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The Teaching of Mathematics at the Royal Military Academy: Evolution in Continuity

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Résumé : En 1741, la *Royal Military Academy* de Woolwich est créée par le *Board of Ordnance* afin d'instruire les futurs artilleurs et ingénieurs militaires. Cette instruction s'appuie dès le départ sur les mathématiques. Dans cet article, nous présentons et étudions les différents programmes sur la longue période (entre 1741 et les années 1860). Les évolutions, les changements mais aussi les constances sont évalués et nous donnons les raisons de ceux-ci. L'âge de recrutement, le poids du *Board of Ordnance* ou encore les diverses guerres ont aussi une influence importante sur la place des mathématiques dans les programmes. Par ailleurs, le peu de *turn-over* des professeurs entraîne aussi une inertie de l'enseignement des mathématiques.

Abstract: In 1741, the Royal Military Academy at Woolwich was created by the Board of Ordnance in order to instruct artillery officers and military engineers. From the beginning, the teaching was mainly based on mathematics. In this paper, we study different curricula and point out the long-term (between 1741 and the 1860s) evolution as well as continuity in mathematical learning and we give reasons for them. The age of recruitment, the authority of the Board of Ordnance and several wars had an influence on the role of mathematics in the syllabus. Furthermore, the low turnover of professors led to inertia in the teaching of mathematics.

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1 Introduction

Until recently, certain authors[1] have considered the period between the second half of the 18th century and the second third of the 19th century as a mathematical "dark age". Few or no mathematical innovations appear in Great Britain and the real productivity is on the Continent and more specifically in France. Nevertheless, other authors[2] have relativized this point of view. British mathematicians did in fact produce mathematics and had a detailed knowledge of this science as it was practiced in Europe. The publications that have just been quoted have at least one point in common: they point out the role played by the British military schools in the circulation of mathematics throughout Britain. The mathematics teachers in these academies played an important role in making mathematics known via journals [Despeaux 2002, 2011, 2014], [Bruneau 2020]. Unfortunately there are very few studies devoted to the history of these military institutions [Guggisberg 1900], [Smyth 1961][3] in general and concerning their teachers in particular.[4]

This article aims at studying the teaching of mathematics within the Royal Military Academy from its creation in 1741 up until the 1860s. A study over a broad period of time makes it possible to distinguish the changes, the developments, as well as the periods of stability in the curricula and the textbooks used or promoted. In a chronological progression through these 120 years, we shall try to identify the conditions and modes of evolution, giving special attention to the circulation of the teachers and evaluating the ways in which students were recruited. Furthermore, we will show that the authority organizing this school, the Board of Ordnance and certain wars had a strong influence on the changes occurring in this educational institution.

2 The Royal Military Academy (RMA)

In April 1741 it was after a request by King George II to the Board of Ordnance that an "Academy or School was instituted, endowed, and supported, for instructing the raw and inexperienced people belonging to the Military branch of this office, in the several parts of Mathematics necessary to qualify them for the service of the Artillery, and the business of Engineers"

1. By putting the emphasis on the following period, Flood, Rice *et al.* minimize this one [Flood, Rice *et al.* 2011]. Ackerberg-Hastings shows the important role played by British mathematicians (in particular John Playfair) in the 19th century while giving a negative view of the late 18th century [Ackerberg-Hastings 2008].

2. Without being exhaustive, we could quote [Guicciardini 1989], [Bruneau 2015], [Craik 2016].

3. It would be possible to add [Rice 1996] as part of his work is concerned with mathematics at the Royal Military Academy during the Victorian era.

4. The work of [Johnson 1989*a*,*b*] is a prosopographical attempt.

[Royal Military Academy 1892, 1]. This institution would be housed on the premises of the Royal Artillery Regiment at Woolwich[5] and would train both artillerymen and military engineers. In this royal mandate, only the teaching of mathematics is mentioned, and is thus accentuated, with a view to applying it to artillery and engineering. Intended for 40 cadets in 1744, this school gradually received up to 60 (from 1782), 90 in the 1790s and reached more than 260 at the beginning of the 19th century. But after the Napoleonic wars, the number diminished to 150 in 1820 then almost 100 a few years later. In 1783 it was decided to build new premises for the school, and in 1806 the cadets moved in. An extension was built in the 1860s. The fusion of this school with the Royal Military College caused it to move to Sandhurst in 1947.

This school was directed by military personnel: the Master-General assisted by a Lieutenant-General and the administration remained military. On the other hand, the teachers were mostly civilians, even though from the first third of the 19th century on, artillerymen or military engineers start to appear, to teach fortification or surveying.[6] For the mathematics taught during the period studied, no professor was from the military and among the teachers or instructors, the first non-civilian was Lieutenant Pickering in 1830. However it was only in the 1870s that military teachers really began to appear.[7]

Before the creation of the Royal Military Academy, there were educational institutions more or less specialized in the training of artillerymen or military engineers. Already in Woolwich shortly after the formation of the artillery regiment in 1716, it was envisaged to set up a teaching facility within the regiment, but through lack of finance, this service never became reality. So where were the artillerymen and the engineers trained before they entered the Royal Artillery? The major part of the training was done "on the job"; however, in Woolwich there must have been a place where future officers were schooled, as is shown by a short manuscript dating from 1736 [Brigge 1736]. Certain private schools in competition with the grammar schools also offered courses in military matters (fortification or artillery), like the Little Tower Street Academy in London.[8] At the University of Edinburgh, fortification classes in the first year and artillery classes in the second year Maclaurin taught [Bruneau 2011, 182–183].

5. A locality situated in the southeast of London on the Thames near Greenwich.

6. Given the difficulty of recruiting a civilian teacher of fortification, and with no desire to hire a foreigner, the *Board of Ordnance* decided in 1825 to resort to artillerymen and military engineers to occupy this function [Royal Military Academy 1892, 86].

7. All were members of the *Royal Artillery* and so had been trained at the *Royal Military Academy*.

8. For an overview of these schools teaching science, see [Hans 1966].

3 The organization of teaching at the RMA

3.1 The teaching of mathematics in 1741

From the beginning, a teaching program was set out in two large parts. The first was theoretical and consisted mainly of mathematics, and the second was devoted to the practice of artillery and engineering as well as drawing. Mathematics was spread between two *masters*. The *chief master*[9] looked after trigonometry and conic sections as well as practical geometry, surveying, leveling and mechanics.[10] The second[11] taught arithmetic, first principles of algebra and elements of geometry [Royal Military Academy 1741, 7].

The latter taught elementary mathematics while the chief master took on mathematics at a higher level and its applications. It was not taught for its own value but with a view to applications in artillery and engineering. There is no mention of fluxions nor of Newtonian fluents, nor of drawing. Furthermore, there is no information about the books used. In comparison, the teaching of mathematics by Maclaurin at the University of Edinburgh was at a higher level. To these subjects he added perspective, the direct and inverse method of fluxions, optics, astronomy, including spherical trigonometry, and cartography [Bruneau 2011, 182–183].

The theoretical part of the initial curriculum was concentrated on mathematics and its applications to fortification and artillery. The second part was devoted to practice in the field and was supervised by military personnel from the regiment. But very quickly, without any official justification, new courses were created: French and drawing. Abel Cassel was recruited as French language professor in December 1743 and one year later Gabriel Massiot became the drawing teacher.

The teaching in this academy consisted mainly in copying out reference texts and in drawing under the supervision of the teachers. For example, one cadet Robert Sandham described to his parents what he was doing at Woolwich:

> In the first place, I have written all "Mr. Muller's Artillery",[12] which is forty octavo pages; I am now constructing the plates with Mr. Simpson; I am in Multiplication of fractions; Mr. Mossiott approves my drawings. [Letter by Sandham of 2 November 1750 quoted in Royal Military Academy 1892, 7]

9. John Muller (1699-1768) was the first chief master. He was given a salary of £ 200 per year, twice as much as his assistant.

10. He also was in charge of teaching fortification, artillery and mines.

11. The first assistant was one Mr Derham who died in 1743 and was replaced by Thomas Simpson (1710-1761). He was paid £ 100 per year.

12. In 1750 this book was still just a manuscript. The first edition in use at this school was only published in 1757 [Muller 1757].

3.2 The reorganization of 1764

An important reform in the structure of teaching at the Royal Military Academy took place in 1764. The masters became professors who could then have assistants. So the Chief Master became the Professor of fortification and artillery, while his subordinate was considered from then on as the Professor of mathematics.[13] Several Masters were added to these two teachers: for drawing, French, common arithmetic (associated with writing) and fencing.[14] The whole of the training was divided into classes at four different levels. Most of the cadets stayed there for two years.[15]

The mathematics courses were essentially divided up between the two Professors and the Arithmetic Master. The latter mainly looked after writing and taught the basics of arithmetic "as far as the Rule of Three" [Royal Military Academy 1764, 8]. The Drawing Master taught, among other things, the practice of perspective. The fortification professor was interested in practical geometry and in mathematics applied to lifting and transporting heavy weights, as well as in surveying.[16] So the main teaching load went to the mathematics teacher:

> The Professor of Mathematicks shall teach the Principles of Arithmetick and Algebra, the Elements of Geometry, the Mensuration of Superficies and Solids, plain Trigonometry, the Elements of Conic Sections, and the Theory of Perspective; as also Geography, and the Use of the Globes. [Royal Military Academy 1764, 7–8]

So it was relatively elementary teaching. This is corroborated by the list of reference books indicated by the Board of Ordnance. The Professor of Fortification was to make use of [Muller 1747, 1757], i.e., his own works on fortification and artillery, and [Gregory 1745][17] for practical geometry. The mathematics professor could use part of the *Elements of Geometry* by Nicholas Saunderson [Saunderson 1756], as well as the *Elements of Geometry* by T. Simpson [Simpson 1747]. None of these books mention advanced mathematics such as differential and integral calculus. So this teaching is thoroughly turned towards applications in the military field.

13. The salaries did not change: £ 200 for the Professor of fortification and £ 100 for the Professor of mathematics.

14. The salaries of the different teachers give an idea of the importance of each discipline. Thus the French and Arithmetic Masters were the least well paid at £ 40, the drawing teacher at £ 54 15 *s*., while the Fencing Master was paid £ 100: as much as the mathematics teacher!

15. In 1765, out of the 35 cadets assessed, 1 stayed 5 years, 4 had been there for 3 years and the rest less than 2 years. These cadets were between 14 and 19 years old [Royal Military Academy 1892, 14].

16. Of course his teaching included fortification, the attack and defence of fortresses, rudiments of military architecture and artillery as a whole.

17. This work translated from Latin into English by C. Maclaurin had a great success and went through eleven editions between 1745 and 1796.

3.3 The curriculum in 1776

From the beginning of this school, entrance to it depended on cooptation, the level of the future cadets was not assessed and age was not one of the criteria.[18] The poor level of some students caused fairly strong reactions from the professors and the administration. Thus in 1772, one student was sent down from the school as he did not know how to read or write and so was a burden on the teachers [Royal Military Academy 1892, 17].

To guarantee a minimum level of the candidates, an entrance examination was envisaged around 1772. It consisted only in accepting boys who knew how to read and write and were acquainted with the four operations of arithmetic, as well as the rule of three. This examination meant that the role of the master of writing and arithmetic became obsolete. Furthermore, at the end of 1772, a thorough reorganization of the teaching was proposed by the Lieutenant Governor of the Academy. The school was separated into two parts (the *Upper* and the *Under Academy*) each of them having four classes. The progression in each discipline is described at greater length and in more detail. The Professor of Fortification and Artillery was to keep the same functions and teach practical geometry and applied mathematics. On the other hand, there is no mention of books presenting these disciplines.[19] The changes were more significant for the Professor of Mathematics and the Master of Writing and Arithmetic. This is visible in their titles and their objectives. The latter became the Master for Classics, Writing and Arithmetic. Other than literature and the study of English,[20] he had to teach arithmetic and the basics of algebra. For example, he was the one charged with the extraction of square and cube roots and the solution of quadratic equations. This master only intervened in the *Under School*. So this part of mathematics was no longer part of the obligations of the Professor of Mathematics. Thus his program too was modified. Relieved of the most elementary parts, he had to take on the following matters:

> Mensuration of Superficies and Solids, Algebra and Plane Trigonometry, with their various Applications; the latter, in a particular Manner, to be applied to all the possible Cases that may happen in actual Service: The Elements of Geometry, the Theory and Application of Projectiles in non-resisting and in resisting

18. Nevertheless in 1764 it was decided that it was necessary to be at least 12 years old to become a cadet. As a result, all those who did not satisfy this criterion were suspended and could not stay in the Academy. So several cadets left the school, in particular three of them that were 3, 4 and 6 years old respectively [Royal Military Academy 1892, 13].

19. The recommended books were mostly (4 out of 6) by Muller who was replaced as Professor of Fortification in 1766 by Allen Pollock. For a list of the professors of fortification and artillery, see [Guicciardini 1989, 156–157].

20. He also taught Latin via the study of Latin authors, but this teaching disappeared fairly quickly.

> Mediums:[21] The Elements of Conic Sections, and the Theory of Perspective: Likewise Geography, and the Use of Globes. [Royal Military Academy 1776, 18]

The books quoted are in part those by T. Simpson [Simpson 1745, 1747, 1752], by Charles Hutton [Hutton 1770] and by Hugh Hamilton [Hamilton 1773]. This list of text books shows that there was no policy of publishing a textbook for this school. It also shows the important influence of T. Simpson (through his textbooks) long after his departure from the school.

Another important change concerned drawing which became a whole subject matter in itself. There were thus two Drawing Masters looking after perspective (one for practice, the other for theory). Other than the autonomy of this subject, the status of the Chief Master of Drawing was re-evaluated; his salary became equal to that of the Professor of Arithmetic (£ 150).

Likewise the Professor of Mathematics earned as much as the Professor of Fortification (£ 200 each), while the Masters of French and Fencing received £ 100 annually each [Royal Military Academy 1776, 4].

This new curriculum coincided in 1773 with the arrival of Charles Hutton as Professor of Mathematics in place of J. L. Cowley. This new professor was to have a very strong influence on the teaching of mathematics in the school. Very quickly after his arrival, he managed to replace some of the reference books by his own.[22]

In 1782 it was decided to increase the number of students to 60. This implied the recruitment of a Mathematics Master. This was John Bonnycastle, then working as a tutor in London and as an author of textbooks. The Arithmetic and Writing Master was thus relieved of parts of the mathematics teaching which was passed over to this new teacher who also was in charge of helping the professor of mathematics in private lessons and in checking the copying out of courses.[23]

3.4 The mathematical knowledge mastered in 1792

Entrance into the royal artillery regiment was only possible via a public examination at the end of the schooling within the Military Academy in Woolwich. But in 1792, in the midst of the French Revolution, the need

21. Initially, in the preliminary version of this program, fluxion calculus was taught in the field of the theory and applications of projectiles. But, in the final version, it disappeared. Nevertheless, in 1788, this calculus was evaluated during the final public examination [Royal Military Academy 1892, 30].

22. Hutton [Hutton 1770] was to be the reference work instead of [Simpson 1747] [Royal Military Academy 1892, 23].

23. In 1797 it was decided that the second mathematics master would teach Euclid's geometry and the application of algebra to geometry [Royal Military Academy 1892, 45].

for artillery officers and engineers increased.[24] This is why it was envisaged to recruit outside of the RMA. But the candidates had to display a level of knowledge and competence equivalent to those of the cadets leaving the Academy. Consequently, this list is a precious source of information about the level expected at the end of schooling in this academy and the reference works on whose basis candidates were assessed.

1. *Arithmetics* in all its parts;
2. *Logarithms*: Their nature, use and construction;
3. *Geometry*: The Theory from Euclid's *Elements*: four first books;
4. *Algebra*: From the first Elements to the Solution of Cubic and Higher Equations;
5. *Trigonometry* with Heights and Distances;
6. *Mensuration*: In Superficies and Solids; in Theory and Practice, with Surveying and Measuring of Artificers' Works, Buildings, Timber, &c.
7. *Conic sections*;
8. *Mechanics*: Including Motions equable and variable; Forces constant, variable and percussive; Gravity, Sound and Distances; Inclined Planes; Projectiles; Pratical Gunnery; Pendulums; Centres of Gravity; Percussion, Oscillation, and Gyration; Ballistic Pendulum, &c.;
9. *Fluxions*;
10. *Hydrostatics and Hydraulics*: Including the pressure, motion, and issuing of Fluids; the filling and exhausting of Vessels, &c.; Specific Gravities of Bodies; Syphons; Pumps; Diving Bells, &c.;
11. *Pneumatics* [...];
12. *Practical Exercises*: concerning these and various other branches [...];
13. *Resistance of Fluids* as Water, Air, &c. [...];
14. *Gunnery*: Robin's [*sic*] new principle of Gunnery; Experiments, particularly with the Ballistic Pendulum. [Royal Military Academy 1892, 33]

According to the Lieutenant-Governor, the candidate could claim entrance to the artillery corps by presenting a correct copy of this mathematics course with neat figures. So the candidate is not requested, at first, to show his competence or his cleverness in solving problems.

This mathematics course is based on a list of books and a few manuscripts developed by Hutton.[25] For a candidate who was not a Woolwich student,

24. This also caused an increase in the number of students and in 1794 there was 90 of them.

25. The books are "Dr Hutton's *Arithmetics: Logarithm, Mensuration, Conic sections, and select exercises*; *Tracts*—Mr Robin's [*sic*] *Gunnery*, the 1st vol. of his

that could create a problem of accessibility. In September 1792, Charles Hutton offered to write a textbook containing all the mathematical knowledge necessary for the training of artillery officers and engineers in that school except for Euclid's *Elements* and the logarithm tables.[26] It was only in January 1798 that he announced that the first volume of his course was in press.[27] The Academy ordered 300 copies bound in calfskin as well as 1 000 for the arithmetic part , 850 for the algebra and 700 for the geometry.[28] Each part was meant to be sold separately to the students. Hutton received 100 guineas to cover the publication of each volume. As a result of exchanges between the two parties, it was decided that each extra volume in calfskin ordered by the Academy would cost 8s. 6d. (i.e., 17 s. the two volumes) and that each part would be sold to the students at 2s. 6d. [Royal Military Academy 1892, 46]. In view of the success of this book, a second edition was published the following year and even a third in 1801.[29] Originally intended to cover all the mathematics taught at Woolwich, it apparently answered a need from other private schools or private teachers. In 1811, a third volume appeared as a complement to the first two. New editions continued to appear up until 1841. It became the reference textbook at West Point during the first years of its existence.[30]

Once this textbook had been published, the mathematics program in this school did not change for many years and its teaching was organized around this book even after its author's retirement in 1806. Thus, in 1810 it was reaffirmed that the study of mathematics had to follow to a great extent Hutton's Course with a few minor adaptations [Royal Military Academy 1892, 59]. Likewise, the entrance examination,[31] which was re-evaluated in 1813, quotes this textbook as replacing Euclid's *Elements*:

> Vulgar and decimal fractions, duodecimals or cross multiplication, involution, extraction of the square root, notation and the first four rules of algebra, definitions in plane geometry, English grammar and parsing, French grammar. If not called upon to be

Works; Professor Simpson's (of Glasgow) *Elements of Algebra*; Rossignal's *Geometry*; Bonnycastle's *Algebra*; Simpson's *Algebra for application to Geometry*", to which should be added manuscripts written by Hutton on fluxional calculus, mechanics, hydrostatics and pneumatics.

26. In 1785, he produced a book of mathematical tables [Hutton 1785].

27. The relatively long time required for his project can be partly explained by his intense editorial activity during this period. He was, among other things, editor of the *Ladies' Diary* starting from 1774, and the author of a dictionary of mathematics [Hutton 1795]. For more details about Hutton see for example [Johnson 1989*a*], [Wardhaugh 2017*a*,*b*,*c*, 2019].

28. The parts were bound separately with a common binding.

29. For the latter edition, the advance was re-evaluated at 200 guineas for 300 copies [Royal Military Academy 1892, 51].

30. Concerning the circulation of this work in the United States, see [Preveraud 2012].

31. The candidates had to be between 14 and 16 years old.

> examined at 14, the candidate is expected to pursue his studies, so as to obtain the following additional qualifications by the time he is near 16, without which, or some part of them in proportion to his age, he cannot be received after he is 14 years old, viz.:— The remainder of algebra, except cubic equations, the first two books of Euclid's "Elements of Geometry", or instead of "Euclid's Geometry", the first 65 Theorems of Dr. Hutton's "Course of Mathematics".[32] [Royal Military Academy 1892, 69]

Moreover, in 1828, to graduate from the school, the cadets had to have "a complete knowledge of Dr. Hutton's 'Course of Mathematics' [...] omitting Cubic and higher Equations, and the rules applicable merely to commerce" [Royal Military Academy 1892, 87].

3.5 The "crisis" of 1810

The beginning of the 19th century brought in several important changes. The first was the significant increase in the number of cadets at the school. The number of students went from 90 to more than 153 in 1803 and 200 in 1806, to which should be added 46 students trained for the military regiment of the East India Company. To face up to this rapid rise, several mathematics masters were recruited[33] and to helpu the mathematics professor.

The second was the creation of another military school in England, the Royal Military College[34] at Great Marlow in 1801, intended to train young infantry and cavalry officers. Some of the youngest or least advanced cadets (those of the Lower Academy) at the RMA were sent to Great Marlow to continue their schooling.

This way of teaching based on a single book was not necessarily accepted by all of the Mathematics Masters in Woolwich. The last master recruited, William Saint, considered at his recruitment as "the fittest person, and remarkably well-qualified to fill the situation" [Royal Military Academy 1892, 58], expressed serious doubts as to the quality of the mathematics teaching at the RMA. In November 1809, he addressed a letter to the Lieutenant-Governor Mudge deploring the poor level of arithmetic of a cadet who spent one year at Great Marlow followed by another year at the RMA. For W. Saint, this was due to the character of the professor of mathematics, J. Bonnycastle, and especially to the teaching method, which he considered obsolete and ineffective.

32. This text was slightly modified in 1820 by removal of the reference to Hutton's textbook and by an indication of the number of propositions from Euclid's *Elements* to be known depending on the candidate's age [Royal Military Academy 1892, 80].

33. Lewis Evans in 1799, his son Thomas Simpson Evans in 1802, Olinthus Gregory in 1803, Samuel H. Christie, Thomas Myers, Peter Barlow and William Moore in 1806 as well as William Saint in 1807.

34. For a history of this school, see for instance [Smyth 1961] and concerning some of the professors of mathematics [Craik 1999, 2000].

He thought that a strict copying out of Hutton's textbook was of no use and that the students did not know how to answer questions that were not drawn directly from this work. A problem taken from the book but with different numerical applications could not be solved by a large part of the cadets. So he demanded a complete reorganization of the teaching.

First of all, he considered that the entrance examination was insufficient to really assess the competence of the candidates. To know the real level of the candidate in English, instead of asking him to spell his name, he ought to be asked to read a text at random to avoid reducing the teachers, including the mathematics teachers, to being writing and reading masters. As far as mathematics was concerned, he considered that expecting the candidates to know only the first principles of arithmetic was quite inadequate and he insisted that the future cadet must know how to solve quadratic equations.[35] Furthermore, the motivation of teaching in the RMA ought to be competition and the individual progress of each of the students. In this way, if success was absolutely dependent on an evaluation of real knowledge which manifested the veritable aptitudes of the cadet, then learning would be made easier.

One of Saint's sharpest criticisms concerned the idleness of the cadets in class. The excessive number of cadets in each class and the way in which teaching was performed did not allow the master to pay attention to each student. For example, while a group of four students went to the master's office to be questioned, the others did nothing.[36] Otherwise, the teaching of mathematics, which to a large extent came down to copying out Hutton's course verbatim, encouraged young cadets (at least those who had the money) to have it done by someone else, and these young men were not encouraged to understand the content of the book. Saint also wanted to have freedom in teaching: to get away from copying out a book and make the students understand the mathematics according to their level.

In reality, William Saint was promoting the teaching method of a newly created school: the East India Company Military Seminary[37] at Addiscombe (Croydon). This military academy was meant to train in two years the engineering, artillery and infantry officers for the regiment of the East India Company. Initially schooled within the RMA, these soldiers were given a specific training starting from 1809 . The teaching was more diversified (in particular regarding languages) and the supervision was greater: at its creation there were 9 teachers for 60 cadets.[38] Among them, James Andrew

35. He adds that this is possible for a 14-year old boy. Moreover he has already encountered girls of that age who had no difficulty in doing it! [Saint 1811, 42].

36. A great number of hours are devoted to mathematics and the masters are subjected to a heavy work load, around 6 or 7 hours a day during 5 days per week. The masters tired out by this load, make use of these hours to do other things, in particular correct the proofs of their own production [Saint 1811, 32].

37. Very little has been published about this school, see [Bourne 1979], [Vibart 1894].

38. In comparison, at the RMA there were 20 teachers for more than 180 students.

was mathematics professor and head of the school and James Glenie[39] was mathematics master.

In short, Saint wanted a re-evaluation of the entrance examination to be sure that the candidates really knew how to read and write and that they really knew some mathematics. He insisted that the cadets be enrolled in classes of different levels. He added that during the courses, the students had to really work and that the master should be the one to decide the teaching method. Finally, he demanded that the graduation examination should not just be the verification of a copy of a textbook but an assessment of what the cadet had really understood.

Unfortunately for him, his demands were only partially put into practice at Woolwich. Starting from January 1810 (i.e., after Saint had sent his first three letters), the use of other examples or alternative methods was allowed so as to get students to understand Hutton's textbook, which remained what the students had to know for the final examination [Royal Military Academy 1892, 60]. The Lieutenant-Governor granted a certain amount of liberty to masters.[40] The monthly report for each class was more individualized, the advances became nominative. But it did not go any further. The inspector and his assistant, considering that such profound changes in the way the school operated would be seen as a criticism of the work of their predecessors, were not at all prepared to comply with Saint's demands. Thus, on 12 September 1812, at the graduation examination of 29 cadets, "two days were devoted to Mathematics; the written course books were directed to be examined by the Inspector and reported" [Royal Military Academy 1892, 66]. The above-mentioned re-evaluation in 1813 of the level required for admission into this academy was also an effect of this "crisis".

3.6 Dead calm until 1840?

In 1833, new regulations were introduced but did not cause much change. The candidates had to be between 15 and 17 years old (i.e., a year older than in the previous regulations) and the level of mathematics was much the same. The candidate had to be acquainted with the first book of Euclid's *Elements* and with the first principles of algebra, as far as solving a system of equations with two unknowns without irrational numbers[41] [Royal Military Academy 1892, 96]. The mathematics teaching was the same and relied on Hutton's textbook, of which a new edition was in press.[42]

39. In fact he only stayed one year in this institution.

40. Lewis Evans, one of the mathematics masters at the time, relied to a large extent on Hutton's textbook. Nevertheless he gave other exercises not contained in it [Evans MS23, Archive of the Science History Museum in Oxford].

41. The entrance examination became more substantial with the addition of new subjects to be tested, geography and history.

42. The only change concerned the calculus of fluxions and fluents, which was replaced by differential and integral calculus.

An important challenge to the teaching method, particularly in mathematics, appeared in 1837. The committee evaluating schooling in mathematics considered that the examination methods for moving from one academy to another or for validating the theoretical part at graduation were poor and, above all, that Hutton's textbook contained many errors and was obsolete in comparison with what existed elsewhere [Royal Military Academy 1892, 100]. This resulted in profound changes. Upon arrival at the school, cadets would be assessed on their level in mathematics and after one month, each would be assigned to a class (no longer an academy) that depended on his progress in the discipline. Intermediate examinations would be conducted by the masters but the questions would be written by the professor. The final examination no longer consisted of a faithful copy of Hutton's textbook but of the resolution of 50 questions and the students' papers were made anonymous.[43] In addition, for the teaching of the most advanced mathematics, the committee advised using sources other than Hutton's textbook.[44] A list was even proposed by S. Christie in March 1840 and the program was the following:

> Algebra: To the extent of the properties of Equations; the solution of numerical Equations; the method of Indeterminate Co-efficients; the binomial theorem (demonstration); the exponential series, the properties of the Logarithms of numbers, with their application to arithmetical operations; the Logarithmic series. Geometry: Euclid. The first books, exclusive of a few propositions, in the 2nd, 5th, and 6th books; the 11th book to proposition 22 inclusive; the 12th book, Lemma 1, proposition 1 and 2. Application of Algebra to Geometry: The solutions of Problems, the analytical expression of the properties of Lines by means of Co-ordinates, as introductory to applications of the Differential and Integral Calculus. Trigonometry: Analytically investigated to the extent of obtaining the best formula of solution of several cases of plane Triangles, with applications to examples; application of Trigonometry to the determination of heights and distances; investigation of formulæ for the areas of plane rectilinear figures, and application to examples. Conic Sections: the principal properties of the Parabola, and a few of the leading properties of the Ellipse and Hyperbola. The Differential Calculus: The principles of the Calculus with their application to the determination of maxima and minima, and the drawing tangents to curves. Integral Calculus: The Principles of the Calculus with their application to determining the areas and lengths of curves, the volumes and surfaces of solids; at present this subject cannot be much dwelt on. Mechanics: The

43. In British universities this practice only appeared at the beginning of the 1900s.
44. By an irony of history, after 30 years, Saint's suggestions were at last taken into account.

> principles of Statics and Dynamics with their applications as developed in Whewell's "Elementary Treatise". Under present circumstances we cannot expect that the Course of Instruction can extend much beyond the motions of projectiles in vacuo. [Royal Military Academy 1892, 102]

In this program, the overall level has been raised: in particular differential and integral calculus is more present, and its application to geometry is better presented. In algebra, the study of series becomes explicit and certain methods in vogue on the Continent have been introduced.[45] Arithmetic has disappeared. As a result, the textbook used, in spite of successive up-datings including one by O. Gregory, became obsolete. As of 1841, two editions of Hutton's textbook were in competition and were written by two mathematics teachers from the RMA: the first by Rutherford and the second by Davies [Rutherford 1841], [Davies 1841]. However the Lieutenant-Governor at the introduction of this new program asked S. Christie to write a new textbook for the school. In 1848 this textbook in two volumes [Christie 1845, 1847] was not approved by the school as it was considered unsuitable for the cadets. A new order was placed with the professor of fortification, H. D. Harness. The volumes came out in 1853. Each part was written, not by Harness himself, but by the mathematics masters; the professor of mathematics, S. Christie, was excluded from this enterprise. The chapters devoted to arithmetic, to algebra and to differential and integral calculus were written by W. Rutherford; those devoted to the application of algebra to geometry, to trigonometry, to measurement and to two-dimensional geometry were by T. S. Davies then by S. Fenwick. This was the first time that a British textbook for artillery officers and military engineers contained a part devoted to descriptive geometry.

3.7 The Crimean war and its effects on the RMA

The Crimean war,[46] which came to an end with the peace treaty of February 1856, made the British army conscious of its weaknesses and its backwardness, in particular with respect to France. This feeling was reinforced by the revolt of the Sepoys in India [Herbert 2009]. This loss of confidence also hit the educational institutions for the military elite. So a commission was created to visit the different military schools—French, Prussian, Austrian and Italian (in Sardinia)—and compare the systems and the teaching in these schools with those at Woolwich. In its report [Commission 1857], after an appraisal of the situation, several reforms were suggested. Among these, some were really put into practice: the age of entrance was pushed back

45. For example, Sturm's theorem of use in finding the number of real and imaginary roots to a polynomial with real coefficients was one of the methods taught at Woolwich.

46. For a study of the influence of this war in Britain, see for instance [Sweetman 1984].

to 17 (then in 1862, between 16 and 19) and a harder and longer entrance examination was introduced so that the selection would be entirely by merit.[47] In parallel with these reforms, every year the school had to publish a report about the entrance examination. It contained the entrance conditions and various pieces of information including the names of the examiners and the subjects of each test. In this examination, from then on, it was necessary to sit for 5 tests out of the 9 available. The mathematics test was the only one that was mandatory, with an eliminatory mark [Royal Military Academy 1861, iv–v]. After that, the annals of the mathematics subjects were published every year with the correction used in the entrance examination at Woolwich. They were published to help the candidates to prepare, as well as for their teachers and for anyone wishing to study mathematics [Austin 1880, Preface]. The fields of mathematics were the same: algebra, differential and integral calculus and particularly geometry (essentially Euclidean) as well as mechanics. The real change was more in the level expected rather than in the breadth of the discipline.

4 Mathematics teachers at the RMA

Between 1741 and 1884, 10 professors of mathematics worked in this institution and 32 masters or assistants in mathematics (see Table 1, p. 152). The number of the latter varied with the number of cadets. It was only from the beginning of the 19th century that there appeared a small community of mathematics teachers. They were a maximum of 9 in 1809 (one professor and 8 assistants), but because of the decrease in the number of students, the masters that left were not replaced and Myers was dismissed.

Professor		**Master**	
1741-1766	J. Muller	1741-1743	Derham 2nd master
	chief master	1743-1761	T. Simpson 2nd master
	then prof. Art.	1761-1764	J. L. Cowley
1764-1773	J. L. Cowley	1764-1799	W. Green arithm.
1773-1807	C. Hutton	1782-1807	J. Bonnycastle
		1799-1820	L. Evans
		1802-1810	T. Evans
		1803-1821	O. Gregory
		1806-1838	S. H. Christie
		1806-1823	T. Myers
		1806-1847	P. Barlow

47. The example followed was that of the French École polytechnique where the recruitment was highly selective and preceded by preparative classes.

		1806-after 21	W. Moore
1807-1821	J. Bonnycastle	1807-1810	W. Saint
1821-1838	O. Gregory	1830-?	Lieut. Pickering
		1831-1834	T. Myers
		1834-1834	George Harvey
		1834-1855	T. S. Davies
		1837-1865	James R. Christie
1838-1854	S. H. Christie	1838-1864	Rutherford
		1838-1839	Jeans
		1839-1840	J. Newmarsh
		1840-1860	John F. Heather
		1841-1870	Stephen Fenwick
		1841-1871	George Y. Boddy
		1841-1871	Thomas Bradley
1854-1855	M. O'Brien	1847-1860	W. Racster
1855-1870	J. J. Sylvester	1855-1858	Rev. F. W. Vinter
		1861-1872	Racster
		1864-1870	W. Crofton
1870-1884	W. Crofton	1870-1873	Capt. W. H. Wardell
		1871-1873	J. McLeod
		1872-1876	Lieut. E. Kensington
		1873-	E. F. S. Tylecote
		1873-1884	Harry Hart
1884-	H. Hart		

Table 1 – List of mathematics teachers at the RMA between 1741 and 1884

Of the ten professors, only four were directly recruited as professors (J. Muller, C. Hutton, M. O'Brien and J. J. Sylvester). The reasons for these external recruitments were varied. In Muller's case, it was because he was the first recruited. Hutton's recruitment was related to the fact that the master of arithmetic, W. Green, was not competent enough to become a professor and the Academy was obliged to look for someone outside.[48] A competition was organized to replace S. H. Christie in 1854. M. O'Brien and J. J. Sylvester were among the participants. In spite of his numerous supporters,[49] it was not Sylvester who was recruited but O'Brien. When he died a year later, Sylvester was chosen and this was due to his scientific reputation and his numerous supporters [Rice 1996, 401–402]. On the other hand, the 7 others

48. The Duke of Northumberland was one of the people most in favor of his recruitment [Wardhaugh 2017*c*, xix].

49. The names of these supporters are given in the letter that Sylvester sent to John Lubbock on 24 July 1854 [Parshall 1998, 69–70]. Concerning Sylvester, see [Parshall 1998, 69–70].

had all been masters first and on the death or the retirement of the professor, the one with the highest position became professor.

These teachers stayed a long time in the institution, especially the professors. Hutton taught for 35 years, Muller for 26 years and Sylvester 16 years. But if his time as a master is taken into account, it was S. H. Christie who stayed the longest: 51 years![50] This can be partly explained by the fact that it was a recognized position within the institution. Except for the very beginning, when the professor of fortification had a better salary than the mathematics professor,[51] these two professors received the same wages, then starting in 1810, it was the mathematics teacher who had the better salary.[52] Most of the masters also stayed for a fairly long time. Except for a few of them (specially after 1870), they stayed at least 15 years in the school.[53]

Having professors staying on for such a long time explains the inertia and the lack of change in the curricula. The case of Hutton is typical. Recruited at a time of change in the program, he suggested one of his books as the reference. And very quickly, he offered to write a textbook that would contain all the mathematical knowledge taught at the RMA. Once the book was written, why bother to change the program? Even after the departure of its author, his two successors, J. Bonnycastle, then O. Gregory, continued to rely on the same book. So they were in no way in favour of a change of program. The changes in curriculum were not necessarily requested by the mathematics professor, even if such changes were a chance to renew the program. The modification at the end of the 1830s was set off before Gregory's departure and was caused by the increase in age of the candidates and a greater stringency in the conditions for entry. According to what remains of the archives, change was always at the initiative of the Board of Ordnance, although the professors of mathematics were consulted. However, they took part in the choice of the reference works and in writing the textbooks. Consequently, the military style of functioning, in which it is the members of the Board of Ordnance who decide on change and evolution in the programs, also partly explains the inertia of teaching in general and teaching of mathematics in particular within this institution.

5 Conclusion

Between the creation of this institution and the last third of the 19th century, the teaching of mathematics hardly changed. The prestige of geometry was important and it was taught by the professor of mathematics (and his

50. Cowley stayed 14 years (4+10), Bonnycastle 41 years (26+15), Gregory 37 years (18+19), Crofton 22 years (7+15), Hart 25 years (10+15).

51. In 1764, the professor of fortification received £ 200, with only £ 100 for the professor of mathematics.

52. In 1810 he received £ 540 and the other £ 494.

53. Among the masters, Peter Barlow was the champion of longevity at 42 years.

assistants) as well as by the professor of fortification. The teaching of drawing took on an ever-increasing importance over the years. It was strengthened, for example, by the introduction of descriptive geometry in the 1840s.[54] This is one of the five or so changes in the mathematics program that took place over more than 120 years. So the reforms in the teaching of this discipline, which is essential in the training of artillerymen and engineers, were few in number and were brought about by the Board of Ordnance, especially in the 18th century and in the aftermath of the Crimean war. Some changes took place when there was a change of professor. A typical example was the recruitment of Charles Hutton. He did not hesitate to offer his services in writing a textbook which would be in accordance not only with the teaching program but also with the way of admission. For more than 40 years, with some superficial improvements, this would be the basis of the teaching of mathematics in this school. The desire for reform on the part of some (such as William Saint) was rapidly crushed by the institutional weight of the professors. It was their longevity within the Academy that prevented any change or development.

On the other hand, the changes were closely linked to the conditions of access, in particular the age of recruitment for the cadets. Over the period studied, this was evolving. At the beginning, there were no criteria and very quickly abuses appeared. The extreme youth of a few cadets – some of them under 10 years of age—or the lack of knowledge of writing and reading prevented the teaching from attaining a high quality. When a minimum age and minimum knowledge of English and mathematics were required, the level of this subject improved and so the program was modified. Gradually, the entrance age was raised and as a result, the knowledge of mathematics expanded. It was not until the second half of the nineteenth century, inspired by what was done at the French École polytechnique and with the recruitment of cadets between 16 and 19 years of age, that the mathematics taught became of a higher level. Nevertheless, unlike the French institution, the Royal Military Academy in Woolwich never had the ambition of training scientists but simply officers who would serve their country on the battlefield. Thus, in the archives or speeches of the institutions, it is never mentioned that this school must train the scientific elite of the kingdom, but regularly it is indicated that this academy is at the service of the army and that its aim must only be to train good officers: mathematics is only seen as a means to achieve this end and not an end in itself.

54. In 1841 Thomas Bradley became the instructor in descriptive geometry, a newly created post.

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