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 earliest 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. In 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 instrument makers, textbook authors, and publishers developed their businesses in consonance with the highly profitable establishment of a national network of schools and faculties of sciences and medicine, which constituted a faithful and lasting clientele. Furthermore, the international prestige of French pedagogy, science and technology, the entrepreneurial spirit of French booksellers and instrument makers, and the cultural impact of the Napoleonian imperial expansion in the late eighteenth and early nineteenth centuries contributed to the international expansion of the French trade in scientific instruments and textbooks (Anderson, 1975; Simon, 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 thus provided a disciplinary space for these subjects distinct from mathematics.[2] Finally, the scheme designed to train teachers for secondary education placed strong emphasis on the preparation of teachers in the physical sciences.

The wide range of educational initiatives implemented by the Spanish government yielded uneven results. Furthermore, they depended considerably on foreign (especially French) production in pedagogy and science. Nonetheless, by the 1860s, physics and chemistry were subjects firmly established in the Spanish secondary school curriculum. They were taught in every school across the Spanish territory, and every school had a physics cabinet 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.

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 to change though from the 1830s (Simon, 2009, pp. 34–38).

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 combination of comparison 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 Ministro de Gobernación (Home Secretary) Pedro Pidal, 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; Viñao Frago, 1982, 335 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 budget of 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.

In general terms, the *institutos'* funding was based on student fees (around [illegible] per cent), the contribution of town councils or provincial administrations, and the rents and 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, 1988, pp. 461–67; Gil de Zárate, 1855, p. II; Viñao Frago, 1982, 338 ff.).

In this context, physics and chemistry were taught to a minority of students. The 'Física y Química' 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 hydrodynamics, 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, and it was, in principle, a genuinely Spanish characteristic. However, in France this 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, but always in tension with the traditional classical curriculum. At the beginning of the century, several Liberal projects allocated a large space to scientific 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 Quinto, an influential commentator, as former educational administrator, and editor of the *Boletin Oficial de Instrucción Pública*,[3] 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. 252–54).

The debate on the purpose and contents of secondary education – humanities 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 then 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 teachers able to teach the physical sciences. The first initiatives to provide secondary schools with physics and chemistry teachers were taken independently by some *institutos*, be-

3 The Spanish Parliamentary Papers.

fore the introduction of Pidal's legal framework. The call for positions was designed as a public competition. The qualifications included the preparation of a syllabus, details on its pedagogical implementation, and references to the textbook or textbooks in Spanish which would be used. There was an oral examination, which in certain cases included the performance of some basic demonstrations and experiments.[4]

After 1845, the Spanish government published an official syllabus for the subject and established a national legal framework for the hiring of secondary school teachers. However, the professional profiles of physics and chemistry teachers were uneven, since in the faculties of philosophy the presence of the physical sciences was heterogeneous, and in general poor. In his retrospective analysis of Spanish education, the Education officer Gil de Zárate noted that most teachers were not experts or lacked the appropriate pedagogical training, thus communicating knowledge and using a teaching style often inadequate for the education of secondary school students (1855, pp. 44–45, p.66–67).[5]

The educational and professional profiles of the first 'physics and chemistry' teachers were thus heterogeneous. Most of them had been trained as apothecaries or medical doctors. Around a third of them had obtained a diploma in the sciences after concluding their elementary secondary education, and a similar number had previously taught physical sciences in the faculties of philosophy. Only a few of these teachers had a doctorate in sciences or in pharmacy. Others had previously been educated in law and pursued informally their interest in science.[6]

In order to confront this lack of preparation and professionalisation, the Spanish government followed the French example in attempting to establish a special institution aimed at training science teachers for the secondary school network (Fournier-Balpe, 1994, pp. 119–42). The preparation of science teachers was considered a priority, for they were more scarce than other teaching staff. However, in contrast to the French case, the existence of such an institution was too ephemeral and did not have a major impact.

After an early trial experiment in the late 1840s, in 1850 the Escuela Normal de Filosofía was established with the exclusive aim of training science teachers (Gil de Zárate, 1855, II, pp. 66–67; Moreno, 1988, pp. 310–11). To gain admission to this school, candidates should have successfully completed secondary education and were offered a scholarship to attend lectures for four years. The curriculum was organised in three different sections: literature, 'physico-mathematical sciences' and 'natural sciences', and the lectures were given by university pro-

4 These positions were advertised by the *institutos* of Cáceres, Tudela, and Sanlúcar de Barrameda in the *Gaceta de Madrid* (1 September 1841 and 16 May 1843).

5 In fact, during the first half of the nineteenth century, similar remarks can be found in the reports of French education inspectors concerning the performance of physics teachers in the French colleges (Balpe, 1997).

6 Lists of all the Spanish secondary school teachers, specifying their educational and professional backgrounds and the history of their educational contracts, appeared from 1860 periodically in publications such as the *Gaceta de Madrid* and the *Revista de Instrucción Pública*.

fessors. On graduating, students were automatically conferred a university degree in science and were given preference in the awarding of secondary school teaching positions. Subsequently, they were expected to serve as teachers for a decade; and breaking their contract was penalised by the loss of their teaching and academic status (Seijas Lozano, 1850, pp. 33–34). The Escuela Normal produced a selected number of science teachers who found positions in the Spanish *institutos* and universities. However, it was suppressed for political reasons in 1852 and was thus unable to have a significant effect on the teaching of the sciences (Delgado y Vargas, 1860; Yanes Cabrera, 2006). From 1857, the newly established faculties of sciences assumed the role of providing teachers for the secondary school system (Moya Cárcel, 1991).

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 analyses; be part of literary and scientific societies; collect meteorological data for the government; perform mineralogical surveys; collect minerals, botanical, and zoological specimens; and actively participate in the public sphere through contributions in general and specialised 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 (López Martínez, 1999; Moreno, 1988).

As the first initiatives to provide the *institutos* with 'physics and chemistry' teachers show, the production of science textbooks in the national language was a major priority. Three physics textbooks had a major circulation in the Spanish *institutos*: *Manual de física y nociones de química* (1847) by Manuel Rico y Sinobas and Mariano Santisteban; *Programa de un curso elemental de física y nociones de química* (1848) by Venancio González Valledor and Juan Chavarri; and *Tratado elemental de física experimental y aplicada* (1856) by Adolphe Ganot. All three saw many editions.

Juan Chavarri and González Valledor were professors of physics at the Central University in Madrid, Santisteban held the chair of 'physics and chemistry' at the *instituto* of San Isidro (the largest in Spain), and Rico y Sinobas was professor of physics at the University of Valladolid. These authors took the responsibility of preparing the first 'physics and chemistry' textbooks for the Spanish secondary schools (Egido et al., 2000; Guijarro Mora, 2002). Some of them had already been involved in this task through translation work. For instance, González Valledor had translated a major physics textbook by the French secondary school teacher Nicolas Déguin. Translations from the French had been usual in previous decades. Hence, from the 1850s Adolphe Ganot's textbook found a place in the Spanish market, in spite of important competitors. It was translated by José Monlau, a former student of the Escuela Normal.

While these three books dominated the market, there were many other physics textbooks prepared by Spanish secondary school teachers. The contribution of Spanish authors rose from the late 1860s, attaining a high level of independence

from foreign production, and making the introduction of French textbooks in the Spanish market very difficult – with the exception of Ganot'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.[7]

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 Orfila (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 Orfila's advice, Gil de Zárate obtained the services of four Parisian instrument makers: Messrs Pixii and Deleuil for the physics instruments; Lizé & Clech 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-

7 Some *institutos* already had collections, though. The *institutos* located in university towns initially used the university cabinets. Others, such as that of San Isidro in Madrid, inherited important collections held by previous eighteenth-century and early nineteenth-century institutions.

nets", "precision scales", steam machine models, chemical apparatuses and substances, a mineralogical collection and a large number of medical charts.

By the same token, in September 1846 a reference catalogue was established to equip the physics and chemistry cabinets of secondary schools (Gil de Zárate, 1846). The list of instruments was based on the catalogues of the French makers Lerebours and Pixii, including 152 physical instruments (valued at 9,531 francs) and 133 chemical items (valued at 6,448 francs) (Gil de Zárate, 1847 and 1855, III, pp. 255–57; Simon Castel, García Belmar, and Bertomeu Sánchez, 2005). However, the collection was subsequently reduced, particularly in the case of chemistry, for which the funds were reduced to just 10 per cent of the initial amount (that is, 600 francs). The collection of physics instruments was reduced to 116 items only, although for almost half the price of the original amount (5,000 francs). The fields better represented in the physics list were electricity and magnetism (39), mechanics (15) and pneumatics (19) (Pastor Díaz, 1847a).

In the making of the reference catalogue, Gil de Zárate had considered that the teaching of the physical sciences in secondary education should not be based only on oral presentations of the subject. It should especially include the examination of instruments and the performance of experiments and manipulations. Furthermore, teachers should not limit themselves to teaching. It was also their mission to get involved in research and thus contribute to the patriotic advancement of the country through the production of original science and its applications to industry. His dealings in Paris in relation to university collections saw a larger purchase than originally expected, and thus a certain number of additional instruments might have been distributed to some *institutos*. For this reason, perhaps, the reference catalogue for the latter was subsequently reduced. Furthermore, Gil de Zárate had already established commercial relations with the instrument maker Pixii who provided instruments both for the universities and *institutos* and, therefore, he managed to get discounts which surely reduced the price of the *institutos'* purchase. In addition, by 1847, the subject matter of chemistry in the Spanish secondary education curriculum had been considerably reduced and, as a consequence, it was deemed appropriate to limit its associated collections (Pastor Díaz, 1847a).

Gil de Zárate had followed procedures similar to those promoted a few years earlier in France by Louis-Jacques Thenard. In 1842, Thenard had initially sent copies of the catalogues of instrument makers Deleuil and Pixii to all French schools, followed by a centralised survey of their collections and the publication of a reference catalogue. Pixii had also been one of the major instrument makers recommended by the French government in its previous reference catalogue published in 1821. Both the 1821 and 1842 French reference catalogues suggested that, although the major aim in the development of collections was pedagogical, when possible schools would also purchase instruments intended for research work by their physical sciences teachers (Belhoste, Balpe, and Laporte, 1995; Conseil royal de l'instruction publique, 1842, pp. 181–91).

By the mid nineteenth century, according to a Spanish governmental report, 19 secondary schools had a complete cabinet of physics, 11 other cabinets were

almost complete, and only five secondary schools were ill equipped.[8] A few years later, Gil de Zárate remarked proudly that many *institutos* (such as Palma de Mallorca, Girona, Lleida, and Orense) 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 their 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 *Memorias* were presented. Furthermore, the *institutos* often exchanged their *Memorias* between themselves.[9] 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 affluence and capabilities of each *instituto* (Simon Castel, 2008).

These catalogues display clearly the heterogeneity of the *institutos'* collections around 1860.[10] 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 collèges (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* (Alicante, Badajoz, Baleares, Burgos, Cáceres, Castellón, Ciudad Real, Cuenca, Gerona, Huelva, Huesca, Jaén, León, Lérida, Logroño, Málaga, Orense, Palencia, Pamplona, Pontevedra, and Soria), and two local *institutos* (Figueras and Monforte de Lemos). 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 the 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 the *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 collège catalogues shows that the French school reference model contained a fifth more physics instruments, but a similar number of chemistry items.[11] 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 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 collège 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.[12] Some provincial *institutos* were also in this range (Orense, Lérida, and

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*

Baleares). A similar number of provincial schools were above the Spanish university catalogue but below the French collège 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.[13]

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 Chavarri (physics professor in Madrid and a major textbook author), had a huge impact on Spanish collections.[14] 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 diversi-

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.

13 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 *institutos*. 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.

14 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.

fying 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 *instituto* 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 *institutos*, 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 polarimetry instruments such as Arago's polariscope (Oviedo Salamanca, Burgos, Baleares, and Gerona; but Ciudad Real, and Cuenca, as well) and Norremberg's polarimeter (Salamanca; Baleares, Burgos, and Gerona, but also Málaga, Cuenca, and Monforte de Lemos, a local school), induction apparatus such as Ruhmkorff's coil (Valencia, Salamanca, Lérida, Baleares, Gerona, Alicante, and Pontevedra), and instruments for the study and illustration of discharges in gases such as Geissler tubes (Lérida, Baleares, Gerona – provincial but not university *institutos*). The smaller *institutos* 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 affluence 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 *institutos* (with the exception of Salamanca), but in small schools such as that of Logroño and especially Huesca and Monforte de Lemos. Analogously, many *institutos* 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 Edreira, 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 Francesc 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 *instituto* established another meteorological station in its premises. The instruments, made in Paris, were calibrated in the Madrid Observatory before being sent to the school (Sergio Sánchez, 1861, p. 9). However, in general the meteorological instruments of the *institutos* made an exception to the general pattern of dependence on the French instrument trade, which was not challenged by the timid emergence of the Spanish instrument industry. In schools with large meteorological collections such as Oviedo, Salamanca, and Burgos, many of the instruments were made by leading makers in London of Italian origin such as Casella, and Negretti & Zambra (Ruiz Castell, Simon, and Bertomeu Sánchez, 2002; Williams, 1994).

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

CONCLUSION

About fifteen years after the official establishment of physics and chemistry school collections in Spain, secondary schools still depended considerably on foreign instrument makers, and many of them had not managed to considerably update their collections. However, almost all the schools updated giving due priority – and according to their budgets – to the most topical areas of research at the time, and all of them made significant additions to their library of experimental demonstrations. The centralised initiatives of the Spanish government had a major impact on the configuration of physics and chemistry collections. But their subsequent development depended in great measure on the financial capacity of the different *institutos*, which was related to the number of students, their connection with the local political administrations, and their geopolitical location. The largest schools, located in university and provincial towns, were able to update their collections, increasing the pedagogical repertoire of science teachers and incorporating some contemporary advances in the physical sciences and instrument making. The smaller schools, located in some provincial towns and in some small towns with educational traditions, faced major problems in increasing and updating their collections. However, in many cases they were able to change with the times by including new items for pedagogical illustration of the most topical areas of physics.

The analysis of the Spanish school collections in physics and chemistry offers valuable approximations to the study of science in the classroom. However, a more in-depth study is still needed in order to elucidate how the collections were used. This research will have to integrate other sources as well, such as scientific instrument collections, teacher and student notebooks, textbooks, and trade catalogues. The recovery of these sources is currently being developed through an online project supported by the Catalan Scientific Instrument Commission (COMIC) which is currently creating a repository integrating these sources and offering updated information tools on Spanish projects in this field.[16]

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

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