THE SCIENTIFIC CULTURE IN EIGHTEENTH TO NINETEENTH CENTURY GREEK SPEAKING COMMUNITIES: EXPERIMENTS AND TEXTBOOKS

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ABSTRACT

The scope of this paper is to describe how the Greek scholars of the late eighteenth and the early nineteenth centuries related to the political and intellectual developments in Europe during the Enlightenment through scientific instruments and experimental physics. We review the organization of Greek education during the Ottoman domination, focusing on the secondary schools and the scholars who introduced the experimental methodology in the late eighteenth century. In our analysis, the role of the scholar–teacher and his textbook are central to the adaptation and appropriation of the new scientific culture based on experiments and the experimental method. Furthermore, our analysis of the late eighteenth and early nineteenth century Greek physics textbooks focuses on what we term 'iconic experiments' (experiments performed by famous European scientists), since they constitute one of the main channels through which European experimental tradition was transferred to the Greek speaking regions. Throughout this paper, the teaching of the new science of 'Newtonianism' is associated with the ideas of the Enlightenment and the French Revolution, and is considered to have paved the way for the liberation of the Greek population from the Ottoman Empire.

INTRODUCTION

Scientific instruments in modern Greece appeared in the late seventeenth century when Chrysanthos Notaras (1663–1731) built some basic astronomical instruments, including a quadrant astrolabe (for his life and work, see Stathi, 1999). This type of astrolabe was a cheaper version of the classic astrolabe and was well known to the Ottomans. It originated from the Arabs and the first person who introduced it to the West was Profatius Tibbon (1236–1305), a Jew from Provence; thus the name given to the instrument was 'astrolabe of Profatius'. Notaras' instruments are the first for which there was profound evidence and they were preserved even around the 1930s, but since then they have been missing. Around 1700, Notaras purchased some survey instruments during his educational trips to

Italy and France, as one might infer from his book *Introduction to Geographie and Sphere* (1716). Later, he also purchased telescopes for the entertainment of the Greek princes of the Romanian provinces of the Ottoman Empire.

These instruments along with a few others that were available in the Greek area in the eighteenth century were exceptions in an educational landscape where experiment and observation were absent. The Byzantine tradition did not favour the acquisition of scientific instruments. Byzantine mathematical sciences supported the learning of complex calculations, but disregarded experiments and observations in favour of formal reasoning. The University of Padua, the main seat of study for Greeks in the seventeenth and eighteenth centuries, resisted the advent of the new physics and hence the experiment before the establishment of the Teatro di filosofia sperimentale by Giovanni Poleni in 1739 (Vlahakis, 1998).

During the late eighteenth century, and especially the years after the French Revolution and the changes that took place in the Greek speaking communities of the Ottoman and Austro-Hungarian empires, experimental physics made its way into Greek secondary schools (Henderson, 1971). There were experimental laboratories in the schools of Ioannina, Milies, Chios, Smyrna, Kydonies, Constantinople, Bucharest, and Jassy. The articles of the teachers in the journal *Hermes the Scholar* and travellers' reports give evidence for the scientific instruments and laboratories. Very few of these instruments have survived, such as those of two partisans of modern Greek Enlightenment, Anthimos Gazis and Theophilos Kairis. Gazis sent instruments to teach physics and geography to the school of Milies from Vienna, and Kairis purchased a telescope during his stay in Paris in 1810 (Vlahakis, 1999). These instruments were used mainly for qualitative demonstration experiments and were intertwined with a certain ideology: the introduction of the new science as a product of the Enlightenment. In this framework, experiments were performed both for the students and the public. Their purpose, apart from teaching, was to impress the audience so it could recognise the importance of science, which was considered in enlightened Europe as the champion of all human activities.

The scope of this paper is to describe the following relation: how the Greek scholars of the late eighteenth and the early nineteenth centuries related to the political and intellectual developments in Europe of the Enlightenment through scientific instruments and experimental physics. Our research is situated within a wider research area examining the reception of scientific ideas from countries of the European scientific centre to countries of the European scientific periphery (see on that theme, Blay and Nicolaïdis, 2001; Skordoulis, 2009).

To examine issues of reception requires discussing the ways in which ideas and methods that originate in a specific cultural and historical context are introduced into a different context, with different intellectual traditions and educational institutions (see Dialetis, Gavroglu and Patiniotis, 1999; Mendoza, Nicolaïdis, and Vandersmissen, 1999). In this respect, examining the role of the scholar-teacher is crucial. The scholars of the periphery were not simply disseminating ideas and methods acquired from the centres of Europe, but they acted upon them and adapted them to the local setting. The role of the scholar-teacher and his textbook were central to the adaptation and appropriation of the new scientific culture. The 'experiment' and the new experimental method was the most important constituent of this culture.

What we argue in this paper is that the introduction of the new mode of scientific thinking based on experiment was a necessary precondition for the connection of the national aspirations of the Greek middle classes with the Enlightenment project, and that the teaching of the new science of 'Newtonianism' became a political action associated with the ideas of the Enlightenment and the French Revolution, and was thought of as paving the way for the coming national liberation. Our paper gives a general outline of the introduction of the experimental method in Greece, and of the physics textbooks published during the late eighteenth and early nineteenth centuries by Greek scholars for citizens living in what is now mainland Greece and among the Greek speaking communities in what was then the Ottoman and Austro-Hungarian empires.

The paper is organised as follows: in the first section, we describe the socio-historical context for appreciation better understanding of the opposition to the new experimental method and its political and educational function. In the second section, we give an account of the educational institutions in mainland Greece and among the diaspora (the Greek communities that were founded in western Europe by the Byzantines after the Ottoman conquest, for example, in Venice, and later by Greek merchants who fled the Ottoman empire, for example, in Vienna, Trieste, Odessa, etc.) where the new experimental method was introduced in physics instruction, and also of the teachers who introduced the new curricula. We discuss the didactical use of the experiments and its importance in educating the population in a new way of thinking, paving the way for the course of national liberation that was to follow. In the third section, we classify the published physics textbooks and analyse the experiments described in five of the most widely used textbooks published in the period between 1766 and 1812 in Vienna, Leipzig, and Venice. Our analysis is based on a thematic classification of the experiments described therein, with emphasis on what we term 'iconic experiments' (that is, experiments performed by scientists that were already famous in the period of interest).

SOCIO-HISTORICAL BACKGROUND

After the conquest of Constantinople by the Ottomans in 1453, Sultan Mohamed II appointed a new patriarch to the Orthodox Church, granting him jurisdiction over many aspects of religious and civil life of the Christian populations of the empire. The Patriarchate was integrated as a state institution in the Ottoman Empire. That was a well-calculated manoeuvre in order to reinforce the schism between the Catholic and Orthodox Churches initiated in 1054. One of the most important privileges granted to the Patriarchate was the responsibility for the education of the Christian population.[1] Till the seventeenth century, the curriculum aimed at strengthening the Orthodox Christian faith and preparing the students, whose number was limited, to become members of the clergy and to hold administrative positions in the institutions of the Patriarchate. During the eighteenth century, however, the content of what was taught was not solely determined by the Church; rather, it was the outcome of the social relations of power, the often diverging priorities and conflicting interests of the religious hierarchy and of the various social groups with significant economic activities. It is therefore necessary to give a brief exposition of the agendas of the religious and social groups involved.

In order to understand the Enlightenment's impact on Ottoman Balkan society, we should remember that in the pre-1820s Ottoman Balkans, most of the urban strata, mercantile groups, and religious and secular elites were either ethnic Greeks or those enculturated into the Greek ethnie. Both the peasantry and the literate and urban Greek Orthodox groups were "Greek" in the sense of being Orthodox. After 1750, the influence of the western Enlightenment led to secularisation, liberalism, and an undermining of the religious world view of the Eastern Church. With the French Revolution, this trend intensified. Greek Orthodox intellectuals reconceptualised the Orthodox Rum millet. They argued for a new, secular "Hellenic" national identity (see Roudometof, 1998).

At the beginning of the sixteenth century, the education of the Greek speaking population was mainly religious and centred around the education of the officials of the clergy. Later in the seventeenth century the Patriarch Kyrillos Loukaris (1570–1638) appointed the Neo-Aristotelian philosopher Theofilos Korydaleas (1574–1646) as the director of the Patriarchal Academy. Korydaleas introduced the study of Aristotle's physics in the Academy and wrote extensive comments on *Physics* and on *Generation and Corruption*, initiating an educational policy aimed at shaping a cultural identity of the Orthodox population distinct both from Muslims and Catholics, and in direct continuity with the Ancients. Within this framework, secondary schools were founded, scholarships were granted to students to study at the universities of Western Europe mainly in Italy, and the publication of books was financed (Nicolaïdis, 2001).

In the late seventeenth century, a new social stratum appeared in the scene. This was a bourgeois group of Greek origin called 'the Phanariots'[2] who were involved in commercial and financial activities, and who wanted to increase their capital through an affiliation with the state institutions of the Ottoman Empire. Thus the Phanariots served as high-ranking officials in the Orthodox Patriarchate

1 The Ottoman Empire based its domination on the organisation of 'millets', that is to say, a system for controlling non-Muslim populations by delegating major responsibilities to their religious leaders who were appointed by the Sultan. The first millet to be created was that of the Orthodox Christian Church, followed by the Armenian millet and the Jewish millet. The millets had their own laws, collected their own taxes in lieu of their loyalty to the empire, and managed their own educational system.

2 The Phanariots took this name from the neighbourhood of Phanari in Constantinople where the Orthodox Patriarchate is still located and where most of them lived.

and in the Sublime Porte (the Court of the Sultan). They were appointed as diplomats by the Sultan and, most important, as Governors of the Danubian counties of Wallachia and Moldavia, developing the already influential cultural Greek presence in these provinces (Demaras, 1977). The Phanariots were situated within the framework of ‘enlightened despotism’ and sought the modernisation of the Ottoman state. In their eyes, this modernisation was associated with the improvement of their position within the Ottoman state structures; therefore, they opposed any idea of a Greek nation state. At the same time, as they matured as a social substratum, they disputed the authority of the Patriarchate as the sole mediator between the Sultan and the Greek population. They especially disputed the sole authority of the Patriarchate over educational matters and so, in their areas of governance, they founded the ‘Hegemonic Academies’ (Colleges) of Bucharest and Jassy and favoured the introduction of Newtonian physics in their curricula.

However, the situation changed drastically during the years both preceding and following the French Revolution. The majority of the Phanariots were of the view that the Revolution jeopardised their political agenda of ‘enlightened despotism’ and their prospects of gaining progressively greater influence within the Ottoman Empire. The French Revolution was portrayed as the result of the philosophical ideas of the Enlightenment and, consequently, the Phanariots’ conviction and affection for the Enlightenment and subsequently for Newtonianism started to decline.[3]

The third social factor that influenced educational matters in that period was the new class of Greek merchants and craftsmen flourishing in what is now mainland Greece and also in diaspora, i.e. the Greek communities that were founded in western Europe by the Byzantines after the Ottoman conquest e.g. in Venice and later by Greek merchants that fled of the Ottoman Empire e.g. in Vienna, Trieste, Odessa etc. (Kardasis, 2001; Kitromilides, 1999). This social class, which had no access to the institutions of the Ottoman state, favoured the foundation of a new nation state, and became the driving force behind the revolution for Greek national independence in 1821.

In the two centuries preceding the Greek national revolution of 1821, this new social class of merchants and craftsmen supported financially the foundation of new schools, and the introduction of the new philosophical and scientific trends of European thought (Bokaris and Koutalis, 2008). This class sought to be educated in the ‘new scientific spirit’; at the same time, the new scientific spirit introduced to the Greek speaking communities of merchants and craftsmen was connected with radical political ideas influenced by the European Enlightenment and the French Revolution (Kitromilides, 1990 and 1999). Furthermore, the intellectuals originating from or who sided with this class were inspired by the Enlightenment,

3 For an analysis of the controversial and ambivalent positions of the Phanariots, see Papachristou, (1992).

and viewed science education as a vehicle that would lead to the liberation of a people living under Ottoman imperial rule.[4]

Our analysis of policies concerning education in the Greek speaking communities of the Ottoman empire is based on the tripole schema of social power relations outlined earlier; in the level of ideas this can be described as a conflict between two intellectual currents: (*a*) the followers of neo-Aristotelianism initiated by Korydaleas in the seventeenth century and (*b*) the followers of 'Newtonianism' as the new science came to be known in the period of interest of this paper.[5]

In the last decades, historians in Greece have introduced the already established term 'Neo-Hellenic Enlightenment' (Demaras, 1977) in order to identify the introduction and adaptation of the ideas of the Scientific Revolution and the Enlightenment in the Greek intellectual space. It is beyond doubt that the new science with its foundation on experimental method lead to a decisive break with scholasticism and metaphysical superstition associated with clergy and feudal rule (Iliou, 1975).

SCHOOLS AND TEACHERS IN THE LATE EIGHTEENTH AND EARLY NINETEENTH CENTURIES

Historians of science and education have shown that in a number of schools for secondary and higher education for the Greek communities of the Ottoman Empire and the diaspora, in the late eighteenth and early nineteenth centuries, there were organised science teaching laboratories and demonstration experiments formed an integral part of physics teaching (see Karas, 1997 and 2003). In this section, we give an account of the schools of higher education and the teachers who introduced the new experimental method in the teaching of physics in the curricula of these schools. It should be noted that at this point in our period of study, the number of schools for higher education was increasing. Till about the middle of the eighteenth century the majority of the student population belonged to the weaker economic classes destined for careers in teaching, the clergy or as lower administration officials, that is, professions with meagre income. In contrast, the children of the upper social classes had private tutorials and then they were sent to study in European universities. What changed in the late eighteenth century, in the period when the influence of the Enlightenment ideas was at its

4 A sound example of an intellectual of this kind is Rigas Velestinlis who wrote *Physics Selections*, published in Vienna in 1790. He was influenced by the ideas of the Enlightenment and especially by the French movement of the Encyclopédie (Paris 1751-65).

5 At this point a remark on methodology should be made: our methodology is based on the analysis of the relations of social classes and institutions of the Greek population in the Ottoman Empire. But one has to note that social classes are not homogeneous formations and that psychological, religious, and other ideological factors influence the behaviour of individual members, besides socio-economic interests.

peak, was the social origin of the students in the schools – it was expanding and students from all social strata attended the schools.

One has to take into account that till about the middle of the eighteenth century most of the teachers/scholars, even the dissidents, were members of the clergy. Therefore, all differentiations and ideological disputes were taking place within the institution of the Orthodox Church. Scholars, like Methodios Anthrakitis (1660–1749) who was a clergyman, were excommunicated by the Orthodox Church due to their adherence to the new philosophical ideas (in Anthrakitis' case, the French philosophers Nicolas Malebranche and René Descartes).[6]

By the middle of the eighteenth century, the figure of the teacher-priest was replaced by the figure of a professional scholar whose mission was to provide secular education. The teaching of the works of the priests of the Orthodox Church, of Aristotle, and of practical arithmetic was replaced by a curriculum influenced by the new ideas of the Enlightenment, serving the social, political, and ideological priorities of the communities which supported the schools financially. In fact, the curriculum of each school was the outcome of the social power relations between the local communities and the Patriarchate. The new generation of professional scholars had also realised that they could not teach the new scientific ideas of the Enlightenment in the same way as the old curriculum. So a new teaching methodology was necessary, based on experiment and observation.

The first school that introduced physics courses based on the new experimental method was the Athonias School in the monastic community of the Holy Mountain Athos (Aggelou, 1988). This school was founded in 1750; after Eugenios Voulgaris[7] was appointed as the Director in 1753, the school started to flourish, attracting not only students who intended to pursue clerical studies, but also others seeking a higher education with the total number of students amounting to over 200 in some cases. The reason for this success was the fame accompanying Eugenios Voulgaris as a teacher and the desire of the literate population to

6 Methodios Anthrakitis, after being excommunicated, was forced to burn his own books in the courtyard of the Patriarchate in Phanari. When reinstated, he taught in the neo-Aristotelian tradition.

7 Eugenios Voulgaris (1716-1806) received his education in his native place, the island of Corfu, under Vikentios Damodos, an important scholar of the period, and then in the island of Zakynthos under Antonio Katifaro, a professor of the Flagginian School of Venice. He continued his studies in the School of Ioannina (a wealthy commercial town of western Greece) under Athanassios Psalidas. After he became a priest, in 1737 or 1738, he went to Italy in order to study theology, philosophy, European languages, and natural sciences. Before taking up the directorship of the Athonias School, Voulgaris was the director of the Maroutsis School of Ioannina (founded in 1742 by Greek merchants of the community of Venice) where he designed a curriculum introducing natural sciences for the first time. For a short period, he was also responsible for the school of Kozani (founded in 1745 by the community of Greek merchants living in the region of what is now Hungary). After leaving Athonias School, he taught at the Patriarchal Academy in Constantinople. He spent the last years of his life, after 1770, in the Royal Court of Catherine the Great in St Petersburg as Archbishop of Slavonia and Chersonesos. In 1788, he was elected a Foreign Member of the Royal Society of London during the Presidency of Sir Joseph Banks.

be acquainted with the new science of Newton (Patiniotis, 2007; Petrou, 2001).[8] Voulgaris was a very experienced teacher and introduced a curriculum that laid special emphasis on mathematics, physics, and cosmography based on the experimental methodology. His teaching notes compiled in the form of a manuscript formed the basis of his textbook that was published later in 1805 in Vienna. In 1759, his strong adherence to the Newtonian ideas did not find favour with the religious hierarchy of Athos, and he was forced to give up the directorship of the school after severe disagreements over the content of his teaching. Gradually, the school lost its fame and was closed in the first decade of the nineteenth century.

In 1780, in the Academy of Bucharest, Konstantinos Vardalachos[9] was a senior teacher of philosophy, mathematics, and experimental physics. He reorganised the school, promoting natural sciences as the main teaching subject and introducing instruments of physics and chemistry in the instruction. Research has shown that every Saturday the students had to devote one hour to the laboratory (Camariano-Cioran, 1974).

In the Hegemonic Academy of Jassy in what is now Romania, teaching experiments were performed by Iosipos Moisiodax and Nikiphoros Theotokis.[10] As a headmaster, Theotokis reorganised the academy around the middle of 1760. In his second period in office (1774), he came in conflict with the neo-Aristotelian cycles of the city due to his insistence in teaching the 'new philosophy' and he was forced to leave the school (Camariano-Cioran, 1974).

In the Kaplaneios School of Ioannina, in north western Greece, the 'experimental physics' of Vardalachos was taught by Christoforos Philitas and Athanasios Psalidas (1797–1820). The latter prepared his own 'general physics' teaching notes based on Horvath's *Physica Generalis*.

In the Patriarchal Academy of Constantinople, the headmasters Dorotrheos Proios (1804–1807), Stefanos Dougas (1809–1810), and Konstantinos Koumas (1814–15) taught experimental physics and performed experiments during lectures. But they faced severe opposition for their teaching practice and they were driven to resign from their teaching posts.

The Academy of Kydonies (now Aivalik in Asia Minor, Turkey) was founded in 1790. From 1800 up to 1821, two well-known scientific figures acted as directors: Benjamin Lesvios (1800–1812) and Theofilos Kairis (1812–1821). Both of them had written textbooks on physics, which they taught during their time of service. Teaching experiments were performed since 1796.

8 Petrou's article is written in Greek but an English translation by the author is available at the Royal Society of London.

9 Konstantinos Vardalachos (1775-1830) studied in Padua and Pisa. He taught the physical sciences in Bucharest, Chios, and Odessa.

10 Nikiphoros Theotokis (1731-1800) studied in Padua and Bologna where he worked with Giovanni Poleni and also made astronomical observations with Zanotti. He taught the physical sciences in Constantinople, Jassy, and Vienna. After 1775, he joined Voulgaris in Russia, where he became the Archbishop.

A course on experimental physics with experiments was taught for a short period in the school of the island of Chios, which was founded in 1815. In 1816, Konstantinos Vardalachos was appointed there as a teacher.

The 'Gymnasium of Sciences' (Iliou, 1975) was founded in the city of Smyrna (what is now called Izmir in the mainland of Asia Minor in what now is Turkey) in 1808 with Konstantinos Koumas[11] as its director. The school was connected with the developing merchant class of the city. In 1810, it changed its name to 'Philological Gymnasium' in contrast to the 'Evangelical School' that remained in the old tradition, and organised experiments in physics and science laboratories. Experiments were performed in public for audiences other than the students of the school. In 1819, the school was attacked and partly destroyed by opponents of the experimental method.

In 1813, the school of Milies in Pilion (the mountain home of the centaurs according to mythology) was founded with Gregorios Konstantas as the headmaster and Antimos Gazis as a senior teacher. Research in the archives of the school has shown that experimental physics and chemistry were taught there, and that a rich collection of scientific instruments has been brought to this school to be used for teaching purposes (Andritsaki-Fotiadi, 1993).

A year before, in 1813, the Greek community of Zemlin (now Zenum), a city then belonging to the Austro-Hungarian Empire (near Beograd of what is now Serbia) founded a school where Demetrius Darvaris[12] introduced the teaching of experimental physics.

In the school of Ambelakia in Thessaly (central Greece), Stefanos Dougas donated a number of scientific instruments with the aim of establishing an Institution for Higher Education. This project was not successful due to political developments and shortage of funds.[13]

DIDACTICAL APPROACH

We do not posses concrete information about the exact curricula of these schools concerning the physical sciences. It seems that every teacher appointed followed his own syllabus. What we know is that physical sciences were taught for six to

11 Konstantinos Koumas (1777-1836) studied in Vienna. He taught in Smyrna and Constantinople. After the Greek national revolution of 1821, he fled to Vienna where he was arrested. After his release, he spent most of his time with scientific writing. He acquired a Doctorate from the University of Leipzig and became a member of the Academies of Berlin and Munich.

12 Demetrius Darvaris (1757-1833) studied in Vienna, Halle, and Leipzig. He taught in Zenum and Vienna.

13 For a detailed account and further reading on schools and curricula, see the work of Karas (2003) and Nicolaïdis (2001). See also various publications of the Institute of Neohellenic Research, NHRF, Athens (presented in the *Newsletter for the History of Science in Southeastern Europe*, http://www.hpdst.gr/publications/newsletter).

eight hours a week in the Academies of Bucharest[14] and Jassy, five to six hours weekly in Kydonies and Ioannina, three to four hours weekly in Constantinople, etc. Experimental apparatuses and instruments were bought by rich merchants in Western Europe and donated to the schools of the Greek speaking communities. Due to the high cost, there was the possibility of only a single experimental apparatus for each kind of experiment to be installed in a school.

The performance of the experiments and the role of the experiment in the teaching process was, in most cases, the sole responsibility of the teacher and, to a lesser degree, of the curriculum that was approved by the Board of each school. Most of the experiments were demonstration experiments, performed by the teacher in front of the students with the sole purpose of the verification of a theory that had been taught.

Students were observers only and not experimenters. What was missing in these experiments was the process of measurement. This meant that students were not trained in the mathematical processing of their findings (the quantification of the observation), missing the most important feature of the new methodology introduced by the Scientific Revolution: the connection in the last analysis of the experiment with mathematics.

In the textbooks used by the students, there were no pictures and drawings of the apparatuses or of the experimental set ups described therein. There were only some drawings (etchings, gravures) in the last pages of the textbooks for some instruments or experimental set ups. Despite these drawings, the majority of experiments described were more or less ‘thought experiments’. The students had to use their imagination in order to construct a mental representation of the experimental set up. This was where the role of the teacher became indispensable. The teacher had a central role in producing additional material in order to facilitate students’ understanding of the experiment.

THE TEXTBOOKS

During the period from the late eighteenth to the early nineteenth century, a large number of science textbooks were published. These textbooks were widely circulated among students and the general public and they played a very important role, not only in teaching but also in familiarising students with the experimental method in schools where there were no organised laboratories and the students were taught about the experiments solely through the textbooks (Karas, 2009; Xenakis, 1994).

In our study, we examine only the physics textbooks published in this period. Besides the physics textbooks, there were textbooks of astronomy, chemistry, geography, botany/natural history, and a very large number of mathematics. M.

14 For example, the curriculum of the Hegemonic Academy of Bucharest was designed in 1707 by Chrysanthos Notaras. The students were introduced to philosophy following independent courses in logic, natural philosophy, and metaphysics.

Patiniotis (2006) proceeded to classify 135 scientific and philosophical textbooks published during the eighteenth century. He classified the textbooks according to their content which is identified with the various disciplines in the structure of the eighteenth century curricula of the schools.

We proceed in a different manner. We have selected only the printed physics textbooks of the late eighteenth and early nineteenth century and we have distinguished the following three types: (*a*) translations of physics textbooks of European authors (Petrou, 2006); (*b*) physics textbooks based to a large extend on similar textbooks by European authors; and (*c*) physics textbooks written by Greek authors sometimes comprising their teaching notes.

The first category of physics textbooks includes:

a) Benjamin Martin (*Grammatica delle Scienze Filosofiche*, Italian edition published in Venice 1795), translated by Anthimos Gazis and published in Vienna (1799),
b) Johann Heinrich Helmuth (*Volksnaturlehre zur Dampfung des Aberglaubens*, 6th edition published in Venice 1810), translated with the editorial assistance of Spyridon Vlantis and published in Venice (1810),

The second category includes the following authors:

a) Nikiphoros Theotokis, *Elements of Physics*, in two volumes published in Leipzig, 1766 and 1767. This textbook is based to a very large extent on Abbe Nollet's Italian edition *Lezioni di Fisica Sperimentalle* (Venice, 1747) and Pieter van Musschenbroek's *Elementae Physicae* (Naples, 1751).
b) Eugenios Voulgaris, *Philosophers' Favourites* (Vienna, 1805), which is also based on van Musschenbroek's *Elementae Physicae* (Naples, 1751).
c) Rigas Velestinlis, *Physics Selections* (Vienna, 1790) based on the *Encyclopédie* published in Paris, 1751–65 and Geneva, 1778–1779.
d) Konstantinos Koumas, Elementary Treatise on Mathematics and Physics (Vienna, 1807), based on Jean Claude Fontaine Cours encyclopédique et élémentaire de mathématique et de physique (Vienna, 1800).

The third category comprises physics textbooks written exclusively by Greek authors that sometimes are edited versions of their teaching notes from the lectures in the schools where they taught. In this group we have selected the physics textbooks of three prominent teachers who used the new experimental method in their course of teaching:

a) Konstantinos Koumas, *Synopsis of Physics* published in Vienna (1812),
b) Konstantinos Vardalachos, *Experimental Physics*, published in Vienna (1812), and
c) Demetrius Darvaris, *Physics* (three volumes) published also in Vienna (1812).

TEACHING EXPERIMENTS IN THE TEXTBOOKS THEMATIC CLASSIFICATION

We have chosen two textbooks from the second category (Theotokis, 1766; Voulgaris, 1805) and the three mentioned in the third (Koumas, 1812; Darvaris, 1812; Vardalachos, 1812). The main reasons for selecting these textbooks were that they had a wide circulation in printed form, they had been used in teaching, and they were written by Greek authors (not translated) since our study focuses on how the Greek scholars distributed in the periphery the ideas and methods acquired from the centres of Europe.[15] We proceed to a thematic classification of the experiments described therein: mechanics, mechanics of fluids, acoustics and optics, heat, electricity and magnetism.

In the mechanics section, the most common experiments described have to do with the study of the pendulum, the free fall in the presence of air or in vacuum, the motion in an inclined plane, the study of friction, the study of the momentum, and the various forms of impact (elastic, plastic) between spheres. There are also experiments to demonstrate the view that the elements are the undecomposable constituents of material bodies, ultimately composed of particles of various sorts and sizes which cannot be resolved in any known way.

In the sections of fluid mechanics (properties of liquids and gases), there are experiments concerning atmospheric pressure, cohesion forces, the shape of the surface of liquids in a vessel, the laws of flux, elasticity, and incompressibility of fluids.

In the acoustics and optics section, there are experiments about the nature and properties of sound, analysis and synthesis of white light, and also experiments in geometrical optics with lenses and mirrors.

In the section on heat, most of the experiments concern expansion and contraction, determination of the boiling point of various substances, melting and freezing, and conduction of heat.

Finally, in the electricity and magnetism section, there are experiments on magnetisation by induction, demonstration of the distribution of magnetic lines around the poles of a magnet, electrification by friction, charging and discharging of a capacitor (‘Leyden jar’), electrolysis, detection of atmospheric electricity, animal electricity, construction of a voltaic pile, etc.

ICONIC EXPERIMENTS

A very interesting feature of the textbooks is the extensive reference to experiments that were considered landmarks in the development of classical physics, and which had been performed by famous physicists of those days. In the textbooks, special emphasis is given to the name of the scientist who performed the

15 The majority of Greek scientific textbooks were printed between 1770 and 1820. See Pappas and Karas, 1987.

experiment, for example, “the experiment of Boyle”, etc. In the following section we give an indicative account of the iconic experiments described in the textbooks considered.

In the mechanics section, there are descriptions of the free fall experiments by Pieter van Musschenbroek, Marin Mersenne, Giovanni Poleni, and Giambattista Riccioli. There are also references to the free fall experiments by Galileo and Newton.

We can also find experiments on friction by John Theophilus Desaguliers and Pieter van Musschenbroek, the experiments on the constitution of matter by Anton van Levenhook and Johann Christophorus Sturm advancing the corpuscular theories, and also the experiments by Willem Jacob Gravesand, G. Poleni, and G. Riccioli in order to prove that the energy of a moving body (“vis-viva” is the term used in the original text) is not proportional to its velocity but to the square of its velocity.

In the mechanics of fluids sections, extensive descriptions are given about the experiments of Robert Boyle, Evangelista Torricelli, Daniel Bernoulli, and others regarding the experimental demonstration of the laws of flux, the dependence of hydrostatic pressure on the height of the liquid inside the vessel, etc. There are also descriptions of the experiments of Blaise Pascal (on the dependence of pressure on altitude), the experiments of Giovanni Poleni showing that the speed of a liquid flowing from the bottom of a vessel depends on the friction between the liquid and the vessel walls, the experiments of Jean Senebier on the elasticity of water, the historical experiment of Otto von Guericke with the ‘Magdeburg hemispheres’, Edme Mariotte’s experiment to prove that the quantity of liquid that flows from the vessel depends on the height of liquid in the vessel, Jean Picard’s experiment on the dependence of flow from the geometry of the vessel, etc.

Extensive references are also made to the experiments performed in the Academy of Florence. From the ancient figures, there are references to the works of Archimedes,[16] especially his Screw and his method to determine the percentage of gold in the crown of the king of Syracuse, and of the findings of Sextus Julius Frontinus (40–103 AD).

In the optics section, there is extensive reference to Newton’s experiment for the analysis and synthesis of white light, Newton’s rings, on Christian Wolff’s observations of the human blood with a microscope, on the observation of the absorption of solar rays by cloths of different colours by Benjamin Franklin, and also William Herschel’s experiment to prove that light and caloric are of different nature.

In the section on heat, there is an account of Fahrenheit’s experiments for the calibration of various types of thermometers, the experiments in the academy of

16 We underline here the reference to Archimedes in order to show that both neo-Aristotelian scholars and adherents of Newtonianism built their work in continuity with ancient Greek thought. In the works of Newtonian scholars there are references to Archimedes, with the scope of highlighting the importance of experiment and practise which was a characteristic of the method of Archimedes.

Florence (the dependence of the freezing point on pressure), Musschenbroek's experiment on the linear expansion of a metal rod when heated, and Alessandro Volta's experiment on water cooling and water freezing during evaporation.

In the electricity and magnetism section, there are references to Musschenbroek's technique for creating new magnets, Abbe Nollet's experiment on electricity and the human body and on capacitor charging by an electrical machine, the electric discharge by Ludolf of Berlin (1744), experiments on electrification by William Gilbert and Grey, the experiment of the magic 'horseshoe' by Benjamin Franklin and also his experiment for the detection of the electricity of the atmosphere.

The electrolysis of potassium, sodium, barium, calcium, and magnesium as discovered by Sir Humphry Davy (1807) is also presented. There is also extensive reference to the works of Luigi Galvani (animal electricity) and Volta (circuits with battery).

The reference to the experiments of these famous scientists served a dual purpose. On the one hand, the name of the scientist acted as a means to persuade the students about the validity of the theory presented. On the other hand, the European experimental tradition was transferred to the Greek speaking regions and the literate population was getting acquainted with the European experimental tradition.

EPILOGUE

Despite the difficulties and the drawbacks mentioned, one has to appreciate the contribution of the new experimental methodology in altering the Aristotelian style of thinking among the educated population of the Greek speaking communities. Such a process of change was not at all easy given the strong affiliation to the 'glorious past' of classical antiquity. The introduction of the new mode of thinking was a necessary precondition for the connection of the national aspirations of the class of merchants and craftsmen with the Enlightenment project.

In many cases the experimental methodology caused reactions not only from the official Church, but also from the group of teachers who sided with the Aristotelian tradition initiated by Korydaleas in the seventeenth century and/or other conservative members of the wider community. One has always to recall that the class of merchants and craftsmen that was politically oriented in the creation of a new nation state, opposed the Church hierarchy and the bureaucracy of the Phanariots who wanted to contain national aspirations within the policy of the modernisation of the Ottoman state. Thus, the introduction of the new experimental method was caught in political turmoil, and the teaching of the new science of 'Newtonianism' became a political action associated with the ideas of Enlightenment and the French Revolution and was thought of as paving the way for the coming national liberation.

REFERENCES

Aggelou, A. 1988. *Όψεις του νεοελληνικού διαφωτισμού (Aspects of Modern Greek Enlightenment*). Athens: Hermes.

Andritsaki–Fotiadi, D. 1993. *Κατάλογος παλαιότυπων της ιστορικής βιβλιοθήκης των Μηλιών (List of Old Editions in the Historical Library of Milies, Pilion).* Athens: Hellenic Ministry of Education and Religious Affairs and Historic Library of Milies.

Blay, M. and E. Nicolaïdis E. 2001. *L'Europe des sciences : constitution d'un espace scientifique*. Ed. Seuil, Paris: Seuil.

Bokaris, E. P. and V. Koutalis. 2008. 'The "System of Chymists" and the "Newtonian Dream" in the Greek Speaking Communities in the 17^{th} – 18^{th} Centuries', *Science & Education*, 17 pp. 641–61.

Camariano-Cioran, A. 1974. *Les Académies princières de Bucarest et de Jassy et leurs professeurs*. Thessaloniki: Institute of Balkan Studies.

Demaras, K. Th. 1977. *Νεοελληνικός Διαφωτισμός (Neohellenic Enlightenment)*, Second Edition. Athens: Hermes.

Dialetis, D., K. Gavroglu and M. Patiniotis. 1999. 'Sciences in the Greek Speaking Regions during the Seventeenth and Eighteenth Centuries: The Process of Appropriation and the Dynamics of Reception and Resistance', in K. Gavroglu K. (ed.), *The Sciences in the European Periphery During the Enlightenment*. Dordrecht: Kluwer Academic Publishers [Archimedes2], pp. 41–71.

Henderson, G. P. 1971. *The Revival of Greek Thought 1620–1830*. London/Edinburgh: Scottish Academic Press.

Iliou, Ph. 1975. 'Luttes socials et movement des Lumières à Smyrne en 1819', in *Structure sociale et développement culturel des villes sud-est européennes et adriatiques aux XVIIe–XVIIIe siècles*, Bucarest: Association Internationale d'Études du Sud-Est Européen.

Karas, Y. (ed.). 2003. *Ιστορία και φιλοσοφία των επιστημών στον ελληνικό χώρο, 17ος–19ος αι.*, (*History and Philosophy of Sciences in the Hellenic space, 17^{th}–19^{th} Centuries)*. Athens: N.H.R.F. –Metaichmio.

———. (ed.). 1997. *Οι επιστήμες στον ελληνικό χώρο (The Sciences in the Greek Space)*. Athens: N.H.R.F. –Trochalia.

———.2009. *Οι περιπέτειες της νεοελληνικής επιστήμης (The Adventures of Neohellenic Science)*, Second Edition. Athens: Hellenic Physical Society.

Kardasis. V. A. 2001. *Diaspora Merchants in the Black Sea: The Greeks in Southern Russia, 1775–1861*. Maryland and Oxford: Lexington Books.

Kitromilides, P. M. 1990. 'The Idea of Science in the Modern Greek Enlightenment', in P. Nicolakopoulos (ed.), *Greek Studies in the Philosophy and History of Science*. Dordrecht: Kluwer Academic Publishers.

———. 1999. *Tradition, Enlightenment and Revolution*, PhD Dissertation, Harvard University, 1978. Also published in Greek: *Νεοελληνικός Διαφωτισμός: οι πολιτικές και κοινωνικές ιδέες*. Athens: MIET.

Mendoza, C-L., E. Nicolaïdis and J. Vandersmissen (eds). 1999. *The Spread of the Scientific Revolution in the European Periphery, Latin America and East Asia*, Proceedings of the XXth International Congress of History of Science, Vol. V. Turnhout: Brepols.

Nicolaïdis, E. 2001. 'L'intégration des Balkans dans L'espace Scientifique Européen', in M. Blay and E. Nicolaïdis, *L'Europe des Sciences: Constitution d'un Espace Scientifique*. Paris: Seuil, pp. 353–400.

Notaras, Chrysanthos. 1716. *Εισαγωγή εις τα Γεωγραφικά και Σφαιρικά* (*Introductio ad Geographiam et Sphaeram*). Paris.

Papachristou, P. 1992. *The Three Faces of the Phanariots: An Inquiry into the Role and Motivations of the Greek Nobility under Ottoman Rule 1638–1821*, MA Thesis, Simon Fraser University, Canada.

Pappas, V. and Y. Karas. 1987. 'The Printed Book of Physics: The Dissemination of Scientific Thought in Greece, 1750–1821, before the Greek Revolution', *Annals of Science*, 44 (3), May, pp. 237–44.

Patiniotis, M.2007. 'Periphery Reassessed: Eugenios Voulgaris Converses with Isaac Newton', *The British Journal for the History of Science*, 40, pp. 471–90.

———. 2006. 'Textbooks at the Crossroads: Scientific and Philosophical Textbooks in 18th Century Greek Education', *Science & Education*, 15, pp. 801–22.

Petrou, G. 2006. 'Translation Studies and the History of Science: The Greek Textbooks of the 18th Century', *Science & Education*, 15, pp. 823–40.

———. 2001. 'Eugenios Voulgaris (1716–1806) and the Royal Society of London', *Neusis*, 10, pp. 181–98 (in Greek).

Roudometof, V. 1998. 'From Rum Millet to Greek Nation: Enlightenment, Secularization, and National Identity in Ottoman Balkan Society 1453–1821', *Journal of Modern Greek Studies*, 16, pp. 11–48.

Skordoulis, C. D. 2009. 'Hellenic Studies in History, Philosophy of Science and Science Teaching: New Perspectives', *Science & Education*, 18, pp. 1193–97.

Stathi, Penelope. 1999. *Χρύσανθος Νοταράς, Πατριάρχης Ιεροσολύμων, πρόδρομος του Νεοελληνικού Διαφωτισμού* (*Chrysanthos Notaras, Patriarch of Jerusalem, Precursor of the Greek Enlightenment*). Athens: Association of the Athens Alumni of the Great School of the Nation.

Vlahakis, G. N. 1999. 'The Greek Enlightenment in Science: *Hermes the Scholar* and its Contribution to Science in Early Nineteenth-century Greece', *History of Science*, 37, pp. 319–45.

———. 1998. 'The Introduction of Classical Physics in Greece: The Role of the Italian Universities and Publications', *History of Universities*, XIV, pp.157–79.

Voulgaris, Eugenios. 1805. *Philosophers' Favourites* (*Τα αρέσκοντα τοις φιλοσόφοις*). Vienna: George Vendotis Hellenic Editions

Xenakis, Ch. Th. 1994. *The Experiment as Methodology of Research and Knowledge in the Works of Prerevolutionary Period Greek Scholars*, Unpublished PhD Dissertation, University of Ioannina (in Greek).