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Foreign influence and the mathematics education at the Spanish College of Artillery (1764-1842)

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Résumé : Le but de cet article est d'étudier l'enseignement des mathématiques au Collège d'Artillerie espagnol de 1764 à 1842, et de repérer les influences étrangères sur elle. Après quelques hésitations, un programme standard est adopté commençant par l'arithmétique et finissant par le calcul différentiel et intégral et la mécanique. L'unique changement important fut en 1819 quand la mécanique devint une matière indépendante. Pendant les premières décennies, avec Giannini comme premier professeur, l'emprise italienne était importante, néanmoins il existait une influence française et anglaise. Avec le temps l'inspiration française augmenta. Les manuels employés pendant la plupart du temps étaient ceux de Giannini ou Odriozola, professeurs du Collège ; mais ils ont utilisé aussi des livres de mathématiciens français comme Lacroix, Legendre ou Monge.

Abstract: The present article studies the impact of foreign influence on mathematics education at the Spanish Royal College of Artillery from 1764 to 1842. After some vacillation, the academy's standard teaching program included from arithmetic to calculus and mechanics. The most noteworthy change occurred in 1819 when mechanics would be considered as an independent subject. During the first decades during which time Giannini was first professor, the academy's approach to teaching mathematics was mostly influenced by methods being used in Italy and, to a certain degree, in England and France. French influence increased considerably with time. While most of the textbooks used at the academy were authored by two of its professors, Giannini and Odriozola, the curriculum would be expanded to include works by French mathematicians such as Lacroix, Monge and Legendre.

1 Introduction

During the 18th and 19th centuries military academies represented the most fruitful contexts for introducing and adopting new mathematical knowledge in Spain. For the College of Artillery, the period from 1764 to 1842 was highly transformative, taking us from its initial opening as an institution giving also a well-rounded education to becoming a second-degree academy better known for its specialized training in gunnery. This was also a time when Spain itself was undergoing major changes; what was once a wealthy absolute monarchy with colonies around the globe had become a relatively poor constitutional monarchy with few territories to call its own outside of Europe.

The primary aim of this paper is to study how methods for teaching mathematics changed at the Spanish College of Artillery and examine which countries had the greatest influence over modifications made during that time. Three different periods can be distinguished in this turbulent epoch. The first one takes place just prior to the Peninsular War when the intellectual and philosophical thinking that defined the Age of Reason or the Enlightenment was most dominant. The second period from 1808 to 1833 (and the death of Fernando VII) was particularly tumultuous and fraught with conflict, notably due to the ongoing wars against Napoleon and pro-independence Americans during a time, with the exception of short periods of liberalism, when absolutism dominated. The period from 1833 onward, when the liberal coalition came to power, marked the beginning of a new epoch, despite the series of civil Carlist Wars that took place in Spain during the 19th century. The third and last period, which for the College of Artillery began in 1830, is pertinent as this is when it was reopened by Fernando VII. Accordingly, we have structured our analysis to be divided in three sections corresponding to these time periods: from 1764 to 1808, from 1808 to 1830 and from 1830 to 1842.

2 The College of Gentlemen Cadets of the Spanish Royal Corps of Artillery (1764-1808)

A royal decree issued in 1762 (*Reglamento del nuevo pie en que S. M. manda establezca el Real Cuerpo de Artillería*) required that the Spanish Artillery Corps establish an educational academy or college for young cadets. The norms and regulations were drafted and published in *Ordenanzas de S. M. para el Real Colegio Militar de Caballeros Cadetes de Segovia* (1768) and it was decided that the location of the college would be in the Alcázar of Segovia (literally, “Segovia Fortress”). It was also deemed necessary to establish in the same

town an additional artillery school for tactical training and related research. [Reglamento 1762, 5, 10].

Before that time, the training of the officers in the Spanish artillery corps was more or less dependent on the Royal Military Academy of Barcelona, which was led by the engineering branch of the Army. The curriculum of the Academy of Barcelona was established by Pedro Lucuce (1692-1779) [Massa-Esteve, Roca-Rosell *et al.* 2011]. Gunners expressed a need for their own academy citing that they considered the program offered by the academy of Barcelona inadequate to follow ongoing advancements in ballistics and chemistry.

The College was first opened in 1764 at the initiative of Count Gazzola (1698-1780), an Italian who was the current director of the Spanish Artillery. Before that time, he had been in command of the Artillery Corps in Naples when Carlos III was the King of Naples. Gazzola had previously worked with the Military Academy of Naples where the Newtonian Nicola di Martino (1701-1769) was head professor [Navarro Loidi 2013, 105–165].

The College was structured to have two separate academies. One was devoted to theoretical education and was directed by the First Professor who was a mathematician; the second would be formed by a company of cadets, made up of one captain and two lieutenants who were in charge of teaching military regulations, drill training and combat arms orientation [Ordenanzas 1768].

Gazzola had specific ideas about the curriculum he wanted for the College. His choice of the teaching staff reflects his decision making, notably by appointing a First Professor who closely resembled Di Martino: his priority was to hire a good mathematician with pedagogical experience. The Jesuit Antonio Eximeno (1729-1808) fulfilled both of those conditions and was hired for the post. The remaining open teaching positions were given to decorated officers in the artillery who had experience and training in methods more commonly taught at the older, established artillery academies.

Eximeno, who was born in Valencia, Spain, had previously studied mathematics in Madrid with Johann Wendlingen (1715-1790), a Czech mathematician and professor at the Imperial College of Madrid [Udías 2010, 19]. Wendlingen published *Elementos de la Mathematica* (1753-1755, 4 vol.), a treatise that was largely influenced by Christian Wolff. Eximeno, would however, give more importance in his own writings to Newton's works than to Wolff's, which may indicate that he was influenced to some degree by the Jesuit Tomás Cerdá, a Spanish disciple of the French Newtonian Esprit Pézenas; or, alternatively, because Gazzola considered that "the groundings of theory needed in artillery is Physics, supported by the experience on gunpowder, on metals, on woods, etc."¹

1. The original in Spanish: "La base de la teoría que necesita la Artillería es la Física, apoyada en la experiencia sobre las pólvoras, sobre los metales, sobre las maderas, etc." [Lanuza 1966, 69]. All translations are mine, unless otherwise indicated.

Eximeno was exiled from Spain in April 1767, as were all Spanish Jesuits, and consequently Gazzola had difficulty finding a well-qualified replacement. The post of First Professor was typically held by military men who relied on manuals issued by the Military Academy of Barcelona. This essentially meant that they followed Lucuce's more modern version of Tomás V. Tosca's *Compendio Mathematico* (1707-1715, 9 vols.), a treatise heavily influenced by the work of the French Jesuit Milliet Dechales (1621-1678). This program was not updated enough for Gazzola's liking and he looked for an alternative solution, which he finally found in a program proposed by the gunner Cipriano Vimercati (1730?-1808), a Spaniard born in Xeres. Vimercati had planned and developed an appropriately updated syllabus that included eight treatises: the 1st and 2nd on arithmetic, the 3rd and 4th dedicated to geometry, the 5th to algebra, the 6th to the application of algebra to geometry, the 7th to infinitesimal calculus and the 8th to mechanics [Salas 1831, 198]. This program effectively included differential and integral calculus, a subject that was at the time considered essential to the study of ballistics.

Vimercati left Segovia in 1777 to direct the Academy of Midshipmen in Ferrol. Gazzola was unable to find a substitute in Spain and was forced to look further afield. He finally appointed Pietro Giannini (1750?-1820?), an Italian from Tuscany. Giannini was a disciple of Vincenzo Riccati and was a competent mathematician but had no previous experience working with the military. Giannini stayed in Spain for one year studying Spanish in Madrid before finally joining the College of Artillery in Segovia. During this year he submitted a report to Campomanes, the then Minister of Finance, on teaching mathematics. This report was published by Rubin de Celis in the prologue of his Spanish translation of Savérien's *Histoire des progrès de l'esprit humain dans les sciences exactes* (1766), wherein Giannini lists the authors most qualified to teach the six different areas of mathematical sciences [Savérien 1775]:

- For geometry, Euclid's Elements explained, Isaac Barrow or Robert Simson (both British),
- For conics, Guido Grandi (Italian),
- For analysis and calculus, Clairaut (French) or Agnesi (Italian),
- For mechanics, Jorge Juan (Spanish),
- For astronomy, Abbé Caille (French), and
- For optics, Smith (English).

He additionally expressed that he felt Wolff's ideas were no longer valid in light of newer theories being proposed [Savérien 1775, XIII, footnote 2]. The list of Giannini's selected recommended authors was comprised of contemporary mathematicians from a variety of schools and of different nationalities, revealing only a slight preference for Italians.

During his stay in Segovia Giannini produced a mathematics course to use at the College that was published in four volumes, the *Curso Matemático*

[Giannini 1779, 1782, 1795, 1803], as well as a book on practical geometry with tables *Prácticas de Geometría y Trigonometría con las tablas de Logaritmos* [Giannini 1784].

The first volume of the *Curso* comprises three parts: elementary geometry, trigonometry and conic sections. Geometry is presented as a version of books I to VI, XI and XII of Euclid's *Elements*. Trigonometry is explained without the use of numerical calculations, which makes the exposition too theoretical. And the conic sections are studied from a geometric point of view [Giannini 1779].

The second volume has also three parts. The first is about operations with numbers or letters, sequences and logarithms. The second part is on equations, finding their solutions algebraically and graphically and studying curves representing equations from the first to fourth degree. The third part consists of elementary problems of arithmetic, algebra and geometry. In his prologue, Giannini again offers the names of his recommended authors for each of the subjects. Here, he mentions Barrow, Maseres and Castiglione for algebra in general, and for curves he lists Newton, Pietro di Martino, Clairaut, Maclaurin, Saunderson, Reyneau, Wolf, Agnesi, Vincenzo Ricatti, Saladini, Simpson, Bézout, Bossut, Euler, Sauri, and Caravelli [Giannini 1782, s. p.], denoting a wide range of the mathematical knowledge of that period.

The third volume is divided into four parts. The first one is on the foundations of the differential calculus and on the calculation of differentials and integrals of polynomials, exponentials, logarithms, trigonometric expressions and others. This part starts with a section entitled "Newtonian lemmas of first and ultimate ratio, containing the geometrical principles of differential and integral calculus".² It is in essence a translation of the part "On the motion of bodies, Book I, Section I of the method of first and last ratios of quantities" [Newton 1729, vol. I, 41–56] from the *Principia*. Following the introduction is an explanation that differentials and fluxions are equivalent, without any justification, and fluents, fluxions and first and ultimate ratios are not mentioned again. The second part of this volume is about integration of polynomial fractions. The third part studies differential equations of the first order, including Johan Bernoulli's and Jacopo Riccati's methods of resolution. The fourth part deals with differential equations of higher order, solving only selected cases using only a few of the methods proposed by Vincenzo Ricatti. In the preface Giannini added recommended authors to the list offered in the second volume to include "Mr. Marquis of L'Hôpital, LeSeur and Jacquier, Bougainville, Cousin and others" [Giannini 1795, s. p.].

The fourth volume is devoted to mechanics and comprises three parts on static, hydrostatic and dynamic. Giannini begins with the "Principle of virtual work", which was outlined by Bernoulli in 1717, and is what Giannini calls "the method of actions". Action is the product of a force by an infinitesimal

2. "Lemas Newtonianos de las razones primeras y últimas, que contienen los principios geométricos de los Cálculos diferencial e integral" [Giannini 1795, 1].

movement, which is an infinitesimal work in modern terms. The second part of this volume studies fluids. Liquids are studied using the method of virtual works. The proposed method to study air, however, is less abstract. Several experiments are described and laws are deduced from them without mathematical proofs. The third part is about dynamics and is considerably longer and more complicated than the previous sections. Uniform motion, uniformly accelerated motion, and compound movements are studied, which continues with an examination of springs, elastic and inelastic collisions, and finally pendulums. After that, the motion of a particle under the influence of a central force and of variable forces is studied. The text concludes with a discussion on motion through resisting mediums. Giannini does not clarify in his treatise on mechanics how the explained theories may be directly applied to artillery. He provides no numerical examples nor does he offer easy to use formulae for practical applications [Navarro Loidi 2013, 499–555].

The absence of information on the practical application of the mathematics studied represented a major drawback of Giannini's course as it failed to respond to what the majority of military men had expressed a need for. Any promotion or support Giannini's programme received was most likely because he had backing from Gazzola who headed the Spanish Artillery. Gazzola's death in 1780 opened the gates for new waves of criticism. A review in December 1781 of cadets' exam results revealed noticeably poor performance, which prompted Count Lacy, the newly appointed head of Artillery, to demand an explanation of the School Council. All members of the council, with the exception of Giannini, responded the same way: cadets' exam marks would improve "if the course was less abstract and compact, if it broadened its practical applications to become more accessible and easier to understand, and at the same time left out sublime theories and advanced calculations".³

Gazzola's successor, Count Lacy, was a military man of Irish descent who, like Gazzola himself, was a proponent of enlightened thinking. He decided to back Giannini and keep the program largely as it was, but proposed making two key changes. The first was that he asked Giannini to incorporate into the *Course* a treatise about practical geometry. The other was to make improvements to the "Escuela Practica de Artillería", the school also located in Segovia that offered practical training to cadets using canons, artillery battery and other military assets. A part of this effort of improvement would include introducing new lines of research through the establishment of a laboratory concentrated on gunpowder and opening a mining school.

In 1784, Giannini published *Practicas de Geometría y Trigonometría* [Giannini 1784] that was comprised of five parts. The first concentrated on geometrical instruments, the second focused on measuring lengths, the third on calculating areas and drawing plans, the fourth on volumes and the last

3. "Si el curso fuese menos abstracto y conciso; si se extendiere en aplicaciones prácticas que lo hicieran más ameno y comprensible, y al mismo tiempo se omitieran las teorías sublimes, y cálculos superiores" [Actas vol. 2, f. 373 r].

dealt with levelling. Following explanations for each, this work provided tables of common logarithms, natural logarithms, and logarithms of trigonometric ratios. The section on logarithms also combined tables of units of lengths and weights used in the most important towns or kingdoms and gave their respective equivalents, with the addition of one table on the density of different materials. Giannini largely referred to French sources when he drafted this work, but was also inspired by Italian, Spanish and English references. He said that the information on the tables of measures and weights had been sourced “from the works of Mr. La Lande, Toaldo, Savary, Bézout, Don Joseph García Caballero & c. The tables of common logarithms of natural numbers and of the sinus are similar to those printed by Mr. Marie in 1768. Finally, the short table of natural logarithms is taken from the tables of Mr. Gardiner”.⁴

Giannini was primarily responsible for the degree of Italian influence on new methods of teaching mathematics at the College, which represented a departure from how the Spanish had approached mathematics education during the last quarter of the 18th century when mathematicians commonly followed the lead of French authors. For instance, Benito Bails (1730-1797), a mathematics professor at the Royal Academy of Fine Arts of San Fernando, was highly influenced by the *Cours de mathématiques à l’usage des gardes du pavillon et de la marine* (1764-1767, 4 vols.) by Étienne Bézout (1730-1783) when he wrote what would become a celebrated reference in Spain, his work entitled *Elementos de Matemáticas* (1779-1804, 10 vols.).

The degree of French influence mostly applied to the College of Artillery. An overview of the college’s library reveals just how important French literature was to professors teaching at that time [Navarro Loidi 2015]. An excerpt from the school’s catalogue published in 1764 shows the following distribution of books by languages (cf. Table 1).

Table 1: Distribution of books by language in the school’s catalogue

French	453	52,1%
Spanish	223	25,6%
Latin	120	13,8%
Italian	61	7,0%
English	6	0,7%
Portuguese	6	0,7%
Catalan	1	0,1%

4. “De las obras de los Señores de la Lande, Toaldo, Savary, Bézout, Don Joseph García Caballero & c. Las tablas de logaritmos de los números naturales y de los senos son las mismas que imprimió M. Marie en 1768. Finalmente la pequeña tabla de logaritmos hiperbólicos se ha sacado de las tablas de M. Gardiner” [Giannini 1784, s. p., The tables are not paginated].

As Table 1 clearly show, the majority of the school's library books were published in French. A second table shows a rough distribution of the authors' nationalities (cf. Table 2).

Table 2: Distribution of authors' nationalities

Nationality	Authors	% of the authors
French	109	44%
Iberian	59	23%
Italian	42	17%
British	14	6%
Germanic	13	5%
Dutch	11	4%

At closer examination, a comparison of the two tables tells us that a number of the textbooks were not published in the authors' native language. In fact, a number of Italian, British, German and Dutch authors had their books translated into French or Latin as most of the Spanish professors who taught at the College simply were not sufficiently fluent in the other languages. As such, the library only offered texts by Cramer and Cotes that had been translated into French, Maclaurin's books were available in both French and English, and works authored by Keill, Neper or Gregory (all Scotsmen), were only available in Latin.

It is also worth noting that mathematics was the principal subject of those books (cf. Table 3).

Table 3: Subjects of books

Mathematics	109	29%
Military Arts	76	20%
Artillery	30	8%
Physics and Natural Sciences	57	14%
Geography	25	6%
Architecture and engineering	37	10%
Drawing	11	3%
Other subjects	36	10%

Table 3 also shows that there were more books on mathematics than there were on artillery or other military subjects [Navarro Loidi 2015].

French influence can also be found relative to other subjects being taught at the College during this time. One example being the area of artillery instruction where the most influential professor was Tomas Morla (1747-1811), who graduated with honors from the College of Segovia and would later become a professor of artillery of the same College. He published a *Tratado de artillería* (3 vols. 1784, 1785, 1786 and complementary volume with the plates in 1803) [Morla 1784-1786], which served as a textbook at the College of Artillery for several decades. In his treatise, Morla mentions a number of the century's most influential thinkers such as Newton, Hawksbee, Daniel Bernoulli, and Johan Bernoulli. For references pertaining to artillery he preferred "Sirs Benjamin Robins [English] and Papacino D'Antoni [Italian], to whom the artillery is in debt for the new distinction and brightness that has taken its scientific component".⁵ When it came to experimental results, however, Morla relied more heavily on works authored by two French gunners; Blondel and Belidor. The fact that Morla incorporated into his own work preparation a fairly diverse range of international references led his seminal work, *Tratado de artillería*, to gain certain renown in other European countries. His work was translated into German in 1795.

French doctrines, however, were better known and more closely followed in chemistry, a subject considered essential by lead officers in the Spanish artillery for studying and producing cannons and gunpowder. Accordingly, they hired the French chemist Louis Proust (1754-1826), who had worked in Segovia from 1786 to 1799. Proust was known among gunners at the college, one of his disciples being Juan Manuel Munarriz (1761-1831), who would translate works by Chaptal and Lavoisier into Spanish.

After a period marked by adjustments, the mathematics being taught at the College of Artillery would closely resemble math courses being offered in academies across other European countries. A comparison of Giannini's treatises with Bézout's *Cours de mathématiques à l'usage du Corps Royal de l'Artillerie* (1770, 4 vols.) or with the textbooks of Sylvestre F. Lacroix (1765-1843) for the école centrale des Quatre-Nations, shows that the subjects presented for study were more or less the same, except that the French texts were more rigorously updated and more clearly written than Giannini's. The Spanish course, when compared to the course offered by the English academy, was more demanding. When Morla travelled to Europe in 1789 to visit and study several other nations' armies and military factories, he reported back that he found Woolwich's mathematics teaching methods "scanty" [Navarro Loidi 2013, 568]. That said, a similar dynamic was true for mathematics offered by a number of Spanish institutions during that same period. Advanced research in mathematics was fairly rare in Spain, as it was in the College of Artillery which had been created with the mission of

5. "Señores Benjamín Robins, y Papacino D'Antoni, a quienes la artillería es acreedora del nuevo lustre y claridad que ha tomado la parte científica" [Morla 1784-1786, 1785, vol. II, 414].

producing competent officers and not competent mathematicians. In a larger sense, modern theories of mathematics already in use in a number of other countries were being introduced as an integral part of the College of Artillery's curriculum. Foreign professors and textbooks from Italy and France were considered essential tools for teaching new theories and would eventually be integrated into the College's standard teaching program taught by Spanish professors [Gavroglu, Patiniotis *et al.* 2008].

When the *Regulation of the new constitution of the college of gentlemen cadets of the Royal artillery*⁶ was published in 1804, requiring that all professors be artillerymen, Giannini was forced to leave the College because he was not gunner, and almost certainly, because it was no longer appropriate for a foreigner to be at the helm. His successor was Francisco Javier Datoli (1767- 1810), a lieutenant colonel who had graduated from the College in 1782. Datoli had fought in the war against the French Convention, but the body of his experience came from working in foundries and he spent a year in the factory in Creusot, France honing his expertise in metallurgy. As First Professor he decided to publish a new and updated course manual that incorporated more innovative pedagogical methods than Giannini's. While Datoli only produced two works, the *Curso Matemático Tomo I Aritmética* (1807) and the *Tomo II Algebra* (1807), both appear to be inspired two books by S. F. Lacroix: *Traité élémentaire d'arithmétique* (1797) and *Éléments d'Algèbre* (1799).

During those decades, Spanish army's artillery took over control kingdom's factories producing arms and gunpowder, and it soon became evident that training offered by the College was not up to par for these two tasks. Consequently, a postgraduate extension course [*Estudios sublimes*] was created in 1804, which offered the most accomplished graduates continued specialized training in chemistry and metallurgy.

3 From 1808 to 1830, a turbulent period for the College of Artillery

When the Peninsular War began in 1808, the College was forced to close and relocate from Segovia to escape the approaching French army. This relocation led to Spain and Portugal and finally settled in the Balearic Islands. The publication of Datoli's new manuals stopped completely during this period.

The fact that Britain was the strongest ally of the Spanish rebels had little to no bearing on the College's course curriculum. Instruction at the College plugged along with increasing difficulty; a series of newly decorated officers, for example, were provisionally appointed First Professor charged with adhering to the established program. A logistical problem emerged being a

6. *Reglamento de nueva constitución en el Colegio Militar de Caballeros Cadetes del Real Cuerpo de Artillería.*

shortage of textbooks, authored by either Giannini or Datoli, for the cadets. Books by other Spanish authors such as Benito Bails, Juan Justo García (1752-1830) or José Mariano Vallejo (1779-1846) were put into use during this time. Texts written by Bails had initially been written for the Academy of Fine Arts of San Fernando, those by Vallejo were published for the Royal College of Nobles in Madrid, and García's works were written for the University of Salamanca. While the content of these works did not differ that significantly from Giannini's *Curso*, they were notably more popular and had been used in a number of universities, colleges and academies, as well as by each of respective founding institutions. For these Spanish mathematicians, the French influence was particularly evident, especially in works by Bails and Vallejo [Dorce 2017, vols. 2, 143–166, 175–193, 222–256]. Manuals by S. F. Lacroix began being translated into Spanish [Lacroix 1807, 1808] and these were also used at the College of Artillery.

In 1814, the College would return to Segovia from Majorca. The country had, however, been suffered severe and widespread damage during the Peninsular War and the Spanish American wars of independence had all but closed the flow of goods coming from overseas. This period represents a particularly turbulent time for Spain as a nation, but also for the College. There was shortage of funds to pay for daily expenses and, needless to say, little to no funds that could be allocated for printing new books. The College did, however, somehow manage to publish an updated version of Morla's *Tratado de Artillería*; but did not reprint Giannini's *Curso Matemático*. The lack of textbooks for teaching mathematics continued to be a problem and books by Lacroix, Vallejo, and García were used as temporary replacements for Giannini's work.

A Royal Order issued on August 23 in 1819 radically changed the College's teaching program. Under this decree, postgraduate studies, "*Estudios sublimes*", were cancelled due to the lack, according to the Artillery's lead officers, of sufficient training in chemistry and metallurgy in Spain, and the Artillery had neither the funds nor the personnel to organize their own courses. Consequently, the length of time to complete studies at the College was extended from 4 to 5 years. Mathematics continued to hold a prominent place in the curriculum as the principal subject of study. The curriculum proposed was: 1st year 1st semester arithmetic, 2nd semester algebra up to second degree equations; 2nd year 1st semester theoretical geometry, 2nd semester conclusion of algebra; 3rd year 1st semester rectilinear trigonometry, practical geometry and descriptive geometry, 2nd semester application of algebra to geometry; 4th year 1st semester differential and integral calculus, 2nd semester mechanics with statics, dynamics, hydrostatic and hydrodynamics. The fifth year was for artillery [Salas 1831, 160].

The manuals were changed, and instead of Giannini's texts Lacroix's books were proposed [Carrasco 1873, 158]. Several volumes written by Lacroix had already been translated into Spanish [Lacroix 1807, 1808, 1819, 1821]. It is here that descriptive geometry first appears as a new part of geometry. A further

change was made in how mechanics was taught which at this point presented separately from the mathematics course using the textbook by F. Francœur, *Tratado de mecánica elemental* (1803) [Carrasco 1873, 158].

In spite of the Peninsular War against France, after 1814 French influence became more pronounced than it ever had been.

At the same time, mathematics education at the College seemed to lessen in importance. Giannini's successor who was appointed First Professor and took over as head of the mathematics department was not a specialist in mathematics. From 1814 to 1815, this position was held by Munarriz who had been a disciple of Proust and was known for his expertise in chemistry, but not for any notable brilliance as a mathematician. From 1816 to 1822, José Vergara (1772-1847) took over, an experienced professor who had taught at the College for more than 20 years, but was not an experienced or celebrated mathematician.

In 1820 a triumphant coup d'État was instigated to reinstate the Spanish Constitution of 1812. Despite the historical significance of this event, regulations and the syllabus of the College of Artillery remained unchanged. Vergara stayed on as First Professor until 1823, when he was replaced by José Guerrero de Torres (1779-1841), an officer of artillery and polyglot who had studied at the College of Segovia and was later imprisoned in France during the Peninsular War. The College continued to use the standard teaching program established in 1819 and largely relied on Lacroix's textbooks for course instruction.

The liberals coalition would likely have changed the Ordinance of the College if they had remained in power longer than they did. A new general regulation for the Spanish education system was published on June 21, 1821, wherein it was proposed that establishing a Polytechnic School should be considered to offer preliminary training for more advanced military and civil technical studies. The thinking was that basic mathematics and physics would be taught at this preparatory polytechnic school, where upon graduation, qualified students could then be allowed to enter the Artillery Academy. This proposal, clearly rooted in French doctrine, was never put into practice. The liberal government was overthrown in 1823 by French troops with the help of absolutist Spaniards. The College escaped from "the fanatic defenders of despotism", under the orders of Munarriz, who was leading the Artillery and moved to Badajoz. Following the victory of the French Army, Fernando VII would rule once again as an absolute monarch in Spain, and following the directives of a Royal Order issued on September 27, 1823, the College of Artillery was closed definitively, the cadets were sent home and the professors were dismissed from duty.

In addition to the closure of the College, a royal decree issued in 1824 ordered that all Army officers, with the exception of those who had served supporting the absolutist troops, would be required to pass an exam as a demonstration of fidelity to the King if they wanted to continue serving in

the Army. Very few artillery officers, however, had actually fought with the absolutists and for several the Spanish Artillery came perilously close to total demobilization. While most Artillery officers received “purification” (were officially purged of their sins) around 1827, the last First Professor José Guerrero was “purified” in 1826, and his predecessor José Vergara would not be “purified” until 1835.

A General Military College was soon opened in Segovia on the grounds of the former headquarters of the College of Artillery. The curriculum of the new establishment did not differ dramatically from the teaching program used at the College of Artillery, insofar as mathematics was concerned. For the textbooks used for teaching mathematics were mostly written by Lacroix, but several others were also used that included works by the Spaniard Mariano Zorraquín (+1823) on applications of algebraic geometry, works by Giannini on practical geometry and works by Monge that focused on descriptive geometry.

The artillery branch (of the Spanish Armed Forces) was almost completely excluded from this particular Military College. Training specific to artillery was eventually made possible in 1827 when a cluster of theoretical training centers were launched for cadets preparing for lead roles in the five specialized departments of the artillery and the Military Museum of Madrid. The textbooks used for mathematics education at these centers were more often than not those written by Lacroix.

4 The reopening of the College of Artillery (1830-1842)

The level of training within these academies that had been organized by the different departments of the artillery corps proved insufficient in terms of expertise required by the Army and the King agreed to reopen the College of Artillery, which eventually happened in 1830. As the Alcazar of Segovia was already occupied by this time by the General Military College, the gunners were relocated to a dedicated building on the grounds of the University of Alcalá de Henares, while artillery batteries, laboratories and other auxiliary establishments all remained in Segovia. With this new configuration, the College of Artillery now in Alcalá no longer had access to these additional supports and training for cadets was mostly theoretical instruction.

A new Regulation was published for the newly reopened College. The only difference to that which had applied in 1804 was that the appointed First Professor would now be in charge of all artillery courses, whereas previous First Professors were charged with heading the mathematics department. Many credit hours were given to the subject of mathematics as a part of the College curriculum but it had lost its primacy.

The textbook used for mathematics instruction at the College of Alcalá was Odriozola’s *Curso de Matemáticas puras* (1827-1829, 4 vols.) [Odriozola

1827a,b, 1829a,b]. José de Odriozola (1786-1864) had been a captain in the artillery corps and his curriculum vitae differed slightly to those of the other professors at the College. He had initially studied to become a painter in the Royal Academy of Fine Arts of San Fernando where Bails had been professor of mathematics. During the Peninsular War he was made an officer in the artillery corps and assistant professor at the College of Artillery. He would remain as professor of the College in Segovia until 1823. Politically liberal, Odriozola was not “purified” until 1827. During this time, he took refuge with his friend and confidant Count Saceda who lodged him while he wrote a short treatise on artillery and several texts dedicated to mathematics. These books were well accepted by the leading officers of the branch and, once purified, Odriozola was appointed member of the Junta Superior Facultativa (High Expert Board). This institution was initially created in 1816 and was attached to the direction of the artillery corps. Its mission was to review and evaluate all actions aimed at improving the artillery corps and processes related to manufacturing gunpowder or armaments, both in Spain and abroad [Salas 1831, 158–160].

Odriozola had previous experience in research related to pyrotechnics and ballistics, but had no research experience in mathematics. As such, during his investigative travels abroad in 1836 when he travelled to France, Belgium, Holland, Prussia, and England, his primary interests were questions related to military operations, armament production and metallurgy, but never about mathematics. This lack of interest in mathematics was common to most artillery officers who set out on information gathering expeditions during this period. The more common way for new knowledge related to mathematics to reach the College was by published books or information shared by other Spanish mathematicians.

Odriozola’s *Curso de matemáticas* was published in four volumes. The first volume is about arithmetic and elementary algebra. In the prologue he explains that “I have always tried to found the teaching on general theories, following the advice of Laplace”,⁷ which reveals that he was more synthetic and less didactic than Lacroix. The second volume is on elementary and practical geometry, and on plane and spherical trigonometry including their application to geodesy and surveying. In some subjects of geometry or trigonometry he recommends Legendre to the reader and in topography he mentions French mathematicians such as Cassini, Borda and Delambre [Odriozola 1827b]. The third volume includes a section on advanced algebra and another about the application of algebra to geometry. He refers to Newton for binomials and series or Cotes for high order roots; but when discussing new theories in indeterminate equations he praises “The doctrine about this subject that has been spread by modern wise men such as Lagrange, Monge and others”.⁸

7. “Siempre he procurado fundar en teorías generales las doctrinas, siguiendo el consejo de Laplace” [Odriozola 1827a, V].

8. “A la doctrina que sobre esta materia han difundido los sabios modernos Lagrange, Monge y otros” [Odriozola 1829a, 279].

The fourth volume is on calculus and has three parts, two long sections on differential and integral calculus and a shorter section on calculus of variations. From the beginning, he states that for infinitesimal calculus he prefers the theories of Lagrange and his use of derivatives and series expansion. For high order differential equations he recommends “Euler, D’Alembert, Lagrange, Lacroix, &c” [Odriozola 1829b, 275] and promotes a method developed by D’Alembert for solving differential equations, or suggests a second method used by “modern analysts, especially Monge” for solving others [Odriozola 1829b, 292].

Odriozola develops on the classic concepts proposed by Leibniz, Newton and Euler, but for modern theories he mainly cites French mathematicians. His *Curso* was fairly state of the art and yet he makes no mention of two of his contemporaries, Cauchy and Gauss.

The degree of French influence appeared to continue to increase in Spain despite the Peninsular War and the invasion of French troops in 1823. An analysis of the books in the library at the College of Alcalá reveals just how important this shift in influence was during this time.

When the General Military College was opened on the location formerly occupied by the College of Artillery in 1824, they integrated the existing library, which meant that when the College of Artillery was later reopened, they were left with very few books, prompting the College to issue a formal request in January, 1831 for more books with the argument that the books on hand were simply too few and outdated. Catalogues of works available in this library from this period were all but lost, however this request is known and it included a list of some 176 titles, some of which were single volumes, while others comprised several volumes or, in some cases, the entire body of works by specific authors; this effectively brought the total number of volumes being requested to much more than 176 [Libro 1830-1845].⁹ This list was divided into two parts entitled “French books” and “Spanish books”, wherein entries were distributed as follows:

Table 4 French vs. Spanish books

French	160	90%
Spanish	17	10%

The request only included books published in French or Spanish; and very clearly, most of the requested titles were written in French. And as for the distribution of titles relative to subject matter, the Table 5 is equally telling. We can see here that mathematics becomes less of a priority, and falls behind the level of interest in artillery, military arts and life sciences.

9. Meeting of the Expert Board of the College [*Junta Facultativa del Colegio*] on the 31st January 1831.

Table 5 Subjects of books

Mathematics	28	17%
Military Art	38	23%
Physics and Natural Sciences	32	19%
Artillery	41	25%
Engineering	11	7%
Drawing	11	7%
Geography	3	2%

Most of the books published in French were written by French authors. Occasionally, translations into French of authors of other nationalities were solicited from the outset. For instance, a part of the College's request included the French translation of the *New Principles of Gunnery* by Robins with notes by Euler and Lombard. Rumford was also solicited for his works in French. Some Spanish authors published their books in French and these titles were listed among French titles being requested, for instance, works by Lanz and Betancourt. On the other hand, the list of titles published in Spanish includes several books by French authors, such as Suchet, Beudant, Thenard and Biot, that were translated into Spanish. Roughly a quarter of the books solicited in Spanish were translations of French books.

A shift toward French sources can be seen in other subjects that were being taught at the College. One example as evidence of the impact of French contributions to other areas of study can be seen in the case of the textbook most commonly used for teaching mechanics, *Tratado elemental de mecánica* [Odriozola 1832], wherein he refers his readers wanting a deeper understanding of dynamics to works such as "celestial mechanics of Laplace, and analyses by Lagrange and Poisson" [Odriozola 1832, vol. I, 402].

For chemistry, the proposed textbook was Orfila's *Elementos de Química Aplicada*. Orfila was born in Mahon, Spain but had worked in Paris and had his works published into French, although this particular book was published in Spanish.

Morla's *Tratado de artillería* was still the textbook of reference for all matters related to artillery at the College. Efforts to publish an updated artillery manual were stopped short for the lack of suitable books in the library at that time, insufficient batteries on hand for testing new armaments and no laboratory to conduct experiments on ballistics and gunpowder.

The command of the Spanish artillery sought to raise the level of scientific knowledge of the best College graduates by reinstating two years of post-graduate studies. To do this, instruction for these further studies was to take

place at institutions in Madrid as the artillery had no funding at the time to have its own higher education institution.

The research was to be conducted as a separate initiative that no longer involved the College and decisions related to research in artillery were left to the discretion of the High Expert Board (Junta Superior Facultativa).

It is worth noting that the less than favourable conditions at the College during this period correspond to a particularly tumultuous period in Spain, notably (from 1833 to 1840) a civil war had broken out between Carlists (absolutists) and liberals. The College and all of its members steadfastly supported the liberal coalition in this conflict.

As the liberal army needed gunners to fight on the front lines, the order was given to shorten the teaching program so that new officers could rapidly begin service. After some debate, a new abridged program was proposed in 1837. Calculus was removed altogether from the curriculum, and required coursework in mechanics was reduced from one year to six months. Only partial changes were made in terms of textbook selection for teaching mathematics. Work by Lacroix was proposed for arithmetic and elementary algebra [Lacroix 1807, 1808], Legendre's *Elementos de Geometría* [Legendre 1807] for elementary geometry, and Monge's *Geometría Descriptiva* [Monge 1803] for descriptive geometry. The *Curso* by Odriozola would continue to be used for any remaining mathematics topics deemed essential. Odriozola's textbook would also continue to be used to teach applied cinematics and dynamics, and a series of notes from the French Academy of Saint-Cyr were proposed for hydraulics [Libro 1830-1845].¹⁰

This new program, however, proved inadequate for preparing graduates for technical work duties the artillery required, such as overseeing production at arms factories, and postgraduate studies were subsequently extended to three years. During the first year, the students were required to read Lacroix's work *Tratado elemental de Algebra* [Lacroix 1808] and to study *Memoria sobre un nuevo método general para transformar en series las funciones transcendentales* (1807) by the Spanish mathematician José Chaix (1765-1809). The second involved studying a volume on calculus by Odriozola's, and the *Curso Matemático and Geometría analítica-descriptiva* (1819) by Zorraquín. Subjects covered in the third year related to physics and engineering, for which the proposed textbooks were the *Traité de Mécanique* (1811) by Poisson, the *Essai sur la composition des machines* (1808) by Lanz and Betancourt, the *Traité complet de mécanique appliquée aux arts* (1818) by Borgins, and Christian's *Traité de mécanique industrielle* (1822) [Libro 1830-1845].¹¹

This proposed program of advanced studies would not formally be adopted for several years. In 1837 the first Carlist War was at its peak and fine-tuning higher education was momentarily not the priority. Further, the town of Alcalá was virtually undefended. In 1836, Carlist troops being led by General Gomez

10. Meeting of the Expert Board of the College on the 26 October 1837.

11. Meeting of the Expert Board of the College on the 26 October 1837.

passed perilously close to Alcalá and the head of the artillery at the time asked for approval to relocate the College to either Madrid or Sevilla. In 1837 the Carlist King gave the directive to launch an attack on the liberal troops in Aragon. To help this effort, the Carlist General Zaratiegui initiated a raid on Castile, conquering Segovia and taking professors and cadets of the General Military College as prisoners. The Inspector General of the artillery submitted a second request to transfer the College to Madrid; his request was finally granted in August of 1837.

Finding appropriate premises in the capital, however, proved problematic, notably because the University of Alcalá had also been relocated to Madrid. In the end, in November 1839, they backtracked and returned to Segovia. The most significant changes during this period essentially resulted from the liberal coalition taking control of the government in 1836; one being that several experienced professors who openly supported the liberal movement were added to the College staff, such as Antonio Sequera and Francisco Lujan. Lujan had completed his own studies in France and was known for his expertise in metallurgy, chemistry and geology—but he was not a mathematician. Sequera, who was previously exiled to London and Malta, had been the Director of the Egyptian College of Artillery from 1829 to 1837. When he returned to Spain he was appointed second captain, a kind of resident head of the College. But he too was not a mathematician, and no changes were made to the mathematics teaching program.

The College did not last long in Segovia with a general teaching program. New regulations issued in 1842 established that a first degree in the General Military College would be required for all military studies and the College of Artillery became a second degree institution for specialized studies in artillery. As such, no cadets were enrolled as new students at the College in 1842, and by 1843 only graduated officers of the General Military College were granted admission. Students received basic instruction at the General Military College which fundamentally changed the nature of mathematics taught at the College of Artillery.

The way in which mathematics education evolved at the College of Artillery illustrates how the perception of mathematics changed during this period, which had effectively lost its prestige. In the 18th century, cadets entering the institution were as young as 12 to 14 years old and the College represented a secondary school aimed at preparing them for further studies with a basis in military training. As other secondary schools opened and the foundations of mathematics were covered by a new general military college, the idea (per the reform of 1842) was to assign the College with providing specialized instruction in artillery. This transition took time given the political climate in Spain at the time.

5 Conclusions

A modern mathematics teaching program was put in place at the College of Artillery around 1775. While the logistics of implementing this program took time to finalize, the final version would include the subjects of arithmetic, geometry, algebra, algebra applied to geometry, calculus and mechanics. The program changed somewhat in 1819 when mechanics would be considered as its own subject. While the subjects themselves would more or less remain the same, the approach to their instruction underwent considerable changes. For instance, marked differences existed between Giannini's method (from 1795) for defining differentials, which followed the ideas of Newton, versus Odriozola's work in 1829 on derivatives, that were more in line with Lagrange.

It would not be entirely accurate to say that one country or academy was specifically responsible for influencing the College's teaching program, which was fairly standard at the time. If outside influence was at play, this would have been in the beginning stages when the Military Academy in Naples served as a model, and during the 19th century when certain inspiration came from established French institutions.

One of the first hurdles the artillery corps faced was appointing an appropriate First Professor. The decision was made to hire the Spanish Jesuit Antonio Eximeno who was followed by Pedro Giannini, an Italian. Suitable professors would later be found in decorated officers from the artillery corps.

The textbooks that were most often used were written either by Giannini or Odriozola, both active professors at the College; texts by Lacroix were also frequently used during the 19th century, and to a lesser extent, works by Legendre, Monge and Zorraquín. If the textbooks used for instruction at the College were generally, if not indirectly, inspired by foreign authors, the reference books that served as a foundation for the College library in the 18th century were largely French editions. This trend would only continue to develop throughout the 19th century when the overwhelming majority of the College's print collection was written by French authors.

The Spanish College of Artillery did not, however, require foreign help when it came to finding professors or publishing textbooks on mathematics, with the brief exception when the College first opened; it was more in the context of adapting new theories and modernizing existing approaches and methods where foreign influence was most important. Not surprisingly, given that the College was a military institution charged with producing trained officers and not mathematicians, any research conducted by College personnel largely had to do with pyrotechnics or metallurgy. Similarly, when First Professors from the College did travel abroad on information gathering missions to educate themselves about current scientific and technical advances, their focus was limited to military arts and much less to developments happening in mathematics.

The fact that French influence during the first half of the 19th century increased so significantly was in part due to the fact that this period in France was when major advances were being made in the mathematical sciences. In concrete terms, the main reason was the lack of available funds in the Spanish Kingdom that made it virtually impossible to hire foreign specialists or send students abroad to further advance their knowledge of mathematics and train in modern techniques. After the Spanish American wars of independence, Spain was particularly ill-equipped to develop its own agenda for innovation and new theories and advances being made at the time were transferred exclusively through books or from accounts of those who had travelled abroad.

The periods of war pitting Spain against France or those surrounding the alliance with Great Britain did little to change the inclination to assign certain value to work by French mathematicians. This tendency can be found firmly rooted in history, the geographical proximity of Spain and France and the fact that the Spanish were fairly well versed in the French language.

Finally, the degree of French influence needs to be considered in a more nuanced context of other subjects being taught at the time, such as a applied artillery where the dependence on French innovation and research (published works) was not nearly as notable as it was in mathematics or chemistry.

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