THE ESTABLISHMENT AND DEVELOPMENT OF PHYSICS AND CHEMISTRY COLLECTIONS IN NINETEENTH-CENTURY SPANISH SECONDARY EDUCATION (1845 – 1861)¹

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ABSTRACT

This paper studies the formation of school cabinets of physics and chemistry in nineteenth-century Spain. It places the initiatives of the Spanish government in connection and comparison with those taken in France decades earlier. Thus, it analyses how the scientific, pedagogical, and commercial relations between France and Spain contributed to the establishment of Spanish school collections, and how these compared to those developed in France. Moreover, this paper evaluates the role of centralised policies in the acquisition of school equipment, and establishes a map of physics and chemistry school collections in Spain. In doing so, we locate the interest in studying the rich record of printed, manuscript, and material heritage in schools which is available to historians, and the importance of international comparison. In this context, we single out the major similarities and differences between Spanish and French collections, as well as within Spain, in schools with various financial, political, and intellectual means of support. Furthermore, we evaluate the capacity of Spanish schools and teachers to update their collections in relation to changes in pedagogical, scientific, and technological knowledge over time.

INTRODUCTION

The creation of school collections in physics and chemistry was central to the endeavour of establishing a national secondary school system in nineteenth-century Spain. The provision of cabinets and laboratories was undertaken almost simultaneously with the organisation of secondary schools, the publication of a national curriculum, the preparation of textbooks, and the establishment of a national institution aimed at training science teachers.

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The idea of national 'secondary education' was developed and implemented across Europe and the Americas during the nineteenth century. The first developments in this field happened at the turn of the eighteenth century in France and the German states (Anderson, 2004; Green, 1990). The Spanish educational reforms of the mid-nineteenth century followed closely the French example. This period, the French educational system was already mature, and played an important role in the advancement of physics and chemistry as disciplines. This had not always been the case.

The status of the physical sciences in the French school curriculum was low until the late 1830s. Although secondary education had been established in the first decade of the nineteenth century, the French government did not enact any measure to equip the school cabinets and laboratories until 1821, and this provision was not renewed until two decades later. Nonetheless, French instrumental science and technology, the entrepreneurial spirit of French booksellers and instrument makers, and the cultural impact of the Napoleonic imperial expansion in the eighteenth and early nineteenth centuries contributed to the international expansion of the French trade in scientific instruments and textbooks (Anderson, 1975; Simón, 2009, Chapter 2).

Although the organisation of school science education by the Spanish government relied heavily on the French experience, it also had distinctive features. First, the government provisions tackled the problem of providing schools with appropriate science collections contemporaneously with the establishment of secondary schools. Second, the national curriculum included a new subject 'Física y Química' which coupled the teaching of physics and chemistry, and opened a disciplinary space for these subjects distinct from mathematics. Finally, the scheme was designed to train teachers for secondary education and placed strong emphasis on the preparation of teachers in the physical sciences.

The wide range of educational initiatives implemented by the Spanish government (especially foreign, French) production in pedagogy and science. Nonetheless, the Spanish secondary school curriculum. They were taught in every school across the Spanish territory, and every school had a physics and chemistry laboratory. A large amount of these teaching collections have survived, together with associated sources such as manuscript and printed inventories, trade catalogues, equipment invoices, and student notebooks and examinations.

The aim of this paper is to study the making of the Spanish school cabinet of physics, to extract its major characteristics and principal variations, and to reflect on how the study of the characteristics of teaching collections can feed into the study of how they were actually used. While introducing a number of basic historical facts necessary to understand the making of these collections, our historical analysis is based on the comparison of combination with the study of connections. Thus, we will study both how the scientific, pedagogical, and commercial relations between France and Spain contributed to the making of Spanish school cabinets, and how Spanish school collections compared to those developed in France.

Furthermore, by comparing different Spanish collections, we intend to show that, in spite of the centralised initiatives of the government, there were different types of collections in different schools, and that this implied an uneven state of the teaching of the physical sciences across the Spanish territory. Finally, we will evaluate the capacity of schools and teachers to update their collections in relation to changes in pedagogical, scientific, and technological knowledge over time.

**THE ESTABLISHMENT OF SECONDARY EDUCATION IN SPAIN**

The first Spanish secondary schools were created during the 1830s and 1840s through isolated but overall coherent initiatives of municipal political forces, after the disentailment of the property of religious orders by the Spanish Liberal government. Between 1835 and 1844, 24 secondary schools — called *institutos* — were established. In 1845, an educational reform promoted by the Minister of Education (Home Secretary) Pedro Fidalgo, and the officer Antonio Gil de Zárate provided secondary education with a legal framework, and gave rise to the establishment of additional schools. In 1868, *institutos* numbered 66, of which 49 were located in the capitals of the Spanish provinces constituting the administrative structure of the country, and 17 were established in other resourceful towns (Gil de Zárate, 1855, II, 61ff; Víñales, 1982, 33.5 ff).

However, the status of these schools was uneven and related to their capacity to raise funds. There were 11 *institutos* attached to universities (Madrid — with two *institutos* — Barcelona, Granada, Oviedo, Salamanca, Santiago, Sevilla, Valencia, Valladolid, and Zaragoza) which were the only ones offering the whole secondary school curriculum. This consisted of five years of the elementary secondary school curriculum, followed by two additional years which presented two options (literary and scientific) and gave access to university studies.

Provincial *institutos*, located in the province capitals, were funded by the provincial governments, were funded by the provincial administrations provided by the central government. Most of them (around 30 by mid-century) were able to offer the complete elementary curriculum. Local *institutos* had to rely on funding provided by their town council or foundations established in them, and many of them were unable to offer more than the first four years of secondary education.

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2 During the first three decades of the French secondary school system, the physical sciences were in general annexed to the teaching of mathematics as this subject and its teachers had a higher status in the school curriculum and professional system, respectively. Also, there were not many teachers prepared to teach physics and chemistry. This state of affairs had started the change through from the 1830s (Simón, 2009, pp. 34-38).
In general terms, the *institutos*’ funding was based on student fees (around 60 per cent of the contribution of town councils or provincial administrations, and 40 per cent by property released after the Liberal confiscation of Catholic estates. By the end of the century, many *institutos* were highly profitable institutions, but some of them suffered losses. Some *institutos* had to fight against the fierce competition of private Catholic schools, which were favoured by the Conservative government who came into power in the 1850s (Delgado Criado, 1994; Díaz de la Guardia, 1998; pp. 461–67; Gil de Zárate, 1855, p. II). Víctor Frago, 1982, 338 ff.).

In this context, physics and chemistry were taught to a minority of students. The subject was commonly taught during the fifth year of studies, involving five hours per week. Thus, it was not available in all the *institutos*. The first official syllabus was published during the 1840s, covering the whole spectrum of experimental physics (mechanics, hydrostatics and hydrometries, acoustics, heat, optics, electricity and magnetism), together with some lectures on "notions of chemistry". The disciplinary coupling of physics and chemistry had its origins in the first Liberal educational reforms of the 1830s, even though it was, in principle, a genuinely Spanish characteristic. However, in France, the formal coupling had briefly existed after the Revolution and, like in other countries in the nineteenth century, physics and chemistry were often taught together in French schools, within a more generic subject termed "sciences physiques" (Simon, 2009, Chapter 2; Sisto Edreira, 2007, 183 ff.).

The sciences had an important driving agency in the development of modern curricula, always in tension with the traditional classical curriculum. At the beginning of the century, several Liberal projects allocated a large space to specific subjects such as chemistry applied to the arts, experimental physics, mathematics, and natural history. But subsequent reforms limited their importance, promoting a more humanistic approach focused on Latin, grammar and literature, and ethics and religion. Javier de Cueto, an influential commentator, as former educational administrator, and editor of the *Boletín Oficial de Instrucción Pública*, remarked that improving the status of the sciences meant diminishing that of the humanities, and that specialisation would have deprived secondary education of its preparatory role for university studies (Moreno, 1988, pp. 227-54).

The debate on the purpose and contents of secondary education – humanistic versus science, and specialisation versus *Bildung* – endured even beyond the nineteenth century, and was common to many countries (Delgado Criado, 1994, pp. 159–60; Donnelly, 2002; Fournier-Balpe, 1994). Scientific subjects were restricted to an early training in elementary mathematics, together with courses in "physics and chemistry" and natural history, only provided in the last years of the secondary school curriculum (López Martínez, 1999).

In fact, by the mid 1840s, it was also difficult to find in Spain physics teachers who taught the physical sciences. The first initiatives to provide secondary schools with physics and chemistry teachers were taken independently by some *institutos*.3

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3 The Spanish Parliamentary Papers.
from foreign production, and making the introduction of French textbooks in the Spanish market very difficult – with the exception of Ganoit’s translation which survived the competition. Another fundamental tool for the implementation of the teaching of the physical sciences was the provision of school collections. As we will see, the French model was also influential in this case.

THE CREATION AND DEVELOPMENT OF PHYSICS AND CHEMISTRY COLLECTIONS

The creation of physics cabinets and chemistry laboratories was a high priority for the Spanish government, and administrative measures were taken to this end shortly after the official establishment of secondary education in 1845. Centralised purchases took place, aimed at establishing collections which would contribute to the development and consolidation of the teaching of the physical sciences in the institutos. The first purchases were organised thanks to the initiative of the Education secretary, Antonio Gil de Zárate.

Before joining the state education administration, Gil de Zárate had been educated in the first two decades of the eighteenth century in France, later attending lectures on experimental physics at the Reales Estudios de San Isidro in Madrid. He subsequently returned to Paris to pursue his preparation, but did not succeed in becoming a physics teacher in Spain due to adverse political upheavals (Gil de Zárate, 1850, pp. iv–xvi). His educational background was crucial in his contribution to the reform of university and secondary school curricula in the 1840s. After surveying the Spanish university collections, a reference catalogue of physics and chemistry collections was compiled by a commission of university professors appointed by the Spanish government (Pidal, 1846).

At the end of 1846, Gil de Zárate – accompanied by Juan Chavarri – travelled to Paris to organise the purchase of physics and chemistry instruments for the universities. In November, they met Mateu Orfília (1787–1853), a Spaniard who had made a successful career in France as a professor of medical chemistry and dean of the Paris Medical Faculty (Bertomeu-Sánchez and Nieto-Galan, 2006). Thanks to Orfília’s advice, Gil de Zárate obtained the services of four Parisian instrument makers: Messers Pixii and Delsuix for the physics instruments; Leduc & Cloch for the glassware and porcelain; and the brothers Rousseau for chemistry products and instruments. 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 cabi-
almost complete, and only five secondary schools were ill-equipped. A few years later, Gil de Zárate remarked proudly that many institutos (such as Palma de Mallorca, Girona, Lleida, and Ourense) had larger collections than those prescribed by the model catalogue (Gil de Zárate, 1855, II, pp. 80–161). So, how important was the impact of the Spanish government’s reference catalogue in the quantitative and qualitative constitution of the institutos’ physics collections? And what were the main characteristics across the Spanish territory?

In the early 1860s, most institutos published complete catalogues of their teaching collections. They were included in the yearly reports submitted by every instituto to the government and published in their Memorias. The publication of the institutos’ Memorias had been established by the Spanish government in the late 1840s. They documented quantitatively and qualitatively life at the instituto, including information about its collections, libraries, premises, staff and students, preceded by a presentation by the school principal. This presentation was based on the annual speech made by every school principal to inaugurate the academic year. In this ceremony, attended by the major social representatives in every town, copies of the previous year’s Memorias were presented. Furthermore, the institutos often exchanged their Memorias between themselves. Thus, the Memorias had a combined administrative and social function. They obliged the schools to keep a regular record of their activities and they helped the government to control them; they were also used as a tool of social and institutional prestige at the local and national level, since they publicly displayed the relative influence and capabilities of each instituto (Simon Castel, 2008).

These catalogues display clearly the heterogeneity of the institutos’ collections around 1860. In general, the school collections followed the foundational pattern provided by the 1847 government reference catalogue, but they had introduced some upgrades, replacements, and additions. Most of the institutos located in university towns had collections which trebled the number of items recommended in the 1847 secondary school reference catalogue, and doubled those in the reference catalogues for Spanish universities (1846) and French colleges (1842). A considerable number of provincial institutos had also managed to increase their collections beyond the recommendations of the Spanish university.

8 The report appeared in the Gaceta de Madrid, 7 September 1850, pp. 1–3. It did not include the university secondary schools and the secondary schools in which physics and chemistry were not taught.

9 Thus, for instance, the instituto of Valencia has preserved in its library a large set of Memorias of almost all the schools in Spain, which allowed us to compare the instrument catalogues of a large number of schools.

10 In this paper we have worked through comparisons with a set of printed collection catalogues published in 1861–62 in the institutos’ Memorias. The set includes four university institutos (Granada, Oviedo, Salamanca, and Valencia), 21 provincial institutos (Albacete, Badajoz, Burgos, Cáceres, Castellón, Ciudad Real, Cuenca, Gerona, Huelva, Huesca, Jaén, Lérida, Logroño, Málaga, Orense, Palencia, Pamplona, Pontevedra, and Sarria), and two local institutos (Figueras and Menorca de Lémos). The complete bibliographical references of these catalogues are available in the bibliography at the end of this paper.
and school catalogues. But many others could only match or approach these recommendations made more than a decade earlier. This was also the case for most local institutos.

The reference catalogue published by the Spanish government in 1847 for institutos was a reduced version of that published the year earlier for the universities. The two catalogues were roughly similar both in quantitative and qualitative terms, but the university catalogue contained almost a third more physics instruments and triple the number of chemistry items. The university collection allowed for the exposition of a wider range of physical and chemical phenomena. Furthermore, the school reference collection was cheaper, indicating that university instruments were probably of a greater quality and sophistication which could be used not only in teaching but, in certain cases, also in research. Examples of this can be found in the range of thermometers, barometers, telescopes, and electric machines included in the two catalogues. Moreover, the university catalogue included items such as a polariscope and an apparatus to demonstrate the development of magnetism by rotation — both devised by François Arago — which were more closely connected to contemporary research.

On the other hand, comparing the 1846 Spanish university and the 1842 French college catalogues shows that the French school reference model contained a fifth more physics instruments, but a similar number of chemistry items. The French reference collection contained a larger number of barometers and thermometers, more advanced instruments for the study of heat, and electricity and magnetism, and more recent industrial applications such as magneto-electric apparatuses. Many of these instruments were related to research work conducted in Paris by physicists such as François Arago, Alexandre-Edmond Becquerel, and Macedonio Melloni. The Spanish catalogue was very poor in acoustics instruments in comparison to the French school reference collection. In contrast, the latter had fewer instruments to illustrate the mechanics of solids, surely because mechanics was considered a subject independent from general physics in France.

In many respects, the 1847 Spanish instituto catalogue was similar to the 1821 French college catalogue in listing a limited number of instruments aimed at illustrating simple physical phenomena (Conseil royal de l'instruction publique, 1821, 1842, 1843; Pastor Díaz, 1847b; Pidal, 1846).

By the early 1860s, the state of the physics collections in the Spanish institutos was diverse. The analysis of the collection catalogues of a sample of 27 institutos shows that, quantitatively, those located in university towns had trebled the number of instruments recommended in 1847, and doubled that of the reference collection for the universities suggested a year earlier. Their collections were larger now than the physics collection of the 1842 model catalogue for the French colleges. Some provincial institutos were also in this range (Orense, Lérida, and Badajoz). A similar number of provincial schools were above the Spanish university catalogue but below the French college model (Pontevedra, Gerona, Burgos, and Pamplona). A larger number of these schools were above the Spanish school reference catalogue but below the university catalogue model (Logroño, Figueras, Soria, Ciudad Real, Alicante, Málaga, and Castellón). Thus, almost three quarters of the institutos had increased their collections beyond the 1847 government recommendations. However, only half of these had increased considerably their collections, surpassing even the recommendations made in 1846 for Spanish universities. Only a select number of institutos located in university and provincial towns excelled in the update of their physics cabinets, by surpassing considerably the size of the collections recommended in previous Spanish and French government reference catalogues.

There were also differences in the ways in which the Spanish institutos updated their collections in the years between their establishment and the general survey of 1861–62. In the early 1860s, the pattern of the 1847 reference catalogue for the institutos could be clearly seen in all the physics collections of the Spanish secondary schools. The largest collections had built on this pattern, and increased and updated it. The smaller collections were similar to the 1847 reference collection or still tried to match it a decade-and-a-half later. Thus, it is without doubt that the initiative of Gil de Zárate had a major impact in the making of the Spanish school collections. Besides the government purchases, the exemplary value of the government model collection, designed by Gil de Zárate and collaborators such as Juan Chavarrí (physics professor in Madrid and a major textbook author), had a huge impact on Spanish collections. However, there were differences which affected not only the largest schools, but most of the institutos.

The largest institutos, in university towns and some provincial capitals, were able to increase their collections with a large number of instruments, especially related to electricity, but also in optics and heat. These additions allowed diversification was lower than that recommended in the 1847 reference catalogue for Spanish schools. This might have been that the instituto was using the university collections, or because it had financial and professional problems in relation to its professorship of 'physics and chemistry' which we have not been able to elucidate yet.

In chemistry, however, only a few institutos (Valencia, Oviedo, Salamanca, Lérida, Soria) appear to have matched or surpassed the recommendations published in the 1840s for the Spanish universities and French colleges, and many of them only matched those for the instituto. However, these results are more preliminary, since chemistry collections are more difficult to count. The chemistry catalogues are more heterogeneous and less systematised. They could, for instance, only contain apparatuses or also include glassware or chemical substances. In our analysis we have not taken into account the latter, which were not recorded in many catalogues.

It is a question for further research to determine how representative the 1847 Spanish model collection was in the international context of physics teaching. A first attempt has been made in this paper to compare it with the French government school pattern, showing differences in the number of instruments in mechanics and acoustics in both models and a lower capacity in Spanish collections to update in relation to contemporary research. However, further comparative work needs to be done.

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11 But chemical substances — in large numbers in the French catalogue — were not included in the Spanish reference collection.

12 This was the case of Valencia, Salamanca, and Oviedo. Granada was an exception, which still needs an explanation. In 1861, the number of physics instruments of the Granada instituto
flying the range of natural phenomena that teachers could demonstrate in the classroom. This included, for instance, phenomena of light polarisation, thermo-electricity, and electromagnetic induction which had been investigated for the first time in the previous decades. By the 1870s, a large university institutio such as Valencia had introduced in its collection instruments of most recent invention such as a Crookes radiometer, a telephone, and a microphone. Many smaller institutios, which did not have great purchasing capacity to cope with recent advances in physics, showed nonetheless an interest in updating their collections. Thus, for instance, many schools introduced polarity instruments such as Arago’s polariscopio (Oviedo Salamanca, Burgos, Baeares, and Gerona, but Ciudad Real, and Cuenca, as well) and Norrenberg’s polarimeter (Salamanca, Baeares, Burgos, and Gerona, but also Málaga, Cuenca, and Monforte de Lemos, a local school), induction apparatus such as Ruhmkorff’s coil (Valencia, Salamanca, Lérida, Baeares, Gerona, Alicante, and Pontevedra), and instruments for the study and illustration of discharges in gases such as Geissler tubes (Lérida, Baeares, Gerona – provincial but not university institutios). The smaller institutios had to be selective in their purchases, and thus they often focused only on one branch of physics, typically electricity. Most schools expanded their collection range of batteries and included some illustrations of industrial or commercial applications of electricity such as a telegraph model, an electro-medical apparatus or electromagnetic apparatus. Other typical additions, which had an explicit pedagogical purpose, were stereoscopes, magic lanterns, and photographic cameras. But size, political location, and economic influence were not the only parameters which explain collection composition. Thus, for instance, the only galvanometers available in Spanish schools were to be found not in the largest university or provincial institutios (with the exception of Salamanca), but in small schools such as that of Logroño and especially Huesca and Monforte de Lemos. Analogously, many institutios increased considerably their collections of thermometers and barometers, and acquired high precision instruments in relation to their meteorological stations. Indeed, secondary schools and their science teachers contributed to the establishment of a national meteorological network, coordinated by the Astronomical Observatory in Madrid. Meteorological data were processed in Madrid, but were also published in local newspapers and in the school Memorias. Some of these observations were also compiled and analysed by the physics professor and major textbook author Manuel Rico y Sinobas (Anduaga, 2003; Sisto Edeire, 2007).15

During the 1850s and 1860s, many schools were equipped with meteorological stations. Small schools such as Cuenca, Huesca, and León could thus increase their instrument collections. In 1856, for instance, the ‘physics and chemistry’ teacher Frances Bonet i Bonfill established a meteorological station in Lérida and two years later started to send data to Madrid (Casals Berges, 2006, pp. 243–46). In 1861, the director of the Cáceres institutio established another meteorologi-

15 We would like to thank Aitor Anduaga for providing us with some data and advice on the Spanish meteorological network.

16 The details of this project and the current state of its repository can be checked at www.instrumentscientifics.com.
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