javier de Quinto, former education administrator, and publisher and editor of the *Boletín Oficial de Instrucción Pública*,[10] remarked that improving the status of the sciences meant depriving that of the humanities, and that specialization would deprive secondary education of its preparatory role.[11] The debate on the purpose and contents of secondary education – humanities vs. science, specialization vs. general education, preparatory character for university vs. cultural, and general *Bildung* – lasted during the nineteenth and even the twentieth century.[12] Scientific subjects were then restricted to an early basic training in mathematics (arithmetic rules and geometry), together with courses on natural history and 'physics and chemistry,' only provided in the last years of the secondary school curriculum.[13] The course on 'elements of physics and chemistry' was commonly taught during the fifth year of studies, involving five hours per week. Its first official syllabi were published during the 1840s, covering the whole spectrum of experimental physics (mechanics, hydrostatic and hydrodynamics,

acoustics, heat, optics, electricity and magnetism), together with some lectures on 'notions of chemistry.'[14] Another difficult issue for the first secondary schools was the lack of textbooks. During the 1840s, through the initiative of publishers and teachers, some French textbooks were translated into Spanish, but the government encouraged Spanish teachers to publish their own textbooks according to the official curricula. The state Educational Board controlled education by periodical publication of a list of recommended textbooks and, during most of the century, secondary school teachers were compelled to choose textbooks from these lists. [15]

An even more difficult problem was the lack of well-trained secondary school teachers, especially in the sciences. Initially, teachers were provisionally appointed (with the title of *regentes*) after passing an examination, in which they were requested to prove their mastery of the official syllabus for their subject.[16] After some years, if a teacher had obtained favourable government reports, he could be appointed as full teacher (*catedráticos*). The selection process was by no means perfect, and nepotism and lack of standards were reported.[17] By 1860, around one third of physics and chemistry teachers had studied pharmacy, and the other important professional groups were physicians and lawyers (who represented one of most important groups of secondary school teachers in any area). During the 1850s and 1860s, many teachers obtained the title of *licenciado* or *doctor* in science, including some pharmacists such as Mariano Santisteban y Lafuente (1821-1886), who became a very influential professor in Madrid in subsequent years.[18] After the 1857 reform, also designated 'plan Moyano,' the secondary school teacher's career was consolidated and developed. Candidates had to be 24 years old and possess the *bachiller en ciencias*, a title awarded by the Faculty of Philosophy after completion of secondary school studies. In 1867, a new law requested the title of *licenciado en ciencias*, awarded by faculties of science, and the new position of assistant teacher was introduced, to assist and substitute teachers during illness or holidays. [19]

As in France, the Spanish government attempted to solve the problem of the provision of secondary school teachers through the creation of a college in charge of their training. However, in contrast to the French case, its existence was too ephemeral and did not have an influential role in the configuration of the secondary school teacher's profile and of the sciences as disciplines. In a first attempt, during the mid 1840s, the *Escuela Normal de Ciencias*, was established in order to train science teachers, the need for which was considered more urgent.[20] In the early 1850s, a new institution was created: the *Escuela Normal de Filosofía*. Successful candidates should be *bachiller en filosofía* and were offered a scholarship to attend lectures during four years. The curriculum was organized in three different sections: literature, 'physico-mathematical sciences' and 'natural sciences.' Some lectures were given by university professors. Successful students directly obtained the licence and were given preference in the award of secondary school teaching positions, but they were expected to serve as teachers for a decade. Breaking the contract was penalized by automatically losing their teaching and academic status. By 1860, eight years after the closure of the college, a small number of its former students were holding positions in secondary and higher education.[21] One of them was Jaume Banús i Castellví. After graduating during the 1850s, he was appointed professor of physics and chemistry at the Girona school, then at Valencia, where he became secretary (1865-1880) and, later on, director for most of the last two decades of the nineteenth century. In Girona, in addition to physics

and chemistry, he taught industrial mechanics and significantly contributed to the development of both the school's collection of instruments and its library.[22]

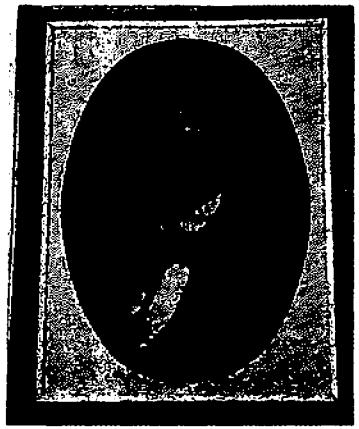

FIGURE 1. Jaume Banús i Castellví, nineteenth-century physics and chemistry teacher and director of the Valencia secondary school. Oil painting preserved at the Instituto Luis Vives, Valencia.

The first secondary school teachers were influential actors in their local context. Their high and broad educational qualifications and intellectual authority allowed them to participate in public health committees, perform chemical analysis, engage in literary and scientific societies, collect meteorological data for the government, perform mineralogical surveys, collect mineral, botanical and zoological specimens, and actively participate in the public sphere through contributions in general and specialized periodicals. A small but not negligible group of teachers published textbooks and sometimes scientific papers, and also gave lectures at industrial schools, faculties of science, and other institutions engaged in furthering the country's scientific, industrial and agricultural improvement.[23]

The nineteenth-century scientific instruments collections

The new institutions were equipped with collections of scientific instruments and natural history specimens. In most cases, the first instruments were acquired during the 1840s and 1850s, thanks to the active support of Antonio Gil de Zárate.[24] Before joining the state education administration, he had been educated in France in the first two decades of the century, subsequently attending lectures on experimental physics at the Reales Estudios de San Isidro in Madrid. He returned to Paris to prepare himself for becoming a teacher of experimental physics in Spain, but did not succeed due to adverse political upheavals.[25] His scientific background was crucial when he became involved in the reform of university and secondary school curricula in the 1840s. After a survey of existing university collections, a reference catalogue of physics and chemistry collections was compiled by a commission of university professors appointed by the Spanish government.[26] Just few weeks after, at the end of 1846, Gil de Zárate – accompanied by Juan Chavarri, professor of physics at the Spanish Central University

– travelled to Paris to organize the purchase of physics and chemistry instruments for universities. In November, they met Mateu Orfila (1787-1853), a Spaniard who had made a successful career in France as professor of medical chemistry and dean of the Paris Medical Faculty.[27] Thanks to Orfila's advice, Gil de Zárate obtained the services of four Parisian instrument makers: 'Ms. Pixii and Deleuil for the physics instruments; Lizé & Clech for the glassware and porcelain, and the brothers Rousseau.' The importance of the purchase allowed him to negotiate a deal and acquire more instruments than initially expected, thus expanding the range of recipient institutions. The purchase included 'physics instruments for eleven cabinets,' 'precision scales,' steam machine models, chemical apparatus and substances, a mineralogical collection and a large number of medical charts.[28]

By the same token, in September 1846 a reference catalogue was established to equip the cabinets of physics and chemistry of secondary schools.[29] The list of instruments was based on the catalogues of the French makers Lerebours and Pixii, including 152 physical instruments (valued at 9531 French francs) and 133 chemical items (valued at 6448 francs). However, the collection was subsequently dramatically reduced, particularly in the case of chemistry, for which the funds became just 10% of the initial amount (i.e. 600 francs). The collection of physics instruments was reduced to 116 items only, although for almost half the price of the original amount (5000 francs). The fields better represented in the physics list were electricity and magnetism (39), mechanics (15) and pneumatics (19).[30]

During the following years, the purchase of collections was executed under the supervision of the government. By the middle of the nineteenth century, nineteen secondary schools had a complete cabinet of physics, eleven other cabinets were almost complete, and only five secondary schools were ill equipped, according to a governmental report.[31] A few years later, Gil de Zárate described the state of the collections, proudly remarking that many secondary schools (such as Palma de Mallorca, Girona, Lleida and Orense) had larger collections than those prescribed by the model catalogue. In a school such as that of Pamplona, the physical cabinet included 186 instruments (around 70 more than the prescribed list), while the chemical laboratory was 'equipped with a large number of apparatus and substances, allowing the performance of all types of operations.' In Huesca, the chemical laboratory was considered similar to that of the University of Zaragoza. In general terms, most of the collections were thus constituted through purchases made during the 1840s and 1850s.[32] Only in a few cases – for instance, the Madrid secondary school *Reales Estudios de San Isidro*, to be discussed further on – instruments from other former educational institutions were used.[33]

In addition, many secondary schools had natural history cabinets and botanical gardens. Often, natural history collections were assembled by teachers of natural history or donated by local amateurs. In Lérida, the mineralogical collection was gathered by the natural history teacher during the 1850s.[34] In Ciudad Real, during a visit of Juan Vilanova (1821-1893), professor of geology at the Central University in Madrid, the natural history teacher collected a large number of rocks and minerals from nearby areas.[35] Some schools obtained exceptional natural history collections through donations. The Malaga school acquired part of the library and the herbarium of the famous botanist Mariano Lagasca Segura (1776-1839), who was director of the Madrid Botanical Garden and spent many years in exile in Britain because of his liberal ideas.[36] His mineralogical collection (around 219 minerals) was also acquired

by another secondary school.[37] Apart from instruments, plants, minerals and zoological specimens, schools usually used natural history illustrations for pedagogical purposes, such as those published by Achille Comte which, according to Gil de Zárate, could be found in 'all the secondary schools' by the middle of the nineteenth century. [38]

Botanical gardens were often established for the teaching of natural history and agriculture.[39] They often occupied lands belonging to the school or inherited from ecclesiastical establishments. This was the case with the botanical garden of Ciudad Real, which was established in 1847, four years after the opening of the secondary school. By 1860, it occupied an area of more than 1300 m^2, a large herbarium had been assembled by the teacher of natural history and a collection of 'woods, ashes and charcoals,' organized by a forestry engineer, had been donated by the provincial government (*Junta provincial de Agricultura*).[40] In Lérida, the botanical garden was created on land belonging to the teacher of physics and chemistry, Francesc Bonet i Bonfill. Plants were organized in natural families, employed in the teaching of botany and agriculture, and the school had a greenhouse and a large herbarium with 1500 species, most of them of local origin. [41]

Figure 2. Early twentieth-century physics and chemistry classroom in Valencia secondary school. A few science wall-charts can be seen at the top left part of the image (*Instituto Luis Vives, 1870-1970. Crónica de su primer centenario*, Valencia, 1970).

In addition, secondary schools and their science teachers contributed to the establishment of a national meteorological network, coordinated by the Astronomical Observatory in Madrid. During the 1850s and 1860s, many schools were equipped with small meteorological stations. In 1861, the director of the Caceres school established a meteorological station on its premises. The instruments, made in Paris, were calibrated in the Madrid Observatory before being sent to the school.[42] In 1856, the physics and chemistry teacher Francesc Bonet i Bonfill established a meteorological station in Lérida and two years later began sending data to Madrid.[43] In Castellón, the meteorological station was established much later, in the 1880s, by Francesc Llorca i Ferrandis, physics and chemistry teacher. For that purpose, a meteorological tower was placed on top of the school as an integrated part of the building.[44] Meteorological data were processed in Madrid, but were also published in local newspapers and in the schools' publications.

The stations usually included a small range of thermometers, barometers, hygrometers, anemometers and pluviometers.[45]

Meteorological observatories are just an example of the broad range of activities that made secondary schools and their teachers central agents in the creative dynamics of cultural life in the provinces. Teachers acted as cultural agents through participation in conferences, public lectures and cultural societies, general and specialized publications, the provision of general education and professional training, and the promotion and supervision of cultural, commercial and industrial ventures. Secondary schools were central locations for teaching, research and popularization. Their annual opening ceremonies were an essential cultural event attended by local notables and civil and military authorities. Their physics, chemistry and natural history cabinets, and their meteorological stations attracted many visitors and were a matter of pride for both schools and local authorities. An example of this is the Murcia school, one of the earliest established in Spain, which brought together an important collection of physics instruments during the nineteenth-century (around 667 items in 1869, increasing to more than 800 in twenty years). The collection was so impressive that, on his visit to Murcia in 1876, the king of Spain visited the cabinets and the teacher performed several experiments for him.[46]

As previously mentioned, the purchase of scientific instruments was coordinated by the state educational department.[47] However, in certain cases, schools purchased on their own. At the Pontevedra school, between 1847 and 1848, instruments made by a Parisian maker were acquired through the collaboration of Antonio Casares Rodríguez (1812-1888), professor of chemistry at the nearby university.[48] During the 1850s and 1860s, the Burgos secondary school bought a large number of instruments thanks to funding provided by the provincial administration.[49] The director of the Figueres school proudly mentioned a 'pneumatic machine' received in 1861: 'It has excellent characteristics due to the latest advancements in the art of making [instruments], which earned its manufacturer, Mr. Deleuil of Paris, a prize.'[50] In fact, the firm established by Louis-Joseph Deleuil (1795-1862) was an important provider of instruments to Spanish and French schools during the 1850s and 1860s.[51]

Although most of the instruments purchased by Spanish schools and universities in this period were produced in Paris, a small precision industry emerged in Spain during the late eighteenth century and nineteenth century. An outstanding early case is that of the instrument-making workshops of the *Reales Estudios de San Isidro* in Madrid, a secondary school established in the last third of the eighteenth century, but having its roots in an early-modern college. From 1770 onwards, a chair of physical chemistry was established and the instruments were provided by a machinist, Diego Rostriaga, who had been trained with the 'chamber clock-maker of King Fernando VI.' He and his brother constructed many instruments requested by the teachers of experimental physics, Antonio Fernández Solano (1774-1823) and Joaquín González de la Vega (fl. 1791-1811). Moreover, although some of the instruments of the collection were acquired by Fernández Solano during his travels to France and Britain, and through subsequent purchases by González de la Vega, an important part was produced in the school's workshops. At the beginning of the Napoleonic war, the school had an excellent cabinet comprising around 240 items. After several decades of stagnation, two influential teachers of physics and chemistry, Venancio González Valledor and Mariano Santisteban, took care of the collection, largely contributing to its present preservation.

Santisteban, who wrote an historical essay about the collection, defended the quality of the instruments constructed by the Rostriaga brothers. He regarded them to be much more sophisticated than the 'cheap' French instruments bought in the middle of nineteenth-century under the patronage of Gil de Zárate:[52]

> Enlightened people [...] will be persuaded that the number of apparatus [purchased from foreign makers] that were allocated to the San Isidro cabinets was very small, they all were the most simple and elementary from the point of view of their average quality, and for their prices, the most advanced available in the Physics and Chemistry catalogues of French instrument makers, the cheapest in Europe in that period [...] [Spanish instruments] reveal the great ideas on Physics that were common amongst the men of the previous century who commissioned their construction; with the former [French instruments], science appears so small, that anyone would tend to think that they were intended to make the blackboard images a bit tangible for the students, absolutely denying any assistance for teachers' study and for the experimental advancement of science.

The case of the *Reales Estudios de San Isidro* is exceptional. No other secondary school had such a large and valuable eighteenth-century collection and a workshop with skilled craftsmen like the Rostriaga brothers. However, some schools asked local craftsmen to make, repair or even change some characteristics of instruments, so they could be advantageously employed in their classrooms. For instance, around 1850, the Figueres secondary school asked the instrument-maker José Rossell from Barcelona to construct a barometer and a 'Clarke electro-magnetic apparatus' (of which he modified the 'shape of the commutator, thus making more intelligible and demonstrable the theory to which it is devoted')[53]. Another important nineteenth-century Spanish instrument maker was the firm Graselli y Zambra, 'Opticians to Her Majesty,' who provided instruments to many secondary schools, some of which have survived.[54] José Grasselli and Cayetano Zambra were probably of Italian origin, and – taking into account the traditionally familiar structure of the instrument trade and its nineteenth-century international expansion –[55] the latter might perhaps be related to the Italian-naturalized-British Joseph Warren Zambra (1822–1897), co-founder, in 1850, of the successful firm Negretti & Zambra in London.[56] Unfortunately, there is still much to be done in order to write the history of nineteenth-century Spanish precision industry.[57]

FIGURE 3. Two members of the Spanish royal family passing an examination in chemistry at the Reales Estudios de San Isidro (1929-1930) [From *Instituto de San Isidro. Homenaje al Excmo. Sr. D. José Ibañez Martin*, Madrid, 1946].

Evidence suggests that the purchase of instruments slowed down during the late 1860s and early 1870s, but that it gained momentum again after 1877, when the government established that part of the academic fees should be consumed in the purchase of scientific instruments and other pedagogical resources.[58] However, when secondary schools were integrated into the centralized financial administration of the state, purchases slowed down again.[59] In 1898, after many years of not receiving funding for instrument purchases and repairs, the director of the Castellón school stated:[60]

> We will repeat what we said in previous years, not disposing of a special budget, the only acquisitions have been the necessary substances for manipulations in the cabinets [...] But this year we dare add that, if this situation should continue, not acquiring new apparatus nor replacing those that are useless, in a few years the cabinets will become stores of useless instruments, losing their powerful assistance in teaching.

At the beginning of the twentieth-century, the government created an Institute for Scientific Material (*Instituto de Material Científico*) with the aim of coordinating equipment demands and needs of the schools, the calculation and distribution of the due budgets and the purchase, making, repair and exchange of instruments. The new commission was made up of 15 members, amongst who were some of the foremost Spanish scientists of the time, under the presidency of the Spanish Nobel Prize laureate Santiago Ramón y Cajal.[61] In November 1911, an associated workshop for the repair of instruments was established,[62] and during the next year numerous instruments were sent to schools, many of them constructed by Max Kohl, which became an important provider of instruments for both Spanish schools and universities during the first half of the twentieth century.[63] The activity of the Institute for Scientific Material remained crucial during the next decades, as was its successor, the Instituto 'Torres Quevedo,' established after the Spanish Civil War under the dictatorship of General Franco.[64]

What has been preserved?

The preceding analysis shows that most of the nineteenth-century Spanish secondary schools were furnished with teaching laboratories, physical cabinets, natural history collections, botanical gardens and meteorological stations. Even if many of these instruments have been destroyed or dumped, a substantial part has survived. The most outstanding case is the collection of the *Reales Estudios de San Isidro*. Thanks to teachers like Mariano Santisteban, who recognized the value of the historical collection, many eighteenth-century and early nineteenth-century instruments have been preserved. A substantial part of the collection is now housed at the Spanish Museum of Science and Technology in Madrid. From around 240 items described in the eighteenth-century and nineteenth-century catalogues, the Museum now has 84, i.e., around one third of the most important eighteenth and early nineteenth-century pieces, some of them constructed by the Rostriaga brothers.[65]

However, also from the point of view of preservation, the *Reales Estudios* is an exceptional case. In other secondary schools, most of the instruments remain in the same buildings in which they were employed during the nineteenth century and

have never enjoyed the benefits offered by museums. They are barely regarded as a relevant part of cultural heritage by the political and educative authorities, which explains the mixture of disregard and arbitrariness that sometimes seems to guide decision-making regarding the collections, unfortunately a non-exceptional situation in many other European countries. As a result, the state of the collections (cataloguing, preservation, exhibitions, accessibility, curatorship, associated research projects etc.) is very diverse.[66] Curiously enough, stable school premises and several generations of teachers, with scarce economic and moral support from the administration, have been the factors contributing the most to the preservation of part of the collections. Thus, the most common cause of their disappearance or destruction has often been the relocation of schools to new premises, involving new buildings, larger numbers of students, changing the teaching staff, etc. Celebrations and commemorations have been useful to preserve the memory of these collections and to raise the awareness towards their precarious conditions. During the 1980s and 1990s, many of the oldest schools were celebrating their 150th anniversary and in certain cases this has clearly contributed to improving the preservation and present use of the collections.

An example of this is the Murcia school, which celebrated its 150th anniversary in 1987 with several activities, conferences and publications, including a catalogue of part of the instruments related to experimental physics (around 300 items).[67] The Segovia school was established in the 1840s and also managed to constitute an important collection which was preserved and partially catalogued by a group of teachers during the 1980s.[68] In the case of Palma de Mallorca, no comprehensive catalogue has been published, but many pieces have been restored and studied.[69] Even schools established in the late nineteenth century or early twentieth century often have excellent collections. The 75th anniversary of the secondary school *Pare Vitòria* at Alcoi was celebrated in 2006 with several academic activities, including an exhibition and a beautiful catalogue of the physical instruments collection and the publication of a herbarium made by a teacher during the 1930s.[70]

In recent years, a new and important step has been taken with the establishment of some regional collective catalogues. In Andalucia, 16 secondary school collections have been catalogued, representing more than 1700 physics and chemistry instruments and a large quantity of natural history specimens. Only in a few cases were instruments exhibited in small didactic museums intended for the school's students and organized by teachers.[71] In the Basque Country, a large exhibition of scientific instruments was opened to the public between January and March 2003. Among other activities associated with the exhibition, an inventory of instruments belonging to several Basque universities, schools and also private collections was produced.[72] In Galicia, a recent historical study about nineteenth-century secondary schools has been made in conjunction with the compilation of a general catalogue of their scientific instruments collections.[73] A few of the collections have been the object of temporary or permanent exhibitions, thanks to which they have been restored and stored in optimal conditions.[74] A new project on the Madrid secondary schools, which probably keep very rich collections, has been recently announced.[75]

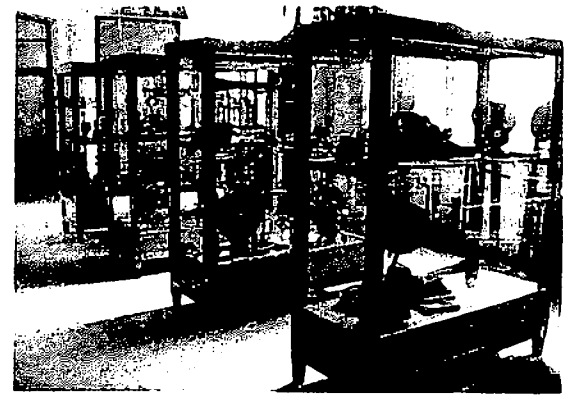

FIGURE 4. Current state of the Castellón secondary school physics and chemistry collection (photo by the authors).

Another interesting collaborative project is the recent Catalan Scientific Instruments Commission (COMIC), whose major aim is to implement a network of collections, including secondary schools, universities, museums and other institutions. The Commission also plans to offer different resources for cataloguing and preserving scientific instruments: bibliographical orientation, cataloguing guidelines, Spanish instrument-makers' trade catalogues, specialized meetings and workshops, on-line data bases, etc.[76] During the last few years, and in collaboration with this Commission, our group has been working in the collective cataloguing of the Valencia, Castellón and Alicante school collections.[77] At this point, we have a preliminary catalogue for each institution and some preliminary quantitative data about the nature of instruments, number, purposes, instrument-makers and scientific disciplines (see TABLE 1).

	ALICANTE	CASTELLÓN	VALENCIA
Physics cabinet	241	400	300
Total items (rough numbers)			
Areas (%)			
Matter, force and motion	[-]	5	1
Gravitation and molecular attraction	5	8	7
Liquids	9	4.5	7
Gases	14.5	9.5	10
Sound	5	4.5	2
Heat	12	8	11
Light	10	11	11
Magnetism	0.5	[-]	1
Static electricity	8	8.5	8
Dynamical electricity:	24	33	23
Other	12	8	19
Chemistry instruments	c. 10	c. 150	c. 280

TABLE 1. Distribution of instruments by areas in the extant physics and chemistry collections at the IES "Luis Vives" (Valencia), IES "Francisco Ribalta" (Castellón) and IES "Jorge Juan" (Alicante).

As pointed out by Heilbron, a collective catalogue can 'make possible the discovery of missing pieces and the comparative study of the coverages, emphases, uses, functions and practices of the institutions that held or developed the collections.'[78] The quantitative analysis of the three collections shows similarities from many points of view. The collections contain between 200 and 400 physics instruments and a smaller collection of glass and terracotta chemistry pieces (between 100 and 300 pieces) in the case of Castellón and Valencia. In Alicante, like in many other schools, chemical instruments have not been preserved. The proportional representation of the different areas of physics is similar for the three preserved collections.[79] Dynamical electricity (between 20 and 30% of collections) is the field best represented in quantitative terms, followed by instruments used for the study of gases, heat and light, respectively (around 10% of the collections); static electricity follows in quantitative importance (8%). On average, instruments used in introductory chapters in mechanics (matter, force and motion, and gravitation and molecular attraction) have a similar representation, but perhaps a bit lower. In number of instruments, the study of magnetism is the least represented (less than 1%), followed by that of sound (3–5%). This distribution pattern cannot be explained without taking into account various issues: the importance of each of these areas in nineteenth-century lectures and textbooks, the prolonged and intense use of certain instruments (interfering with their preservation), the relative importance of demonstrations in each area (some parts of a lecture requiring more instruments than others), the price of instruments and the school budget, the availability of instruments in each period, the size, materials and fragility of instruments (a very important issue in the case of chemistry), the presumed cultural and aesthetic value of the pieces, among others. Focusing on the first of these issues, an exploratory analysis shows that the relative proportion of subjects in the three collections coincides reasonably well with that in nineteenth-century physics textbooks and their evolution. By mid-century, the largest chapters were those on heat and light, followed by that on dynamical electricity.[80] In the following decades, the latter commonly expanded to equal the size of the former. In the late 1880s the three chapters still had similar length, but the chapters on heat and light usually displayed a lower number of instruments than those on electricity, as instruments in them were often shown as part of experimental sets, being thus included in several of these.[81]

Apart from these statistical conclusions, the collective catalogue of the mentioned collections provides additional data on instrument makers. Information about makers is very scarce and in general limited to bills and trade-catalogues preserved in archives, so data provided by the instruments themselves is very important. The analysis of the Valencia school instruments shows some interesting conclusions. The oldest instruments were generally constructed by famous French nineteenth-century instrument makers such as Secretan, Lerebours, Salleron, Ducretet, Ruhmkorff, Carpentier, Deleuil and Pixii. Another small group are signed by German instrument makers (Liesegang, Reichert, etc.). Another small group was made by nineteenth-century Spanish instrument makers (Rossell, Dalmau, Grasselli y Zambra) and an incipient local precision industry in Valencia (Juan Lubat being the most important), which appeared at the beginning of the twentieth century. Another group of instruments (mostly from the second third of twentieth century) consists of those made by Sogeresa, Cultura and other national industries supported by the government (especially the 'Torres Quevedo' institute, which replaced the Institute for Scientific Material after the Spanish Civil War).[82]

Conclusions

The previous discussion shows that instruments are excellent material sources for studying how science was taught in nineteenth-century secondary schools. However, like any other source, it has to be double checked with other historical information and data.[83] Fortunately, many secondary schools have excellent archives and libraries, some of which have recently been inventoried.[84] Moreover, the schools published an annual report (*memorias*), in which they described, among many other issues, the state of their scientific collections.[85] Apart from these and other local sources, the archives of the National Educational Office gathered many files with biographical profiles of teachers, nineteenth-century inventories of collections and reports on the teaching of science and the purchase of instruments. These sources (bills, directions of use, students' notebooks, laboratory practices, etc.) are essential for an understanding of instruments in their contexts: they can offer crucial information, not easily found elsewhere, about the uses of instruments, the local industries of precision manufacture and the historical actors (teachers, students, instruments makers) who employed them. Many other sources are still unexplored by historians of education and historians of science, and the issue of nineteenth-century pedagogy of science is a topic open to future research.[86]

The development of large and impressive scientific cabinets in Spanish secondary schools took place during what Brenni calls the 'Golden Age' of scientific instruments, i.e., the second half of the nineteenth century and the early twentieth century. This explains the high value of the preserved collections despite the disregard, arbitrariness and lack of consistent heritage policies which have destroyed a huge number of unique instruments. Apart from some particular cases, collections are still preserved in schools, even if their situation is far from satisfactory. Many collections have not yet been catalogued (or their catalogues remain unpublished) and a general policy or guideline concerning cataloguing, conservation and restoration, as well as the provision of convenient storage location, role of curators, etc., is nonexistent. Although there are an increasing number of people interested in the collections, their efforts are scattered in many different and heterogeneous projects and their different backgrounds (teachers, curators, historians, collectors, etc.) and interests (teaching, history, exhibitions, etc.) make interaction and sharing difficult. Therefore, at this point, it seems very important to encourage collaborations such as the Scientific Instruments Commission (COMIC), recently created by the Catalan Society for the History of Science. Moreover, exchanges with other studies on other European secondary school collections will be very useful for a future comparative analysis, which would provide many clues about the development of the pedagogy of science and its material culture.

Notes

1. This paper is part of an ongoing research project on 'Science in Nineteenth-Century Classrooms' funded by the Spanish Government (HUM2006-07206-C03-02). The study has been possible thanks to a grant awarded for the purpose of cataloguing the collections of scientific instruments in several secondary schools (CSIC-BANCAIXA).

2. A. Anderson, 'The idea of the secondary school in nineteenth-century Europe,' *Paedagogica Historica* (2004), **1 & 2** (40), 93-106; A. Green, *Education and State Formation. The Rise of Education Systems in England, France and the USA*, Macmillan, Basingstoke and London, 2004.

3. P.J. Pidal, *Plan de estudios decretado por S. M. en 17 de setiembre de 1845* ... Imprenta Nacional, Madrid, 1845, 5-7 and 19; A. Gil de Zárate, *De la instrucción pública en España*, Imprenta del Colegio de Sordo-Mudos, Madrid, 1855, I-III, in vol. II, 1-2 and 37 (Reprinted by Pentalfa Ediciones, Oviedo, 1995). For an overview of the development of Spanish secondary education, see A. Viñao Frago, *Política y educación en los orígenes de la España contemporánea. Examen especial de sus relaciones en la enseñanza secundaria*, Siglo XXI, Madrid, 1982.

4. For a contemporary review of secondary schools, see Gil de Zárate, *op. cit.* (3), vol. II, 80-161. Apart from 11 university and 37 provincial secondary schools, four local secondary schools existed.

5. *Ibid.*, and see Viñao Frago, *op. cit.* (3), 421-428.

6. See also E. Díaz de la Guardia, *Evolución y desarrollo de la enseñanza media en España, 1875-1930. Un conflicto político-pedagógico*, Universidad Complutense, Madrid, 1988, and M. de Morante, *Informe que acerca de la reforma del plan y reglamento de estudios* ... Imprenta de José M. Ducazcal, Madrid, 1853, 31-32. See the case of Cuenca reported by Gil de Zárate, *op. cit.* (3), vol. II, 98-99.

7. Gil de Zárate, *op. cit.* (3), vol. II, 64. The numbers do not include the students of religious centres and other private institutions. See also Viñao Frago, *op. cit.* (3), 408-418.

8. See J. M. Hernández Díaz, 'Los alumnos de segunda enseñanza en el siglo XIX,' *Historia de la educación* (1986), **5**, 251-274. See particular cases in V. Altava Rubio, *Aportaciones al estudio de la Enseñanza Media en Castellón. 1846-1900*, Universitat de València, València, 1993, chapter III; I. Martín Jiménez, *El sistema educativo a Menorca (1800-1939)*, IME, Maó, 2000, 217-230.

9. R. Stichweh, *Zur Entstehung des modernen Systems wissenschaftlicher Disziplinen: Physik in Deutschland*, Suhrkamp, Frankfurt, 1992, and R. Stichweh 'La structuration des disciplines dans les universités allemandes au XIXe siècle,' *Histoire de l'éducation* (1994), **62**, 55-73.

10. The official publication reproducing the texts of the laws passed in the Spanish Parliament.

11. A. Moreno González, *Una ciencia en cuarentena. La física académica en España (1750-1900)*, CSIC, Madrid, 1988, 252-254.

12. See Viñao Frago, *op. cit.* (3), 441-459, and B. Delgado Criado, *Historia de la educación en España y América*, Ediciones SM, Madrid, 1994, vol. III, 159-160. The debate took place in other European countries. See J.F. Donnelly, 'The 'humanist' critique of the place of science in the curriculum in the nineteenth century, and its continuing legacy,' *History of Education* (2002), **6** (31), 535-555; C. Fournier-Balpe, *Histoire de l'enseignement de la physique dans l'enseignement secondaire en France au XIXe siècle*, Université Paris XI, Paris, 1994.

13. On the teaching of mathematics, natural history and physics and chemistry, see, respectively; F. Vea Muniesa, *Las matemáticas en la enseñanza secundaria en España en el siglo XIX*, Seminario de Historia de la Ciencia, Zaragoza, 1995, 2 vols; A. Gomis Blanco, *Las ciencias naturales en España en el siglo XIX (1833-1874). Morfología, fisiología y sistemática*, Tesis doctoral, Madrid, 1989; J. D. López Martínez, *La enseñanza de la física y química en la educación secundaria en el primer tercio del siglo XX en España*, Tesis doctoral, Murcia, 1999.

14. For instance, the syllabus prepared for the University of Valencia in 1847-1848 included 112 lectures on physics but just 12 on chemistry. See J.M. Guillén i Tomàs, *Programa de Física y nociones de química seguido en la Universidad Literaria de Valencia* por ... *Curso de 1847 a 1848*, Imprenta Benito Monfort, Valencia, [1847].

15. See J. L. Villalaín Benito, *Manuales escolares en España. Vol II. Libros de texto autorizados y censurados (1833-1874)*, UNED, Madrid, 1999.

16. In some cases, science teachers were requested to perform experiments. Cf. *Gaceta de Madrid*, 9 July 1843.

17. See Gil de Zárate, *op. cit.* (3), vol. II, pp. 44-46 and C. Bensó Calvo, 'Ser profesor de bachillerato. Los inicios de la profesión docente (1836-1868),' *Revista de Educación* (2002) **329**, 291-309.

18. See 'Lista nominal de los Catedráticos' published in the *Gaceta de Madrid*, 7 to 30 March 1860. Many documents about the secondary school teachers are preserved at the *Archivo General de la Administración*, Alcalá de Henares (Madrid). In addition, substantial information about the first teachers is provided by the publications and archives of secondary schools. See L. Miralles Conesa, 'Catedráticos de física y química que desempeñaron docencia en el instituto F. Ribalta (1846-1996),' *Ribalta* (1997), **10**, 41-52; C. Yanes Cabrera, *Los primeros profesores del Instituto Provincial de Sevilla : historia de una experiencia docente (1845-1868)*, Diputación, Seville, 2004; C. Bensó, *Profesores y textos en el bachillerato. Uso y producción de obras de texto en los institutos gallegos del siglo XIX*, Tórculo edicións, Santiago, 2003.

19. Benso Calvo, *op. cit.* (17), 304-306.

20. Cf. Moreno González, *op. cit.* (11), 310-311. The problem was perceived in other countries. See Fournier-Balpe, *op. cit.* (12), 119-142.

21. Moreno González, *op. cit.* (11), 309-315; M. Seijas Lozano, *Plan de estudios*, Imprenta Perinat, Madrid, 1850, 33-34. See C. Yanes Cabrera, 'Análisis histórico sobre la creación y desaparición del primer centro español para la formación del profesorado de Educación Secundaria,' *Revista de educación* (2006), **339**, 745-762.

22. On Banús, see L. Querol Roso, 'El instituto provincial de segunda enseñanza de Valencia ...' in *Instituto Luis Vives (1870-1970). Conmemoración de su primer centenario*, Instituto, Valencia, 1970, 9-47, quoted at pp. 40-41. M. Ametller y Marill, *Memoria leída en ...1861 a 1862 en el instituto provincial de segunda enseñanza de Gerona*, F. Dorca, Gerona, 1861. J. Banús y Castellví, *Memoria del curso de 1877 a 1878 por el Dr.* ... Imprenta José Rius, Valencia, 1878. Other students of the 'Escuela Normal de Filosofía' were Natalio Cayuela (professor of natural history, physics and chemistry at the Pamplona secondary school), Inocente Fernández Abas (Guadalajara) and Gonzalo Quintero Rodríguez (Jerez). See Gaceta de Madrid, 7 to 20 March 1860, and Moreno González, *op. cit.* (11), 310-311. The early organization of the supply and training of secondary school science teachers in Spain clearly differs from the well-organized mid-nineteenth-century French system. However, it had many similarities with the early organization, at the beginning of the century, of French education in its transition from the *Ancien Régime* to the Napoleonic reforms. Furthermore, the early organization of Spanish secondary education follows many trends of the already mature French model. See C. Balpe, 'L'enseignement des sciences physiques: naissance d'un corps professoral (fin XVIIIe - fin XIXe siècle),' *Histoire de l'éducation* (1997), **73**, 49-85.

23. See *Gaceta de Madrid*, 7 to 20 March 1860. On the Spanish Industrial Schools, see the publications by J. Cano Pavón, for instance, *La Escuela Industrial de Valencia (1852-1865) y sus antecedentes. La difícil formación de un capital humano*, Imprenta Montes S.L., Málaga, 2001. On the Faculty of Sciences, see Moreno González, *op. cit.* (11); T. Moya Cárcel, *La enseñanza de las ciencias. Los orígenes de las Facultades de Ciencias en la Universidad Española*, Tesis doctoral, Valencia, 1992. For further information about the teachers of secondary schools in the first third of the twentieth century, see López Martínez, *op. cit.* (13).

24. There were a few exceptions: Secondary schools in cities with a university (like Valencia, Madrid, Granada, etc.) initially used the university cabinets. The particular case of the 'Reales Estudios de San Isidro,' inheritor of important collections held by previous eighteenth-century institutions, will be discussed later on.

25 See the biographical account in A. Gil de Zárate, *Obras dramáticas de D ... Edición precedida de una noticia biográfica y dada a luz por D. Eugenio de Ochoa*, Baudry, Paris, 1850, iv-xvi.

26. *Colección de las leyes, reales decretos, órdenes, reglamentos, circulares y resoluciones generales, expedidas sobre todos los ramos de la Administración y Gobierno del Estado*, Madrid, 1847, 213-215. *Real Orden mandando se adquieran instrumentos y aparatos de física y química para proveer a las Universidades*, Madrid, 28 October 1846.

27. On Orfila, see J.R. Bertomeu-Sánchez and A. Nieto-Galan (eds.), *Chemistry, Medicine, and Crime: Mateu J.B. Orfila (1787-1853) and his times*, Science History Publications, Sagamore Beach, MA, 2006.

28. *Gaceta de Madrid*, 3 March 1847, Report by Gil de Zárate, Madrid, 14 February, 1847. 'Real órden por la cual se manifiesta al señor director general de instrucción pública que S. M. ha visto con agrado el buen éxito de la comisión que llevó al estrangero para adquirir máquinas y útiles necesarios en las universidades.' *Boletín Oficial de Instrucción Pública* (1847), **5**, 129-137. For more details, see Gil de Zárate, *op. cit.* (3), vol. III, 255-257 (quoted on p. 256). See also J. Simón-Castel et al., 'Instrumentos y prácticas de enseñanza de las ciencias físicas y químicas en la Universidad de Valencia durante el siglo XIX. *Endoxa* (2005), **19**, 59-121.

29. *Boletín Oficial de Instrucción Pública* (1846), **6** (17), 545-557. *Circular previniendo a los Institutos se provean de los instrumentos necesarios para la explicación de las ciencias físicas y naturales*. A similar catalogue was established in France in 1843. See B. Bruno Belhoste, *Les sciences dans l'enseignement secondaire en France. Tome 1, 1789-1914*, INRP, Paris, 1995, 181-190. Many excellent collections of nineteenth-century scientific instruments are preserved in French *lycées*. See, for instance, F. Gires (ed.) *Physique impériale. Cabinet de physique du Lycée Impérial de Périgueux*, ASEISTE, Niort, 2006 ; F. Gires (ed.) *L'empire de la physique. Cabinet de physique du lycée Guez de Balzac d'Angoulême*, ASEISTE, Niort, 2006. For more details, see http://www.inrp.fr/she/aseiste/index.htm (accessed on 25 February 2008).

30. *Colección*, *op. cit.* (25), 330-338. *Circular para que los institutos de segunda enseñanza se provean*

de los instrumentos para la enseñanza de la física, 10 April 1847. See J. López Martinez and M.A. Delgado, 'El material científico de los institutos como indicador de intenciones pedagógicas y estilos de enseñanza en ciencias experimentales,' in *Etnohistoria de la escuela... XII Coloquio Nacional de Historia de la Educación*, Universidad, Burgos, 2003.

31. *Gaceta de Madrid*, 7 September 1850, 1-3 (quoted on p. 2). The report did not include the University secondary schools and the 'second class' secondary schools in which physics and chemistry was not taught.

32. Gil de Zárate, *op. cit.* (3), vol. II, 80-161. Quotations from pp. 118, 103-104 and 125.

33. The secondary school of Jerez de la Frontera inherited a collection of physics and chemistry intruments from a previous ecclesiastical educational establishment, thanks to a donation. In Toledo, the school inherited the apparatus of the abolished local university but, according to Gil de Zárate, the teachers only could rescue 'a broken air pump' and 'a badly mounted magnet.' See Gil de Zárate, *op. cit.* (2), vol. II, p. 318. (and page numbers).

34. Q. Casals Berges, *Tots a l'escola? El sistema educatiu liberal en la Lleida del XIX*, PUV, Valencia, 2006, 243-246.

35. G. López, *Memoria leida* [...] *en la solemne apertura del instituto de segunda enseñanza de Ciudad-Real por el directro D. ...*, Clemente Rubisco, Ciudad Real, 1861, 5-6.

36. Gil de Zárate, 1855, *op. cit.* (3), vol. II, 110.

37. F. Sánchez Rubio, *Memoria leida* [...] *en la somene apertura del instituto de segunda enseñanza de Albacete*, Imprenta de la Unión, Albacete, 1861, 7. It includes the list of minerals of Lagasca's collection.

38. Gil de Zarate, *op. cit.* (3), vol. II, 94. The textbook on natural history by H. Milne Edwards and A. Comte was translated into Spanish. Cf. *Cuadernos de historia natural por Milne-Edwards y Aquiles Comte : traducidos al español y arreglados al programa publicado por la Dirección General de Instrucción Pública por Miguel Guitart y Buch*, Imprenta de Joaquin Verdaguer, Barcelona, 1849.

39. Gil de Zárate, *op. cit.* (3), vol. II, 80-161.

40. López, *op. cit.* (35), 67-80.

41. Casals Berges, *op. cit.* (33), pp. 244-246.

42. L. Sergio Sánchez, *Memoria leida* [...] *en el instituto provincial de segunda enseñanza de Cáceres*, Antonio Concha, Cáceres, 1861, p. 9.

43. Casals Berges, *op. cit.* (34), 242-243.

44. P. Aliaga, *Memoria del instituto de Castellón por el catedrático y secretario del mismo D. ... Curso de 1879 a 1880*, Rovira Hermanos, Castellón, 1880, 10: 'se ha construido una elegante torre, sobre las azoteas del edificio, que mide 4 metros de longitud, y 3 de latitud, elevándose 20,50 m. sobre el nivel del suelo, y unos 45 metros sobre el nivel del mar, y reuniendo por consiguiente las condiciones más a propósito para el objeto a que se destina.'

45. See R. Sisto, *A disciplina de Física e química na educación secundaria do século XIX...*, Universidad de Santiago de Compostela, Tese de doutoramento, 2007, 374-376, for more details about the meteorological stations in the Galicia region.

46. López Martinez, *op. cit.* (13), 195-196. See also López Martinez and Delgado, *op. cit.* (30) for more examples.

47. Gil de Zárate, *op. cit.* (3), vol. II, 68-69.

48. Sisto, *op. cit.* (45), 343-344.

49. J. Martínez Rives, *Memoria expresiva del estado del instituto de segunda enseñanza de Burgos al principiar el curso académico de 1861 a 1862*, Timoteo Arnaiz, Burgos, 1861, v-x. Many of the instruments were provided by 'Mr. Abadie,' a Parisian maker.

50. J. Boix i Monrós, *Memoria leida* [...] *el instituto local de segunda enseñanza de la Villa de Figueras por D. ...*, Lorenzo Miegeville, Figueras, 1861, 25: 'La máquina pneumática de que hablamos en la memoria del curso de 1859 a 1860 y que, por una mala inteligencia, no llegó cuando esperábamos, recibiose junto con cuatro campanas de cristal a principios del que acaba de espirar: es de excelentes condiciones, debidas algunas a los últimos adelantos del arte de construir, y las que le han valido un premio a su fabricante, Mr. Deleuil de Paris. Con dicha máquina se obtiene el vacio hasta medio milimetro.'

51. J. Oloriz Serra, *Política i educació. L'Institut de Segon Ensenyament de Girona 1845-1900*, Universitat de Girona, Girona, Tesis doctoral, 1999, 296. Quoted by López Martínez, *op. cit.* (13). Deleuil also produced instruments for French secondary schools. See P. Brenni, 'Nineteenth-century French scientific instrument makers. IX: Louis Joseph Deleuil (1795-1862) and his son Jean Adrien Deleuil (1825-1894),' *Bulletin of the Scientific Instrument Society* (1995), 47, 1-4, and H. Chamoux. 'Constructeurs d'instruments scientifiques pour les établissements publics au XIXe siècle.' in: http://www.inrp.fr/she/instruments/hcx_instr_constructeurs.htm. (accessed on 26 February 2008).

52. Cf. M. Santisteban, *Breve historia de los gabinetes de Física y Química del Instituto de San Isidro de Madrid*, Imprenta Aguado, Madrid, 1875, 44-45. For more details about the origins of the collection, see V. Guijarro Mora, *Los instrumentos de la ciencia ilustrada. Física experimental en los Reales Estudios de San Isidro de Madrid (1770-1835)*, UNED, Madrid, 2002.

53. Boix i Monrós, *op. cit.* (50), 24. The machine was introduced by the English instrument-maker Edward M. Clarke (c. 1806-1859). See B. Gee, 'The early development of the magneto-electric machine,' *Annals of Science* (1993), 50, 101-133. By the middle of nineteenth century, José Rosell had a workshop in Barcelona where he manufactured instruments for astronomy, surveying, mineralogy, optics, physics, mathematics, etc. See C. Puig Plà, 'Desarrollo y difusión de la construcción de máquinas e instrumentos científicos: el caso de Barcelona: siglos XVIII-XIX,' *Scripta Nova* (2000), 69, 8.

54. Some instruments were bought by the *Reales Estudios de San Isidro*. See Santisteban, *op. cit.* (52), 46-47.

55. As outstandingly illustrated by Paolo Brenni's series of papers on French scientific instrument makers, published in the *Bulletin of the Scientific Instrument Society*.

56. J.K. Bradley, 'Negretti, Henry Angelo Ludovico (1818-1879),' in *Oxford Dictionary of National Biography*, Oxford University Press, 2004.

57. For more information on Spanish instrument makers, see Puig Pla, *op. cit.* (53), and P. Ruiz Castell, J. Simón Castel and J.R. Bertomeu Sánchez, 'Los fabricantes de instrumentos de la Universitat de València,' in *Abriendo las cajas negras: Los instrumentos científicos de la Universidad de Valencia*, (ed. J. R. Bertomeu Sánchez and A. García Belmar), PUV, Valencia, 2002, 367-381. We are preparing a bibliography of Spanish instrument-makers trade catalogues.

58. *Gaceta de Madrid*, 15 August 1877, 463-464: 'el importe de los derechos académicos en cada Facultad o instituto se destinará: la mitad para el material científico de sus respectivas enseñanzas y auxilios pecuniarios a los alumnos sobresalientes y pobres a que se refiere el artículo siguientes, y la otra mitad servirá para formar un fondo común, que se distribuirá por partes iguales entre todos los catedráticos numerarios de los establecimientos a que hace referencia este decreto.'

59. López Martínez, *op. cit.* (13), provides substantial statistical data. See also Díaz de la Guardia, *op. cit.* (6), 506-507.

60. J. Sanz Bremon, *Memoria del instituto de Castellón, por el catedrático y secretario del mismo D. ... Curso de 1897 a 1898*, José Armengot, Castellón, 1898, 9.

61. *Gaceta de Madrid*, 18 March 1911, 769-770. Among the members were Ignacio Bolivar y Urrutia, Amalio Gimeno y Cabañas, José Rodriguez Carracido, José Casares Gil, José Muñoz del Castillo, Leonardo Torres Quevedo, Juan Ramón Gómez, Federico Oloriz y Aguilera, Juan Flores Posada, José Gómez Ocaña, Eduardo Mier y Miura, Blas Lázaro e Ibiza, Blas Cabrera y Felipe and José Rodriguez Mourelo.

62. *Gaceta de Madrid* , 11 November 1911, 325.

63. *Gaceta de Madrid*, 2 November 1912, 324-326, contains a list of instruments and centres to which they were sent. See also *Gaceta de Madrid*, 1 October 1913, 5-7, and *Gaceta de Madrid*, 13 September 1915, for further examples of the activity of the centre.

64. For additional information, see A. Romero de Pablos, 'Dos políticas de instrumental científico: el Instituto del Material Científico y el Torres Quevedo,' *Arbor* (1998), 160 (631-632), 395-386.

65. See Guijarro Mora, *op. cit.* (52), pp. 189-194, for catalogues of preserved instruments.

66. In the former paragraph, we quote the excellent study by M.C. Lourenço, *Entre deux mondes. La spécificité et le rôle contemporain des collections et musées des universités en Europe* (Between two worlds. The distinct nature and contemporary significance of university museums and collections in Europe), doctoral thesis, *Conservatoire national des arts et métiers*, Paris, 2005, at 5 and *passim*. See also H. Chamoux, 'L'inventari descriptiu sistemàtic dels instruments científics als liceus i universitats de França,' in *Obrint les Caixes Negres: Els instruments científics de la Universitat de València* (ed. J.R. Bertomeu and A. García), PUV, València, 2002, 153-167. For a recent discussion of the studies on Spanish secondary schools' collections, see J. Simón-Castel, 'Els instruments científics dels instituts d'ensenyament mitjà,' in *I Jornada sobre història de la ciència i ensenyament* (ed. P. Grapí), SCHCT, Barcelona, 2005, 109-114; J. Simón-Castel, 'Les colleccions de física i química dels instituts de secundària. Catalogació, estudi i metodologies,' in: *Actes de la IX Trobada d'Història de la Ciència i de la Tècnica*, SCHCT, [forthcoming].

67. *Patrimonio histórico-científico-social del Instituto Alfonso X el Sabio*, CEC, Murcia, 2002. J. A. Vidal

de Labra, *Conservación, actualización y divulgación del patrimonio histórico-científico-social del Instituto Alfonso X el Sabio de Murcia*, CEC, Murcia, 2002. See also A. Sánchez González and C. López Fernández, Museo de Física. in: http://centros5.pntic.mec.es/ies.alfonso.x.el.sabio/Historia/historia0.htm (accessed 4 June 2007).

68. J. L. García Hourcade et al., 'El Gabinete de Física en el Instituto de Segovia en el siglo XIX,' in *Estudios sobre Historia de la Ciencia y de la Técnica*, Junta de Castilla y León, Valladolid, 1988, 505-517.

69. A. Vázquez Alonso, 'Arqueología científica en el Instituto Balear ...' *Revista de Ciència* (1992), **11**, 9-18; **12**, 67-80; **13**, 65-72.

70. C. Pascual, *Patrimoni científic d'Alcoi. Col·lecció d'instruments i aparells del Museu Pare Vitòria. 75 anys d'ensenyament de les ciències*, Institut Pare Vitòria, Alcoi, 2007.

71. M. García del Real, 'Un gran patrimonio al descubierto: Los materiales científicos utilizados para la enseñanza en los institutos andaluces,' *Andalucía Educativa* (2001), **25**, 18-20; M. García del Real, 'El patrimonio científico de los institutos andaluces. Los laboratorios de Física y Química,' *Azimut* (2002), **7**. One of the best natural history collections belongs to the Granada secondary school 'Padre Suárez.' See http://www.museocienciaspadresuarez.com/ (accessed 19 June 2007).

72. Espiral (eds.), *OCNI – Objetos científicos no Imaginados. Fisikaren irakaskuntzarako tresnak Bizkaian*, Bilbao, 2003.

73. See Sisto, *op. cit.* (45).

74. R. Sisto Edreira, *O patrimonio histórico-científico do Instituto Xelmirez I (Santiago de Compostela). Inventario e Catalogación* ... Deputación Provincial da Coruña, A Coruña, 1999.

75. We are grateful to Leoncio López-Ocón and Pedro Ruiz Castell for this information. The project includes the collection of the 'Cardenal Cisneros' school, which celebrated its 150th anniversary in 1995.

76. See http://www.uv.es/comic, which includes a list of collections, among them, many from secondary schools.

77. The study has been possible thanks to a grant provided by Bancaixa-CSIC. For an overview of the collections, see the various chapters in J.R. Bertomeu and A. García (eds.), *Abriendo las cajas negras: Los instrumentos científicos de la Universidad de Valencia*, PUV, Valencia, 2002. We are very grateful to all the teachers who helped us in this project, particularly to J. Payá, F. Mezquita, L. A. Villada and Carlos Lancis. For additional studies and bibliography, see http://www.uv.es/comic.

78. See J. Heilbron, 'Some uses for the catalogues of old scientific instruments,' in *Essays on Historical Scientific Instruments* ... (ed. R.W. Anderson et al), Variorum, Aldershot UK, 1993, 1-16, quoted, on p. 4.

79. We employ the divisions presented in Adolphe Ganot's *Traité Elémentaire de Physique Expérimentale et Appliquée*, the first edition of which was published in Paris in 1851. Ganot's textbook, translated into Spanish and English among other languages, was one of the most to be frequently employed in physics teaching in Spain and many other countries, and it is an outstanding document of the French instrument trade and of the configuration of physics as a discipline in the school curriculum.

80. In the second edition of Ganot's *Traité*, the chapters on Heat and Light represented 20% of the book respectively, while the chapter on Dynamical electricity represented 14%. See A. Ganot, *Traité élémentaire de physique expérimentale et appliquée et de météorologie*, Chez l'Auteur, Paris, 1853.

81. Fournier-Balpe, *op. cit.* (12), appendix, 17-18; J. Simón Castel, *Els instruments científics de l'IES 'Lluis Vives*, 'Universitat de Valencia, València, 2002, 51-52.

82. See Simón Castel, *op. cit.* (81). On the Institute for Scientific Material, see *supra*.

83. See Heilbron, *op. cit.* (78), for a discussion on the analogy between material sources such as scientific instruments and written sources (manuscript or printed).

84. We are grateful to Carles Sirera and Francisco Mezquita for allowing us to employ their inventories of the archives of the Valencia and Castellón secondary schools, respectively. In many other schools, the archives and historical library have not yet been inventoried.

85.See the bibliography quoted in the first part of the paper.

86. For an introduction, see D. Kaiser (ed.), *Pedagogy and the practice of science: Historical and contemporary perspectives*, MIT Press, Boston MA, 2005; and the recent reviews by K. Olesko, 'Science pedagogy as a category of historical analysis: past, present, and future,' *Science & Education* (2006), **15** (2-3), and John L. Rudolph, 'Historical writing on science education: a view of the landscape,' *Studies in Science Education* (2008), **44** (1): 63-82.

The *Laboratorio Chimico* of the Museum of Science, University of Lisbon: Reflections on documenting a collection

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The *Laboratorio Chimico* of the Museum of Science of the University of Lisbon gives the historian an interesting opportunity: the *Laboratorio*'s surprisingly intact state and its collection provide an excellent case to look into the conditions of scientific practice at the Lisbon Polytechnic School by the end of the nineteenth century. Until now, narratives about the accomplishments of the important local chemists, Júlio Máximo de Oliveira Pimentel (1809–1884), António Augusto de Aguiar (1838-1887), Agostinho Vicente Lourenço (1826-1893) and José Júlio Bettencourt Rodrigues (1843-1893), have been based on textual sources: official reports, memoirs, scientific and popularising publications, archive material, and, to a great extent, oral tradition.[1] Material heritage offers another important source that can be explored further in the future. This chapter is the result of a study of about 40 objects belonging to the Museum's chemistry collection aimed at contributing to a better knowledge of their contexts of use. Our exploration of the collection brought us into contact with the practice of chemistry at the *Laboratorio Chimico* of the Polytechnic School, and late nineteenth-century higher education laboratories in general. This chapter focuses on two case studies: the Bunsen-Kirchhoff spectroscope and related spectral charts; and the gasometer, which will be discussed by addressing the major difficulties encountered during this research.

The Polytechnic School of Lisbon was a landmark in Portugal because it was one of the few schools where chemistry was taught. It was founded in 1837 in