

# **The unrecognized mechanism: History of science education in the nineteenth century**

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## **Abstract**

Despite the many assumptions that usually surround the historical role of science education in scientific practice, scholarship on the subject has been scattered, disjointed and usually undertaken en route to other pursuits. It is the purpose of this paper to show that science education is very often implied in much of the recent scholarship in the history of science and to bring to the fore science education as an unrecognized integrating mechanism within nineteenth century science. It proposes to do so, firstly, by highlighting some ways that established historiographical narratives centered in the nineteenth century are enriched by taking into consideration the role of science education and secondly, by underlining how science education facilitated and contributed to the circulation and appropriation of scientific practices within nineteenth century European space. To achieve these goals, specific case studies will be presented from the German lands, post-Napoleonic France, England and early Modern Greece, each one focusing on different aspects of the interplay between science and education, across different national and institutional spaces.

## **Introduction**

The circulation and appropriation of scientific knowledge and practice has been an important theme for the historiography of science and has inspired an impressive corpus of research<sup>1</sup>. In many ways, it has been recognized as one of the central question for the history of science (Secord 2004, 655; Simon et al. 2008, 11-12). It is thus worth noting that this expansion of the research horizon has resulted in a shift of the historiographical focus away from traditional loci of investigation. Europe, the archetypical space of such investigation, has evolved from being the unproblematic origin of modern science to becoming the nominal boundary of different and diffuse spaces. It is perhaps time to reconsider the ways recent scholarship can be directed to once again shed light on the mutual, parallel emergence of scientific practices and European sociocultural space. This, it seems, was not an historical event, but rather a

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<sup>1</sup> The literature on the subject is vast and it is not the aim of this paper to provide a synopsis, even if such a thing would be possible. Very schematically, the starting landmark study is taken to be Bassala 's famous, if widely contested, paper (Bassala 1967, Raina 1999). Later on, relevant scholarship expanded to include studies on science and imperialism (Pyenson 1985, 1989, Paladino, Worboys 1993) and on the reception of theories and practices (Glick 1988, Brush 1999). In recent years, very similar themes are discussed in relation to a global history of science (Schaffer et al 2009, Elsakry 2010, Sivasundaram 2010) or to inquiries on 'centers' and 'periphery' in scientific production (Gavroglu et al. 2008). Finally, there is a flourishing discussion on the relation between space and scientific practice (see for example Smith, Agar 1998, Livingstone 2003)

process, which continued well into the nineteenth century and in many ways, it still goes on today.

In this light, the goal of this paper is to present science education as an unrecognized mechanism of scientific integration within nineteenth century European space. While a full, normative definition of the term 'science education' is not easy to formulate, for the purposes of this study science education will be taken to include the teaching of science and its related pedagogy, as well as the material and institutional panoply it requires, such as textbooks, laboratory equipment, curricula and legislative actions. With such a broad operative definition, one would expect, at first glance, for the history of science education to figure prominently in the historiography of science. Within the practice of science education, society and ideology and science explicitly converge (Olesko 1993, 21-28). The classroom is where science confronts the public, but also where the scientist himself is made (Rudolph 2008, 64-65). Finally, science education is the most concrete example of science policy, or of lack thereof. It is the state, by its intervention or absence, which defines educational reality and which decides what and how it will be taught.

It is thus peculiar that, so far, scholarship on the history of science education has been scattered, disjointed and usually undertaken en route to other pursuits. It is also indicative that there has not yet been an autonomous, comparative or synthetic monograph on the history of science education<sup>2</sup>. More often than not, pedagogical activities are implicitly considered the 'last existential acts' of mature scientific communities (Brooke 2000, 2). In short, the classroom, the textbook and the curriculum seem to appear in historical discourses after the scientist is done being a scientist. Science education is taken, at best, to push scientific Paradigms across generations without ever intervening in their core. It is the purpose of this paper to at least partially challenge these historiographical assumptions, by focusing on two themes. Firstly, it aims to highlight ways that established historiographical narratives centered in the nineteenth century are enriched by taking into consideration the role of science education. Secondly, it aims to underline how science education facilitated and contributed to the circulation and appropriation of scientific practices within nineteenth century European space.

To achieve these goals, in the next sections, specific case studies will be presented, each one focusing on different aspects of the interplay between science and education, across different national and institutional spaces. In that way, common elements and processes will become more easily apparent and the importance of the underlying European cultural and intellectual space will be easier to recognize. However, it will also mean that in some cases, the analysis will not be as detailed as it could be and that synthesis will be preferred over fine scaled narratives. It is one of the leitmotifs of this paper that science education is often implied in much of the recent scholarship in the history of science and that it needs to be brought at the fore. Thus, secondary

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<sup>2</sup> The number of studies dedicated explicitly to the interrelation between scientific practice and science education are very few. A recent survey can be found in Rudolph 2008, but it is not exhaustive. The first study explicitly focused on the historiographical relation between science and education was Hannaway 1975, while a survey of the literature until then can be found in Brock 1975 and more selectively in Brock 1990. Landmark studies on the theme are Olesko 1991, Rudolph 2002 and Warwick 2003. A theoretical context for the role of science education in scientific practice can be found in Warwick, Kaiser 2005 and Mody, Kaiser 2007, while internalistic accounts of science education in specific national contexts are DeBoer 1991, Hulin 2007. Finally, for a much needed, albeit contextually confined, focus on the historical interplay between gender and science education, see Tolley 2002.

literature will also be used, in order for examples to be drawn across a variety of contexts.

### **Scientific and educational reforms in the German lands**

Our first case study is to be drawn from the German lands during the nineteenth century. Despite the fact that Prussia, Bavaria, Saxony and Baden did not form a unified political entity until 1871, they followed parallel paths in their scientific development. It is a very familiar narrative the one that describes how Germanic science followed a meteoric rise during this period, which in turn caused at first the surprise and later the consternation of French and English scientists and politicians (Knight 2009, 196-219). This is also what the rhetoric of contemporaries seems to suggest. For example, Charles Adolph Wurtz, a prominent member of the French scientific community, filled pages upon pages of anguished reports detailing how his German colleagues had surpassed his countrymen (Wurtz 1870, 1882). He was not the only one. Another telling example is Victor Cousin, who, after his ejection from the *École Normale*, chose Prussia for a year long tour (Cousin 1833). Finally, it was in Prussia and Bavaria that American scientists on leave would seek inspiration for organizing their science faculties and institutes (Sinclair 1979). The characteristics of Germanic science that its contemporaries admired, such as the existence of a scientific hierarchy of science workers, the need for joint research and education, the value of precision and the prominence of careful experiments backed with careful mathematical descriptions, are well known and have been the subject of intense and varied scholarship and debate (Turner 1971, Olesko 2010). In this paper, the focus will be on the role played by science education.

To begin with, most of these new practices were the results of a serious institutional reformation of the German universities. After the defeat of Prussia in the Napoleonic Wars, French military might was seen to stem at least partly from the training of French engineers and officers in the *Écoles*. A series of changes were thus instigated within the German educational system to match the French developments (McClelland 1980, 99-145). At their center, there was the neohumanistic matrix of reform associated with Wilhelm Von Humboldt, who also happened to have a famous scientist for a brother. Von Humboldt proposed an explicit version of *Wissenschaft* and *Bildung* as the foundation for German education, he pushed for the strengthening of the role of secondary education, he attempted to link it with the university, he professionalized teacher training and he proposed the unification of teaching and research (Olesko 1991a). While his program was not created *ex nihilo*, and while its causal role has at times been exaggerated, it worked as an exemplar for many reformations and policies within the German lands. It is thus interesting to see how these mostly educational measures led to scientific achievements. The joint research/teaching imperative was first initiated in the famous philological seminars in Göttingen during the late 18th century, where students and members of the faculty came together to discuss advanced questions. It was the first time that research was seen as part of the university ethos and the seminars' success was soon copied across disciplines, also reaching the natural sciences. The physics seminars, for example, in Bonn and Königsberg created a ripple of institutional and disciplinary changes that transformed the way physicists were trained, perceived and employed (Olesko 1991b). At the same time, Justus Von Liebig was the first to use his chemical laboratory not only to demonstrate, but also to routinely let students engage original problems, creating a new school of chemical education and research. His example was

imitated by Gustav Kirckhoff and Robert Bunsen and then widely copied across the world, leading to the 20<sup>th</sup> century paradigm of the Research University<sup>3</sup>.

The above example of science and education interplay is perhaps the most widely known. Less known is the role played by secondary education and pedagogical theory. During that period, Germanic secondary education consisted of the classically oriented *Gymnasia*, which were at first the only schools that allowed entrance to the University and the more practical and science oriented *Realschullen*. Setting aside the interesting observation that science curricula at the *Gymnasia* mirrored exactly the fortunes of science within Germany, we must note that Humboldt, in his quest for stricter teaching standards, encouraged many secondary teachers to attend the schools of the pedagogues Johann Heinrich Pestalozzi and Johann Herbart (Olesko 1989, 99-100). Their theories, however, stressed the importance of experience and hands on experimentation, ideas that were very conducive to the new scientific ethos which was being formulated at the time. In fact, many famous evangelists of science, such as Aldous Huxley, Herbert Spencer and later Ernst Mach, would unknowingly or knowingly quote Herbartian pedagogy when defending a new role for science (Banks 2003, 1-26)<sup>4</sup>. Within Germany, Herbart shared classes with the astronomer Friedrich Bessel, who in turn pioneered the adaptation of Herbartian ideas in science education (Olesko 1991a). The secondary teachers Bessel and Herbart trained would afterwards return to secondary education and form a cadre of men dedicated to the importance of the experiment as a base for secure knowledge. Impressed by their achievements, Carl Theodor Anger initially, and later the more famous Franz Ernst Neumann pioneered the use of astronomical techniques of precision and error treatment in science education, as well as the Herbartian idea of science problems to be solved at home. The same methods were also seen and used as tools for the refinement and introduction of French mathematical physics within German scientific discourse (Olesko 1991b, 61-127). Teachers trained in Neumann's Königsberg physical seminar based their scientific ethos in these values, not incidentally around the same period that many quite well organized laboratories appeared in *Realschullen* and *Gymnasia*. As a consequence, the next generation of students that would form the much admired German scientific community of the late nineteenth century had already been familiarized with the characteristics of its success even from their time in secondary schools (Lundgreen 1984, 64).

Or, to make the point more forcefully: What were seen by contemporaries as the triumphs of German science were at least partially concurrent, if not the results, of pedagogical and educational reforms. In the case of nineteenth century German space, science reformation started at the classroom, not in the laboratory. And in the eyes of many contemporaries, it stayed there. The many successes of the German scientists of the era should not obscure the fact that most scientifically trained men worked in education. As Werner Siemens put it in a public lecture in 1883, on his way to asking for more research funding:

*No nation in the world has done so much for scientific and technical education as Germany, and especially Prussia... Its educational institutions*

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<sup>3</sup> For a discussion on Justus Von Liebig and his legacy, see Morell 1972, Holmes 1989, Brock 2003

<sup>4</sup> Johann Friedrich Herbart (1776-1841) presented an holistic educational, philosophical and psychological theory now considered post-Kantian. His pedagogy was appropriated in different ways in different contexts, but initially it stood for a strong, formalized, rigorous education whose goal was the moral and intellectual development of the subject. He also considered abilities not as innate, but as something that could be cultivated using a sturdy methodological framework. For a more rigorous discussion see Dunkel 1969.

*produce a large number of highly trained scientists whose profession, in almost all cases, is teaching.*" (Siemens 1891, translation in Cahan 1985,1)

### **French decline and French teaching**

A similar point can be made about the connection between French science and French education. As in the case of Germanic science, some thirty years ago there was an established narrative on 'the decline of the French science'. It was taken as a given that somehow, someway, French scientific practice lost its way during the post Napoleonic period, and the task of the historian of science was to explain the reasons (Paul 1972, 416-418). However, more recent scholarship has cast serious doubts on the validity of this premise. The reevaluation was based on the de-centering of the picture away from the *École Polytechnique* and the *École des Ponts et des Chaussées*, and on factoring in the role of the emerging science faculties (Fox, Weisz 1980, 8-20). For our purposes, we will underline two points apparent in the relevant historiography: The first is the antinomial relation between the *École Polytechnique*, a school initially seen as purely scientific and the *École Normale Supérieure*, a school which was founded with purely pedagogical intentions. As many recent studies have shown, by the final decades of the nineteenth century, the *École Normale Supérieure* had displaced the *École Polytechnique* as the alma mater of French scientists. Explanations so far have been based on the turbulent social, economical and political climate of the period, or on the pivotal role played by Louis Pasteur, who as a director of the *École Normale Supérieure* actively campaigned for the upgrading of its status. In any case, the fact remains that the *École Normale Supérieure* did indeed become the prime scientific school of the French state<sup>5</sup>. The second important consideration for our study concerns the French scientific faculties. From 1802 onwards, more than ten new science faculties were established in France, in Marseille, Clermont, Bordeaux, Grenoble, Lyon, Toulouse and elsewhere. In fact, it is by looking at their role within contemporary French scientific practice that the 'French scientific decline' thesis becomes hard to defend. And it is at this juncture that the history of science education becomes relevant.

From the first decades of their existence, the newly founded science faculties were expected to act as mentors for the *lycées*. Science professors were responsible for supervising the courses in secondary education, for acting as examiners in the *Baccalaureat* and in many cases for teaching there. In fact, the expected career of a faculty member begun in the *lycée*, whereas after some years he would get a position in the university. This mobility reflected the initial disposition of the late 18th century French administration that the skills required for teaching in the *lycée* and in a science faculty were only quantitatively, not qualitatively, different (Karady 1980, 100-119). Usually, the archetypical professor continued to teach at both. The large disparity between the hours needed by the *lycées* and those required by university lectures gradually made the professors devote most of their time and energy to their *lycée* lectures. Moreover, the subjects and manner taught were totally dependent on the *Baccalaureat* requirements, an orientation that did not change when they entered their university's lecture hall. There are numerous reports on how *lycée* and university lectures were in fact identical<sup>6</sup>. Finally, the lack of any research imperative made the

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<sup>5</sup> A complete examination of the role of the *École* during the era of the Third Republic can be found in Amith 1982.

<sup>6</sup> This conclusion is based on the *Procès verbaux* of the *Assemblée Professeurs* of the various faculties, as described in Shinn 1979.

science faculty identify more with their *lycées* than with their faculties, as is evident from their strong protests whenever secondary education were threatened, but by their indifference towards their faculty's expansion. Thus, until at least the middle of the nineteenth century, the science faculties in fact acted more as an expansion of secondary education than like autonomous institutions.

At the time that Pasteur succeeded in revitalizing the *École Normale Supérieure*, there was also a confluence of factors that led to a rejuvenation of the peripheral science faculties. The traditional discouragement of the Paris administration towards any research or private fund mobilization changed rapidly and until the time of the Third Republic, the situation had been reversed (Paul 2003, 143-168). For our purposes, it is worthwhile to mention how Pasteur managed to make the *École Normale Supérieure* the first choice of talented students. Alongside the creation of positions that would enable brilliant graduates to remain at the *Ecole* and pursue research, he also mobilized the extended network of *Ecole* graduates that were to be found in both *lycées* and faculties. He maintained regular correspondence with professors, in which he urged them to steer their most brilliant students towards the *École Normale Supérieure*, rather than to the *École Polytechnique* (Zwerling 1980, 30-32, 40-50). In the end, it was the strong affinities between the *École Normale* and secondary education that helped create the conditions for the latter's eventual rise, even while Pasteur aimed at distancing the institution's future from its educational past.

Thus, nineteenth century France is another example where the transformation of scientific practice involved explicit and careful negotiation with secondary education, both institutionally and privately. For many decades, secondary education dominated the vocational, pedagogical and cultural life of French science. However, there are no comprehensive studies to date which document the exact influences reciprocally exerted. But once again, for the contemporaries both inside and outside French society, the situation was clear. It was for its pedagogical might, alongside its scientific, that French intellectual life was admired. It is no accident that French textbooks were found across the Western world for almost a century<sup>7</sup>. It is also no accident that traditional historiography remains silent on how a scientific community 'in decline' continued to produce first rate, albeit rare, scientific protagonists until at least the Second World War. It is the tentative proposal of this paper that the answer is partially to be found in French science pedagogy and its relation with the scientific community.

### **Teaching science and the creation of the physics laboratory in England**

Our third case study will be drawn from nineteenth century England, where at least in one case the influences of science education on the formation of a 'national' scientific community can be readily traced. The established narrative on Victorian physics usually focuses on the rise of the 'new theories' in England in relation to the needs of the Industrial Revolution, or recounts the works of great scientists located in Edinburgh, Cambridge, Oxford or Birmingham. Indeed, electricity, telegraphy, heat and the manufacturing of first rate scientific equipment were considered almost national disciplines by the English craftsmen and scientists<sup>8</sup>. Thus, the fact that, in the Paris International World Exhibition in 1867, British equipment fared significantly

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<sup>7</sup> For a general discussion, see Dhombres 1984. A specific, well researched case study of Ganot's Physics manuals can be found in Josep 2011.

<sup>8</sup> Precision instruments and their role within Victorian science have been the focus of several detailed studies. Exemplary accounts are to be found in Schaffer 1997, Hunt 1997 and Gooday 2004.

worse in comparison to French and German exhibits than in the Crystal Palace Exhibition of 1851, caused quite a stir among several scientific and technological circles within Victorian society. The subsequent unavoidable realization prompted lively debates on science education, the status of science and the need for a specific science policy (Gowing 1978).

The study of the role of science education within this context provides some very interesting insights. A telling case in point is to be found in the career of William Thomson. He was one of the pioneers of telegraphy, as well as a respected science savant. He had also combined his interest in the metrology and theory of electricity with a vested interest in the transatlantic telegraphy company. The later baron Kelvin had managed to play an active role in the initial vicious disputes among scientists and engineers regarding electrical telegraphy and he had come across as the victor (Smith, Wise 1989, 446-487). In fact, it was this success that established the term 'physics laboratory' within English discourse. Until then, there was no such thing. Laboratories were by definition chemical or multipurpose and exhibition oriented, like that of Faraday in London. The laboratory William Thomson had established in Glasgow in the mid 1850s was the first to claim the title 'physics laboratory' and acted as the exemplar for all that followed (Gooday 1990, 27-29). Moreover, until the late 1860s, it was the only academic sight where practical and theoretical knowledge on electricity could be learned. The government recognized its importance for the development of cutting edge industrial science and awarded it with praise, recognition and subsidies. It is thus interesting to note that Thomson's laboratory had from its founding, no divide between its research and teaching functions and that student participation was vital for its operation. There were no dedicated teaching equipment and no scheduled lectures. Trainees and students learned by doing, especially by pursuing whatever problems were relevant at the time for the success of this or that telegraphy project. In later years, the lines between student and company engineer would dissolve completely, and students were routinely sent to supervise projects or to help with problems abroad (Sviendrys 1976, 420-436).

Thus, the same space that founded the idea of 'physics laboratory' in England was in essence a hybrid teaching/research space and was celebrated as such. This interplay can be observed in another famous laboratory, namely the Cambridge Cavendish laboratory. Founded in 1874 with the help of Lord William Cavendish, an industrialist and scientifically trained member of the aristocracy, the Cavendish laboratory was a direct result of the calls for modernization directed towards the classically oriented Cambridge and Oxford. The promising but not yet famous James Clerk Maxwell was selected as its first director (Kim 2002, 10-19). It is from this point on that the role of educational practice becomes important. Maxwell had several disparate demands to balance. To begin with, he had to justify the existence of a physics laboratory within a conservative university, which considered its ideal the education of gentlemen. He also had to engage in cutting edge research that would make Cavendish work towards the restoration of English hegemony in science. Finally, he had to make sure that he did *not* attract too many students. This final paradoxical constraint was a consequence of the prominence, at the time, of the Mathematical Tripos, an institution akin to a mathematics degree. Considered the most prestigious award of any English university, it provided its best graduates, known as wranglers, nationwide fame, recognition and opportunity<sup>9</sup>. However, it was not designed to lead to a mathematics career, but rather to pave the way for a career in administration, law or medicine. In any case, the most

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<sup>9</sup> On the origins and social role of the Mathematical Tripos, see Gascoigne 1984.

successful wranglers followed rigorous private tutoring in advanced classical mathematics and mechanics, accompanied by grueling preparation (Warwick 2003, 11-48). It was thus important for Maxwell to not appear to steer these prominent young champions away from their studies, since their examination did not include practical knowledge of instruments or subjects from electricity and heat. The later did not yet constitute discourses appropriate for a gentleman (Yeo 2003, 209-230).

In the end, Maxwell succeeded by making Cavendish a research oriented, graduate laboratory, which focused on electric standards. Thus, he engaged in vital, cutting edge research, while attracting a small number of students, charmed by the strange new practical world to be found in Cavendish (Sviedrys, Thackray 1970). However, and somewhat ironically, the existence of the wrangler network was essential for the subsequent dominance of Maxwellian electromagnetism. The few graduates who did attend had first class knowledge of advanced mathematical techniques, which enabled them to comprehend the highly technical and obscure Maxwell's *Treatise*. This enabled Maxwell to give them large scale, original projects supervised by him and designed to validate and promote his theory. With the subsequent establishment of a Natural Sciences Tripos and the recognition of Heat and Electromagnetism as suitable additions to standard Cambridge curriculum, the wrangler network enabled the rapid diffusion of Maxwellian theories and techniques, thus helping establish the new theory (Warwick 1994, 286-356). Thus, the establishment of modern electromagnetism came to depend heavily on the pedagogical and educational contingencies of nineteenth century Cambridge.

As a final note, it was the successor of Maxwell, John William Strutt, later Lord Rayleigh, which made Cavendish a place for widespread physics teaching. In that, he was helped by Arthur Schuster, a scientist in Manchester who had studied under Kirckhoff and Helmholtz and was thus familiar with the pedagogical novelties of the German system. This renovation, coupled with the renewed interest in the new physics and with the aforementioned establishment of the Natural Science Tripos decisively influenced the emergence and character of physics as a discipline within Britain (Wilson 1982). The German exemplar was appropriated and renegotiated and both educational and scientific practices were incorporated in the creation of the Cavendish laboratory. Yet, traditional narratives seem to take as granted that such a space was envisioned and built as a locus of science, construed in turn as pure and unadulterated research, where students had the unfortunate tendency to be found.

### **Greek scientists and national education**

All the above themes on the formative role of education for the development of a scientific community can be observed in our final case study, drawn from the early Modern Greek State of the nineteenth century. It is exactly nineteenth century Greece's absence from all traditional narratives of the era that makes it such an interesting case. It was a space in which modern political formations and scientific practice appeared at the same time, under the same context and thus, where we should expect to see clearly both the mutual constitution of scientific and European themes and the role played by of science education. And indeed, in Greek intellectual space, there was in a sense science popularization and science education before there was scientific practice. In the decades before the Revolution of Independence in 1821, scholars living in Greek speaking, Orthodox communities across the Ottoman Empire and Europe had initiated a movement of intellectual and political revival, collectively known as the Modern Greek Enlightenment. Despite the many differences between



the scholars of the time, one of the most common ideas put forth was the liberating and modernizing effect of modern scientific achievements. Many wrote textbooks in order to present current scientific theories and thus to combat illiteracy and ignorance among the subjugated Greeks<sup>10</sup>. It was an explicitly mentioned theme that modernity and European ideas went hand in hand, and thus that science and science education had a national role to play exactly because of their European origin. In the end, it was not with research but with teaching that scientific practice begun in Greece.

The first Governor of Greece, Ioannis Kapodistrias, took up his duties even before the formal recognition of Greece as a sovereign state. He placed great emphasis on primary and vocational education, which he expanded by founding a number of primary schools, as well as a Military Academy, a Teaching School and an Agricultural School. However, he was reluctant to found a University or even an extensive network of secondary schools and the subjects taught in primary education did not include the sciences (Kiprianos 2004). This was partly a result of the pedagogical system adopted. In Greece, from the first decades of the nineteenth century to the late 1890, pedagogy and primary school operation was based on monitoring schools. Initially a British pedagogical practice developed by Joseph Lancaster and Andrew Bell, it was designed to instill the basics of literacy, numeracy and ethical behavior in a large number of students. This was achieved by assigning to the teacher the role of the conductor in a strictly regimented school life, with the older students assuming the role of helpers. The system was suitable for the needs of the industrializing societies and it was thus enthusiastically adopted, for a time, by a large number of mutual help societies in Britain. After the Napoleonic wars, French pedagogues visited England and brought back the new system, which enjoyed a limited success. It was the French reformulation by Louis Charles Sarazin (Sarazin 1829) that was adopted in Greece, after heavy modifications by influential Greek pedagogues (Papadaki 1992). Ioannis Kapodistrias was later assassinated, in 1831, and after a short civil war, the underage Bavarian prince Otto was selected to establish a royal line in Greece. Until he came of age, power was exercised by three Bavarian Vice-Regents, which soon became widely unpopular. Primary education was allowed to expand and a system of secondary education followed, based this time on the Bavarian and Prussian archetypes, well into the nineteenth century. Meanwhile, the University of Athens was founded in 1837 and the Royal Observatory was established in 1842. As is to be expected, the first specialized science savants appeared as professors in the University, in the Faculty of Philosophy, and as directors and workers in the Observatory. The Polytechnic School, which was founded also around 1837, also initially shared most of its science professors with the University<sup>11</sup>.

It is in the interplay of these two processes, the establishment of a public education and the emergence of a Greek scientific community that is of interest here. The first professors that came to teach in Greece had studied in prestigious European universities, most of them for a significant amount of time. They considered themselves equal to their peers abroad and sent communications, letters and dispatches to journals and conferences. For example, Dimitrios Stroumpos, professor of Physics from 1839 to 1889, had studied in Geneva and Paris and had his

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<sup>10</sup> Some general but non systematic treatments of the Modern Greek Enlightenment are Kitromilides 1994 and Dimaras 1977. For treatments of the movements relation to the sciences, see Vlahakis 1999, Patiniotis 2007.

<sup>11</sup> The only complete history of the Physics and Mathematics Department of the University of Athens' School of Philosophy is to be found in Stefanidis 1948. A much more modern exposition of the role of the Polytechnic School and the parallel emergence of the engineer in Greece is Antoniou 2006.

communication read by Becquerel in the French Academy of Sciences (Stroumpos 1888). Theodoros Orfanidis, Professor of Botany from 1850 to 1886 and recognized poet, participated in the Conference of St. Petersburg in 1870 and corresponded with Boissier (Orfanidis 1868, 19). Finally, Anastasios Christomanos had worked with Liebig, Bunsen and Kirckhoff and attended most of the great conventions of his era. All in all, however, the active Greek scientists from 1838 to 1875 must be numbered less than thirty (Stefanidis 1948, Vol B, 5-25). In its first four decades of operation, the Greek University did not in fact produce even one certified science graduate. However, from 1875 to 1900, almost thirty science graduates took their Diploma from the University of Athens, thus doubling the number of Greek scientists (Lappas 2004). While in other cases, this surge in the interest in science can be explained by upgrading funding, large scale industrial expansion or technological contingencies, that was not the case in Greece at the time. The Physics and Mathematics Department was still under the aegis of the Philosophy Faculty and would in fact become autonomous after 1904. How is then this sudden influx of science graduates to be explained?

The answer must be sought in science education. Due to the Bavarian and Prussian influences, the establishment of secondary education in Greece was based on the archetypes of the *Gymnasia* and the *Volkschulen*. The curricula, for reasons having to do with urgency and the need for the Vice Regents to appear productive by the time the young King Otto I would ascend to the throne, were copied almost verbatim from Bavarian sources (Mylonas 2000). That led science to enter the Greek public school as early as 1837, in the form of Physics, Natural History and Chemistry courses<sup>12</sup>. However, a number of reports indicate that some, if not all, of these courses were never actually taught before 1855 or even later<sup>13</sup>. There were no Greek scientists ready to teach these courses, as at best the professors in the Greek Schools and in the *Gymnasia* were graduates of the general Philosophy School. A state-approved textbook and a detailed curriculum were also missing and secondary education teachers were reluctant to take on and teach a subject which they saw as complicated and suspicious. However, in 1867, a number of textbooks were approved for the use in secondary education<sup>14</sup>. While in reality being amalgams of translations of French and German sources, Greek science textbooks also acted as unofficial curriculum guides. Their contents in effect defined the subject, something that their authors were well aware of. Indeed, it was common for textbooks to retroactively conform to curricular constraints, even if written before these constraints were announced. The writers knew from experience that the Greek Ministry just copied the French instructions on the subject and acted accordingly<sup>15</sup>.

With the appearance of textbooks and, in essence, of a curriculum, sciences start to reach an unprecedented, albeit small overall, number of Greek schoolchildren. Some of the students from 1867 onwards are the same people who will go to the University of Athens in the 1870s and 1880s having already an idea about what science is and

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<sup>12</sup> The first reference of the inclusion of such courses is to be found in the Royal Decree of 16/12/1833, published in the Government Gazette vol. 41. It does not however specify a more detailed curriculum and there are strong indications that the decree was followed schematically, if at all.

<sup>13</sup> Two reports sent by the respective Ministers of Education in 1855 and 1862 specify that Natural History and Physics had not been taught since then. See Antoniou 1987, Reports 4168/31-8-1855 and 3836/1-7-1862.

<sup>14</sup> See Antoniou 1987, Reports 1659/30-8-1874.

<sup>15</sup> A very graphic example is provided in Kondylis 1892, where in the preface the author scolds the Ministry for not following the French laws exactly, despite the fact that “everybody knows that the Royal Decree is a copy of the French curriculum”.

what it consists of as a discipline. Respectively, some of them went on to choose science as their specialization and obtain science diplomas. They also created a vocal minority, alongside their professors, which demanded that only specialized scientists should be allowed to teach science in the Gymnasia<sup>16</sup>. This was to be the one rallying cry of the small community of Greek scientists until 1912, when their demands were granted. From there on, the disciplinary loop was completed: The expansion of secondary education ensured that sciences were taught more or less continually, providing vocations for graduating scientists and allowing for the next generation of students to get acquainted with science as a discipline. In essence, education and more specifically secondary education was the scaffold which enabled a scientific community to emerge in Greece. Textbooks and school classrooms were the causes, not the results of later scientific practice. Moreover, it was the essentially European character of science and the multinationality of pedagogy that enabled their intertwinement. Men schooled at France and Germany worked within educational contexts appropriated from Bavaria, Prussia and France to establish the role and character of a purely and fiercely Greek scientific community.

## Conclusions

The case of the Early Modern Greek State is, I believe, not unusual. It is only the lack of relevant studies that makes the interplay of education and scientific practice seems obscure. Especially in the European space, where not only scientific but also educational theories and practices crossed national borders and were negotiated in different social and intellectual contexts, it should not be a surprise that the rise of secondary public education in the nineteenth century parallels so smoothly the development of international scientific communities. In this paper, the aim was to present specific cases, some well known others less so, that bring across the interplay between science education and scientific practice. In tertiary education and laboratory training, where this sort of interdependence is most expected, the emphasis was given on how specific spaces were created as both educational and scientific, using exemplars that transcended borders and how these two roles were neither clearly separated, nor where they seen as such by the actors themselves. In other examples, the focus was given on the role played by secondary education in the establishment and constitution of the respective scientific communities. It is an often neglected fact that, during the nineteenth century, most scientists were occupied in public education, especially in states where national and central educational systems were the norm. It is thus a peculiar oversight to take for granted that this vocational aspect of the scientific community did not, or could not, affect its development or orientation.

On the theme of science education within history of science, there were of course several possible and fruitful avenues of research not mentioned: The circulation of popularizing science magazines, the role of textbooks, the creation of a standard history of science and its relation to science teaching and the relation between the rhetorics of scientists and the establishment of science education. This paper aspired however to provide some remarks towards how science education interacted with scientific practice in four different national spaces, how educational practices transgressed boundaries alongside educational ones and how in at least one case, science, education and European aspirations appeared simultaneously. In that area, there is a lot of research yet to be done and one can only hope that a research program

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<sup>16</sup> This will become a common theme in the speeches given by science Professors in the University.

aimed at examining the mutual constitution of science and European space will provide the necessary framework for such studies.

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