SURVEYING AND MATHEMATICS EDUCATION IN EARLY AMERICA

A Thesis

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Mircea Ioan Pitici

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ABSTRACT

The history of mathematics education during colonial America and early republic is an underprivileged subject. This thesis focuses on one aspect of this broad topic, the interdependence of land surveying and mathematical instruction. By analyzing the mathematical content of surveying manuals and by locating relevant newspaper advertisements, I conclude that the interdependence not only benefited the American mathematics education at its beginnings, but was instrumental in starting it.

BIOGRAPHICAL SKETCH

Mircea Pitici was awarded a B.S. degree in Mathematics at the University of Bucharest, Romania. Over the last three years he has taught a variety of mathematics courses at Cornell University, Ithaca College, and Wells College. Presently Mircea is pursuing a doctoral degree in mathematics education at Cornell University.

To my daughter, Ioana

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PREFACE

For longer than two centuries, encompassing colonial America and the first half of the 19th century, Americans were on an uninterrupted quest for discovering, conquering, dividing, measuring, mapping,[1] and naming their newly found land. Throughout a territory that by all criteria was immense, the entrepreneurial young people established homesteads, settled in small and big conurbations, built roads, bridges, lighthouses, furnaces, mills, and colleges, dug canals and mines.

New England and the Appalachian Mountains, stretching from Maine to Georgia and from the Atlantic Ocean to the Hudson and St. Lawrence Rivers, presented the first generations of Americans with a rocky land broken by hills and crossed by large valleys of fertile soil, most notably by the Connecticut River Valley. In this part of America the commodification of land started.[2] Transforming land into property involved complex practical and legal procedures. Some land disputes lasted for several decades—or even longer than a century, as in the case of the Mason-Dixon Line.[3]

Throughout the process of parceling newly appropriated land, enterprising individuals, the federal government and local authorities, performed numerous cadastral measurements. This practical work required field specialists in surveying[4]—demand that stimulated mathematical instruction pertinent to the

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[1] For an excellent monograph on the map making in America up to 1900 see Short 2001. For a broader perspective on the importance of maps in history see Thrower 2007. For the more recent digital revolution in map-making see Starr 1990a, 1990b.

[2] See Kain and Baigent 1992 for a global history of the transformation of land into a commodity, from antiquity to modern times, including early America.

[3] A detailed account of the long boundary dispute between Pennsylvania and Maryland, settled along what is called the Mason-Dixon line, is given by Bedini 1975, in the chapter "The Witty Geometers." Bedini gives special attention to the impact of the dispute on the import, use, and (later) manufacturing of surveying instruments in America.

[4] The best monograph to date focused on early American surveying is Cazier 1975. The book does not include mathematical aspects pf surveying. For Canada, see the thoroughly researched monograph by Thomson 1966.

surveying practice; this demand also engendered the first forms of organized mathematics education in America.

My goal in this thesis is to document some of the historical sources that justify the claim in the preceding sentence.

Of all practical endeavors that benefit by incorporating mathematical methods and instruments, surveying has the longest and the most intimate links with the growth of mathematical knowledge. Surveying, using basic mathematical notions, was practiced in ancient Mesopotamia, Sumer, Egypt, and the Roman Empire.[5] Arithmetic, trigonometry, and geometry have always been essential to a surveyor's work, as we will see in the following pages. Over the last few decades, the manufacturing of ever better surveying instruments and the branching out of surveying in previously untapped territories like undersea surveying and planetary surveying[6] vastly expanded the applicability of higher mathematics in various areas of surveying.[7] Historically, a long-term parallelism between the scope of surveying as a profession and the mathematics taught at college level is traceable to such extent that almost all the mathematics taught today in undergraduate courses at American universities is applied, one way or another, in various kinds of surveys.[8]

Yet the parallel development of surveying and mathematics has never been analyzed systematically, mostly because research on the history of mathematics education in colonial America is an underprivileged subject.[9] Despite a revival in

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[5] See Anonymous 1966a, 1966c; Bandy 1966, Crawford 2004.

[6] See an anonymous note (1966b) for the of planetary surveying,

[7] The main professional journal for surveyors in the United States is Surveying and Land Information Science. Customarily it publishes articles of moderate mathematical technicality, understandable for readers with mathematics instruction at undergraduate level. For various applications of plane and analytic geometry to surveying, see Cederholm 2003, Christiansen 1996, Danial 1990, Dracup 1991, Easa 1991a, Hartzell 2002, Li 2003, Meyer 2002, Shrestha 1990, Tamim 1995, Tan 2004. For applications of plane and spherical trigonometry, see Blesch 2004, Dracup 1996b, and Todhunter 1990 (1886). For linear algebra applications in various surveying areas, see Dubeau 1995, Dubeau 1996, Easa 1991b, Even-Tzur 2004, Kelman et all 2004, Marin 2004, Shrestha 1991, Deakin 1998, Doytsher 1997, Dracup 1996a, Alves 2005, Heckroth 2007. For calculus applications see Chen 1991, Easa 1991c, Heckroth 2007, Roman et all 2004. For applications of statistics, see Craig 2003, Gao 2005, Ghilani 1990, Kuang 1996. Numerical methods are used in Christiansen 1996, Danial 1991, Easa 1995, Easa 2007, Ghilani 2000, Smith, S. E. 1995, Vonderohe 1990.

[8] See the references in the previous note.

[9] Corry 2004 provides a useful literature review.

historical studies spurred by the National Council of Teachers of Mathematics (NCTM) in late 20th century, the few comprehensive monographs on the beginnings of mathematics education in America are several decades old, or older.[10]

In this thesis I explore a few questions I find relevant to the history of the American mathematics education: What was happening in surveying and how did it influence mathematics education? Who was surveying and what materials were used (written texts as well as instruments)? What was the level of the mathematical books employed in learning surveying? What were the goals of the authors of surveying manuals? What obstacles impeded surveying, in connection with mathematical instruction—and how were these obstacles overcome?

Land surveying in early America was an exceptionally honorable profession. Surveyors were well regarded socially and were well positioned to start successful careers in business and politics.[11] Three American presidents were professional surveyors in their youth: Washington, Jefferson, and Lincoln.[12] But the surveyor in early America was firstly a pioneer, in every sense of the word. He went to places unseen by any European. He did it with great risks to his health, safety, and life. This speaks much about the surveyor's devotion to his work and explains the almost legendary allure he held for some Americans during the 19th and early 20th centuries. If America's longing for adventure did not have the cowboy figure to worship, it would have had that of the surveyor—the latter equipped with a Gunter chain instead of a lasso, and certainly more authentic than the former.

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[10] In the collective volume A History of Mathematics Education in the United States and Canada, published by the NCTM in 1970, a 10-page contribution covers the beginnings of mathematics education, up to 1821. to my knowledge, the best studies monographic studies on the history of mathematics education in America, remain, to date, Cajori 1974 (reprint of a 1890 book), Cohen 1982 (focused on arithmetic, not mathematics instruction generally), and Smith and Ginsburg 1980 (reprint of a 1934 book). There is a large fragmentary literature of important moments, schools, trends in the history of mathematics education; I mention some of this work in the reference list.

[11] See Bland 1991.

[12] See Bedini 2002, Berns 1968, Berns 1969, Cazier 1975.

CHAPTER 1

MATHEMATICS IN SURVEYING MANUALS

The idea of surveying the American land systematically originated with Thomas Jefferson, who had myriad scientific interests.[1] Surveys undertaken by private interests had occurred—even flourished—a few decades earlier, as we can infer from the newspapers of the time.[2] But as president, Jefferson sponsored the Lewis and Clark expedition (1803-1806) and Pike's expedition (1805-1807) into the Western lands, and established the United States Coast Survey, in 1807. After Jefferson left office, surveying with official support from the federal government fell into disrepute and ridicule for more than two decades. An attempt to revive scientific research, including surveying, made from Jefferson's opposite political camp, did not make much difference. Indeed, John Quincy Adams's plea for the founding of a national astronomy observatory (1816 to 1819) and his serious "report on weights and measures" (1821), fell on deaf ears. In the land of individualism, the attempts at government-sponsored enterprises were more than viewed skeptically; they were considered dangerous.

Yet surveys continued on a small scale, conducted with private funding or by local public bodies. Men from various scientific disciplines were especially encouraging. For instance Benjamin Silliman Sr. (1770-1864), professor of natural science at Yale starting in 1793; Jacob Bigelow (1786-1879), a Harvard trained physician, the first leader of the Linnaean Society, and the man who coined the term

[1] See Bedini 2002.
[2] See next chapter for newspaper sources.

"technology"; and Denison Olmsted (1791-1859), a professor of chemistry, mineralogy, and geology at the University of North Carolina and later at Yale—all went ahead with surveying projects on scales as large as their means allowed.[3] These were just a few of many individuals with similar interests.

The most important sources for assessing the surveying practice and the mathematics underlying it are the books used by the surveyors. Mathematical elements necessary to surveying operations appear in the earliest books containing mathematics distributed in America. In the following pages I present a few of the manuals widely used in surveying throughout the American colonies. The first such books were imported from Europe for practical use; later, they served as models for the first editions of the manuals written directly by Americans.

John Love's *Geodaesia*

One of the oldest surveying manuals that circulated in America was *Geodaesia: Or, The Art of Surveying and Measuring of Land Made Easie*, published in London by John Love, in many editions[4]. The twelfth edition, for the first time published in America, was "adapted to American surveyors." The title was followed by a long subtitle in three parts, with the third part relevant for our subject: "SHEWING,[5] By Plain and Practical Rules, how to Survey, Protract, Cast up, Reduce or Divide any Piece of Land whatsoever; with New Tables for the ease of the Surveyor in Reducing the Measures of Land. MOREOVER, A more Facile and Sure way of Surveying, by the Chain, than has hitherto been Taught. AS ALSO, How to lay-out New Lands in America, or elsewhere; and how to make a Perfect map of a River's

[3] See Struik 1948, p. 183.
[4] The Cornell Library of Rare Books and Manuscripts, where I did much of the research for this thesis, owns 11 editions of Love's manual, from the earliest of 1688 to the thirteenth, published in 1796—a long print life attesting to the popularity of the book. My discussion of the book is based on the 1715 edition.
[5] Read "showing."

Mouth or Harbor; with several other Things never yet Published in our Language."

Explaining the reasons behind the motivation to write the manual, Love wrote in the Preface that he has seen "Young men, in *America*, often nonplus'd so, that their books would not help them forward, particularly in *Carolina*, about Laying out Lands, when a certain quantity of Acres has been given to be laid out five or six times as broad as long. This I know is to be taught by a Mathematician … And to what Book already Printed of Surveying shall they repair to, to be resolved?"[6]

Love's book contained thirteen chapters:

1. Of Arithmetick in general
2. Geometrical definitions
3. Geometrical problems
4. Of measures in general
5. Of instruments and their use
6. [untitled] *How to take the Plot of a Field, at one Station* etc.
7. How to cast up the Contents of a Plot of Land
8. Of Laying out New Lands
9. Of Reduction
10. Instructions for Surveying A Mannor, County, or Country
11. Of Dividing Lands
12. Trigonometry
13. Of Heights and Distances

In Arihtmetick in general, Love explained in excruciating detail, with several long examples worked out completely, the rule for extracting square roots.

In Geometry, he defined angles and basic plane figures, then gave several fundamental constructions with a line and a compass; the most complex was

[6] Love 1715, p. A4 right side; italics in original.

How to make an Ellipsis, or Oval, Several Ways.

In the chapter concerning measurements Love offered a triangular table for the conversion of basic English measures and showed how to tabulate measurements.

In the chapter concerning the Instruments, Love wrote that for measuring angles "there are almost as many Instruments are there are Surveyors,"[7] an important observation for the long history of solving the practical problem of approximating measurements and estimating errors. The chapter contains sketches and examples of the basic geometrical problems that would concern surveyors for centuries to come.

Love called "content" of a plot of land (chapters 6 and 7) what we call today the mathematical *area* of the land. He discussed the cases reducible to triangles, squares, rectangles, and circles – with no mathematical formulas.

Chapter eight of the book, though short, dealt intently with *Laying out New Lands, very useful for Surveyors, in her Majesty's Plantations in America*.

In the chapter "on reduction" Love showed that the area of a polygonal piece of land can be measured approximately by dividing it with a grid of squares. This was followed by a 2-page chapter of general considerations on surveying, as a preamble to Chapter Ten, on reducing variously shaped pieces of land to triangular shapes.

In the chapter on trigonometry Love starts by defining the trigonometrical values of angles as proportions of corresponding sides of a right angle triangle, then solves in detail several problems, both for right angle and scalene triangles.

The last chapter presents applications of the previously exposed notions

[7] Love 1715, p. 56.

to finding heights and distances.

The book, as all surveying manuals to follow for the next two centuries, contained long logarithmic and trigonometric tables.

Hawney's *Complete measurer*

According to Karpinski[8], the first book printed in America to contain geometry was Hawney's *Complete measurer: or, the whole art of measuring, being a plain and comprehensive treatise on practical geometry and mensuration, preceded by decimal and duodecimal arithmetic, and the extraction of the square and cube root, adapted to the use of schools, and persons concerned in measuring, gauging, surveying, etc.*.

The first American edition was printed in 1801 by Cochran and McLaughlin in Philadelphia; three other editions followed, with the fourth printed in 1820 by J. Robinson in Baltimore.

This book was an American reprint of an 18th century English text that has gone through many editions and revisions. Thomas Keith, the editor of the 1798 London edition (the seventeenth), laments in the preface the thoroughness of the author, who detailed all examples, "working them at full length, and explaining every step". That method might have been good in the old times, writes Keith, but "it precluded the use [of the book] in our modern schools; for with such assistance, a boy of good abilities would naturally become indolent, for want of something to foment its genius; and a boy of heavy disposition would be induced to copy all his work from the book."

Hawney's *Complete measurer* had 332 pages and seven chapters: first on arithmetic, the following two on geometry, and the remaining four on practical

[8] Karpisky 1980, p. 136.

applications to the works of various crafters including carpenters, bricklayers, glaziers, and surveyors. The first two thirds of the book could well stand-alone as a textbook on arithmetic and geometry. Besides the arithmetic feats mentioned in the title, the book presented in detail how to find areas of all common polygons and areas of conics, as well as the volumes (the "solidity") of numerous tridimensional bodies. The text was well illustrated with plenty of figures of good quality.

John Gummere's *A treatise on surveying*

John Gummere's *A treatise on surveying, containing the theory and practice: to which is prefixed, a perspicuous system of plane trigonometry. The whole particularly adapted to the use of schools*, was also published in numerous editions. The fourteenth, which appeared in 1838, was "carefully revised and enlarged by the addition of articles on the theodolite, leveling and topography." In 1837 Samuel Alsop had published *A complete key to Gummere's surveying*. In 1880 Isaac Sharpless oversaw a revised edition of *Gummere's Surveying*, "adapted to modern methods." Editions of Gummer's book continued to appear until 1917, more than one century after the publishing of the first imprint.

Sharpless, Professor of Mathematics in Haverford College in Pennsylvania and author of several textbooks in geometry, had "revised and adapted [the book] to [the] modern time". He noted that, upon publishing in 1814, Gummere's Surveying "was the first book which placed the subject in a systematic shape for the use of the students, and the public fully appreciated its merits."

In the original Preface (1814) Gummere had written that "nothwithstanding the importance of the science, and the large number that make it an object of study, it is believed we are not in possession of a treatise on this subject, suited to the wants of the student." He goes on to say that from the existing works at that time “the student would in vain expect to become acquainted with the principles of the science, or the *rationale* of any of the rules, necessary in performing the various calculations.” He notes that “in order to understand the principles of surveying, a previous knowledge of Geometry is absolutely necessary” and defers the reader to specialized works like “Playfair’s Geometry and Simpson’s translation of Euclid’s Elements.” Then he characterizes his own work in relation to the mathematical instruction required to read his book: “As there are many who wish to obtain a practical knowledge of Surveying, whose leisure may be too limited to admit of their going through a course of Geometry, the author has adapted his work to this class, by introducing the necessary geometrical definitions and problems, and by giving plain and concise rules, entirely detached from the demonstrations; the later being placed in the form of notes at the bottom of the page. Each rule is exemplified by one wrought example; and the most of them by several unwrought examples, with answers annexed.”

Consistent with these views, the first eighty pages of the book (preceding the surveying treatise), contain a four-part mathematical introduction: of logarithms, geometry (definitions and problems) and trigonometry. Then Gummere went on to present surveying applications of the mathematical elements he had introduced. His book is the first manual circulated in America to contain explanations about the use of complex surveying instruments.

Jeremiah Day

A manual widely used in the first half of the 19th century was Jeremiah Day’s *The mathematical principles of navigation and surveying, with the mensuration of heights and distances. Being the fourth part of a Course of mathematics. Adapted to* *the method of instruction in the American colleges.* It was first published in 1817 by Steely and Gray, in New Haven, CT. A fourth edition appeared in 1848. The book, at 120 pages, was slim compared with others of similar purpose. It had 50 figures carefully drawn and numbered, placed on three plates at the end of the book.

On the untitled introductory page, Day wrote: "As the following treatise has been prepared for the use of a class in College, it does not contain all the details which would be requisite for a practical Navigator or Surveyor. The object of a scientific education is rather to teach *principles*, than the minute rules which are called for in professional practice. The student [of the book] is supposed to be familiar with the principles of geometry and trigonometry, before he enters upon the present number, which contains little more than the application of those principles to some of the most simple problems in heights and distances, navigation and surveying."

Day was obviously addressing to students who have had already some practical surveying experience, most likely gained by working as apprentices.[9]

The placement of the figures at end of the book must have made the manual difficult to use for learning and applications.[10] The book opened with 15 figureless pages on "Heights and Distances." Here Day solves fully ten problems, including Problem IX, "find the greatest distance at which a given object can be seen on the surface of the earth" (p. 10). He ends this introductory chapter with eight "promiscuous examples," exercises for which only answers are given.

The rest of the manual is divided in two parts: the first half concerns navigation, the second surveying. Navigation problems involved solving a spherical triangle, given some of its elements. Day expresses theoretically the "Theorems" he uses, in word form—and then illustrates by giving a few examples. Without explaining in detail what factors might introduce errors, he writes several times that

[9] See the next chapter.
[10] This was a common inconvenience in mathematics books published in early America.

the "method[s] are not perfectly accurate."[11] As illustration, here is one of his navigation theorems: "As radius to the tangent of the course; so is the meridional difference of latitude, to the difference of longitude."[12] Similarly, a surveying theorem is this: "As radius to the cosine of the angle of elevation; so is the oblique line measured, to the corresponding horizontal base".[13] Day proceeds to solve a few examples but, aware of the imperfections of the results, he cautions: "Any explanation of the subject . . . must be very imperfect. In the demonstration of the problem, the several triangles are supposed to be in the same plane, and the distances of the meridians so small, that they may be considered parallel. But in practice, the ground upon which the measurement is to be made is very irregular."[14]

In solving practical problems Day employed the law of sines, manipulated proportions, and solved simple quadratic equations. He assumed that the reader already knew the basic elements of algebra, geometry, and trigonometry.

Day also mentions the functioning principles of the main surveying instruments at the time: the Gunter's chain, the quadrant, the "mariner's compass," the surveyor's compass.

Abel Flint

Widely circulated during the first half of the 19th century was Abel Flint's *A system of geometry and trigonometry: with a treation on surveying, in which the principles of rectangular surveying, without plotting, are explained*.[15] The first edition was published in 1804; an imprint of the tenth edition, in 1854.

The book had no table of contents. The brief *Advertisement* written by

[11] See p. 37, for instance.
[12] Idem.
[13] See p. 58.
[14] Day, p. 78.
[15] I consulted the eight edition, enlarged with additional tables by George Gillet. Hartford, CT: Belknap and Hamersley, 1835.

the editor in the opening of the volume states that the author "did not fail of success . . . by the estimation in which this treatise has been, and is, at the present time, held by Surveyors, and by the continued and increasing demand for it." It ends by saying that "the work [is] being now used extensively in schools and academies."

More than any other author of surveying manuals examined in this thesis, Abel Flint associates surveying with geometry and trigonometry. He attempts clear-cut definitions of the subjects he treats. "Geometry is a science which treats of the properties of magnitude"[16] while "Trigonometry is that part of practical Geometry by which the sides and angles of triangles are measured."[17] And "Surveying is the art of measuring, laying out, and dividing land."[18]

Unlike Jeremiah Day's manual, Flint's has the figures inserted in text, which makes it easier to follow, but he has only a few figures, meant to clarify definitions and elementary constructions.

The first half of the book is concerned with geometry. By the third page Flint defines geometrically the trigonometric functions and the main polygons (p. 1-15). After that he gives 19 basic geometrical construction problems, fully described. It starts with the drawing a parallel line to a given line and ends with finding the center of a given circle. The second part of Flint's book is concerned with trigonometry. He subdivides this in rectangular trigonometry and oblique trigonometry (the law of sines in a scalene triangle).

After these mathematical foundations, Flint proceeds to applications to surveying. He fully solves a series of problems, encouraging the reader repeatedly to do his homework: "The learner should exercise himself . . . until he is able to do it with facility."[19] In the chapter on Practical Surveying, he writes at length on the proper

[16] See p. 9.
[17] See p. 17.
[18] See p. 39.
[19] Quote is on p. 26.

ways to do a survey on the ground, starting with the advice of thoroughness: "Surveying is a branch of business which will admit of diligence, but it will not bear to be hurried. Sufficient time must be allowed to take course, measure distances, and to make calculations correctly, even if the employer *does not see the necessity of being so particular*."[20]

The book ends with a copious appendix of tables, including one of decimal logarithms of the first 10,000 numbers, a table of decimal logarithms of the trigonometric functions of arcs in the first quadrant, and a table containing the declination and variation of the magnetic needle.

Noteworthy of mention is the austere, even severe tone of Flint's manual. He wastes no time transitioning from general advice to definitions, in the same paragraph: "The learner must understand decimals and the nature and use of logarithms, before he can make any proficiency in this branch. Difference of latitude is the distance between the parallels of the beginning and of the terminating point of a line, or of any numbers of lines, whether northerly or southerly. Departure is the distance between the meridians of the beginning and of the terminating point, or the distance made either east or west from any particular meridian on any course."[21]

John Farrar

John Farrar's *An elementary treatise on the application of trigonometry: to orthographic and stereographic projection, dialing, mensuration of heights and distances, navigation, nautical astronomy, surveying and leveling* is a dense text, with 106 figures neatly placed on nine folding plates at the end of the book.

In the opening *Advertisement,* Farrar writes that "the branches of mathematics comprehended in this volume have usually made part of the course of

[20] See p. 98. Italics in original.
[21] See p. 85.

instruction at the public seminaries of the United States. But the best treatises upon these subjects are too extended, and of too practical a nature, to be used as a text-book. What is here offered is intended to furnish only those general principles and leading methods, which afford a useful exercise to the learner, and which may be considered as belonging to the pursuit of liberal studies." He used Cognoli and Bonnycastle's *Trigonometry*, Delambre's *Astronomy*, Bezout's Navigation, Puissant and Malortie's Topography." For the tables, which took the last third of the 200-page book, he used Bowdithch's Practical Navigation, "the correctness of which is too well known to need any recommendation."

In the first part Farrar treats orthographic and stereographic projections and the construction of maps ("charts"). Toward this goal he deduces the main formulas of spherical trigonometry, likely for the first time in a book printed in America. In the second and third parts, he solves several practical problems in "nautical astronomy," using the formulas he proved in the first part. Finally, in the fourth part, concerned with surveying, Farrar returns to a theoretical treatment that culminates at the end of the book with the laborious demonstration of the formula for the excess over two right angles of the sum of the angles of a spherical triangle.

Once again, following the text was made cumbersome by the placement of figures at the end of the book, on special plates. Yet this inconvenience was supplemented by the necessary expressivity in enunciating mathematical results verbally. Says Farrar: "In the solution to this problem we have made use of the theorem, *the sines of the angles are to each other as the sides opposite to these angles*. We might also apply the rule given for the right-angled triangle, namely, radius is to the tangent of one of the acute angles, as the side adjacent to this angle is to the side opposite."[22]

[22] Farrar, p. 33.

Farrar's trigonometrical sophistication went quite far. In a final note he used De Moivre's formula for complex numbers to find the algebraic expressions for trigonometric functions given as series. This is instructive pedagogically, as long as the trigonometric functions are defined geometrically—as Farrar did, indeed.

CHAPTER 2

APPRENTICESHIP AND THE EVENING SCHOOLS

Basic mathematics instruction in America started early but grew slowly, against daunting challenges. As early as 1661, the "Instructions and Rules for Schoolmaster Evert Pietersen, drawn up by the Burgomaster of this City" [New Amsterdam, later to become New York] mentioned the pay scale for instructors according to the matters they taught, with "ciphering" coming at the very apex of the remuneration, seen almost as a bonus: "Besides his yearly salary he shall be allowed to demand and receive from every pupil quarterly as follows: For each child whom he teaches the a b c, spelling and reading, 30st; for teaching to read and write, 50st; for teaching to read, write, and cipher, 60st."[23]

Long before organized schools in America took on the task of systematic mathematics instruction, basic notions of arithmetic, geometry, and trigonometry were taught by private tutors, or "masters." To attract pupils they advertised in newspapers, usually enumerating not only the general subjects in their competence but also particular problems they could teach. Instruction took place during the evenings. The students were most likely apprentices in various trades, who worked during the day.

In the course of my research for this thesis I perused several newspaper collections, now available in digital format. Much of my research was guided by the excellent work done by Seybolt, decades ago. Based mainly on his sources I compiled

[23] Minutes of the Orphan Masters of New Amsterdam, translated by B Fernow, New York, 1907, v. 2 p. 115-16.

the following chronology of the mathematics topics apparently taught in the evening schools in connection with various trades, including surveying:

Table 2.1: Newspaper advertisements and sources containing mathematical references

Year	**Topic(s)**	**Instructor/ advertiser**	**City**	**Source**
1701	"Writing and Cyphering"	N/A [a "Citty of N. Yorke Indenture"]	New York	Seyb[24] p.21
1716	"Read Write & Cast Accompts to so far as the Rule of three"	N/A	Westchester NY	Seyb p.21
1720	"reading, writing, Accounting and the like"	N/A	New York	Seyb p.21
1720	". . . read write and Cypher so far as will be Sufficient to Manage his Trade"	N/A	New York	Seyb p.21
1720	"writing and ciphering so far as Addition Subtraction and Multiplication"	N/A	New York	Seyb p.22
1722	"reading and writing and Arithmetick"	N/A	New York	Seyb p.21

[24] All Seybolt references in this table are to Seybolt 1925.

Table 2.1 (Continued)

1723	". . . Arethmatik, whole Numbers and Fractions, Vulgar and Decimal, The Mariners Art, Plain and Mercators Way; Also Geometry, Surveying. . . "[25]	John Walton, "late of Yale Colledge. . ."	New York	Seyb p.29
1723	". . . read write and Cypher"	N/A	New York	Seyb p.21
1724	"Writing, Accompts, and the /Mathematicks"	Samuel Grainger	Boston	Seyb p.25
1725	"to Cypher so as to keep his Own accounts"	N/A	Westchester NY	Seyb p.22
1727	". . . Arithmetick, Book-keeping, Navigation, &c.&c."	Samuel Grainger	Boston	Seyb p.29
1730	". . . Arithmetick in all its parts, Geometry, Trigonometry, Navigation, Surveying, Gauging, Algebra, sundry others of the said Parts of the Mathematicks"	James Lyde	New York	Seyb p.29

[25] Seybolt notes that "this is the earliest available record of an 'academy' in the American colonies" (p. 30).

Table 2.1 (Continued)

1734	"Aritmetick in the whole Numbers and Fractions, Vulgar and Decimal, Maerchnts Accompts, Algebra, Geometry, Surveying, Gauging, Trigonometry, Plain and Spherical, Navigation in all kinds of Sailing, Astronomy, and all other parts of Mathematicks.[26]"	Theophilus Grew	Philadelphia	Seyb p.25-6
1735	"[all of the above, plus] the use og Globes, Maps, Planispheres, Scales, Sliding Rules, and all sorte of Mathematical Instruments"	Theophilus Grew	Philadelphia	Seyb p.27
1744	"writing, arithmetick and to draw"	Nathaniel and Mary Gittens	Charleston SC	Seyb p.23
1745	"Merchants Accompts in the Italian manner"	N. Walton and W. Hetherington	Philadelphia	Seyb p.26

[26] ". . . His hours are this Winter from 9 to 12 in the Morning; from 2 to 5 in the Afternoon; and (for the Conveniency of those who cannot come in the Day time) from 6 to 9 in the Evening. He teaches Writing, and Aritmetick at the usual Rate of 10s per Quarter. Merchants Accompts, Navigation, &c. for 30s per Quarter. And will undertake to furnish anyone with sufficient Knowledge in any of the foregoing Branches, in there Months time, provided the Person have tolerable Genius and observes a constant Application".

Table 2.1 (Continued)

1743	". . . Navigation, Mensuration, Dialling, Geography, Use of the Globes, the Gentleman's Astronomy, Chronology, Arithmetic, Merchants Accompts, &c."	Charles Fortesque	Philadelphia	Seyb p.25, 60
1748	"Writing and Arithmetic School"	Mr. Pelham	Boston	Seyb p.23, 60
1749	"Reading, Writing, and Arithmetick"	Thomas Evans	NewYork	Seyb p.22
1751	"Reading Writing, Arithmetick, and Accompts after the Italian Method of Double Entry"	B. Leigh and G. Noel	New York	Seyb p.25-6
1752	"Merchants Accounts"	Nicholas Barrington	New York	Seyb p.25
1752	"BOOK KEEPING after TRUE Italian Method"	Robert Leeth	New York	Seyb p.26
1753	"writing, arithmetic, vulgar and decimal, …[27]	William Dawson	Philadelphia	Seyb p.24
1753	"Writing, Arithmetick, Accompts"	Grew and Jones	Philadelphia	Seyb p.25

[27] "…in a short and concise method, not commonly taught, whereby two-thirds of the time and trouble may be saved from the common methods; and such persons who have not time to go through the ordinary courses of arithmetic, may be made capable of common business by multiplication."

Table 2.1 (Continued)

1753	". . . Reading, Writing, Arithmetic, Navigation, Surveying, &c."	John Lewis	New York	Seyb p.60
1753	". . . an excellent Method of Trigonometry here particularly applied to Navigation; But is of great Use in all kinds of Measuring and in solving many Arithmetical Questions"	John Lewis	New York	Seyb p.28
1754	"the use of the Gunter's sliding rule, necessary for most tradesmen, and others"	William Dawson	Philadelphia	Seyb p.27
1754	"Merchants Accounts"	Joseph Stiles	Philadelphia	Seyb p.25
1755	"geometry, trigonometry, and their application to surveying, navigation, &c"	James Cosgrove	Philadelphia	Seyb p.28
1755	"Merchants Accompts in the true Italian Method of Double Entry, Dr., & Cr."	Andrew Lamb	Philadelphia	Seyb p.26
1755	"Great-Circle Sailing"	Andrew Lamb	Philadelphia	Seyb p.27
1755	"Merchants Accounts"	John Searson	New York	Seyb p.25

Table 2.1 (Continued)

1756	“Vulgar and Decimal Arithmetick, &c.&c.”	John Vinal	Boston	Seyb p.29
1756	“writing, arithmetic and psalmody”	William Dawson	Philadelphia	Seyb p.23
1756	“Steriometry”	William Ranstead	Philadelphia	Seyb p.27
1757	“Merchants Accounts”	Edward Willett	New York	Seyb p.25
1757	“Merchants Accompts according to the true Italian Method of Dr., and Cr., by double Entry”	A. Morton	Philadelphia	Seyb p.26
1759	“Writing and Arithmetic both Vulgar and Decimal, Interest and Annuities, Extraction of Roots of All Powers”	James and Samuel Giles	New York	Seyb p.24
1760	“all the necessary Branches of the Mathematics, with the solution of every Problem by the plain or sliding Gunter”	William Dawson	Philadelphia	Seyb p.27
1761	“”reading, writing, and arithmetic”	Samuel Bruce	New York	Seyb p.22

Table 2.1 (Continued)

1761	"Merchants Accompts"	Thomas Johnson	New York	Seyb p.25
1761	"Merchants Accounts"	John Young	New York	Seyb p.25
1764	"Trigonometry, with its Application to the taking of Heights and Distances . . . Spherical Trigonometry, with its Application to Great Circle Sailing and Astronomy"	William Cockburn	New York	Seyb p.29
1765	"At his Mathematical School [Taught] Vulgar and Decimal Arithmetic; …[28]"	Thomas Carroll	New York	Seyb p.61-2
1766	"fluxions"	Alexander Power	Philadelphia	Seyb p.28
1766	"Merchants Accompts"	William Thorne	Philadelphia	Seyb p.25
1767	"Writing and Arithmetic"	John Griffith	Boston	Seyb p.23

[28] "… the Extraction of the Roots, Simple and Compound Interest; how to purchase or sell Annuities, Leases for Lives, or in Reversion, Freehold Estates, &c. at Simple and Compound Interest; the Italian Method of Bookkeeping,; Euclid's Elements of Geometry' Algebra and Conic Sections; Mensuration of Superfices and Solids, Surveying in Theory, and all its different Modes in Practice, with two universal Methods to determine the Area of right lined Figures, and some useful Observations of the whole; Also Gauging, Dialling, Plain and Spheric Trigonometry, Navigation; the Construction and use of the Charts, and Instruments necessary for keeping a Sea-Journal (with a Method to keep the same, were the Navigator deprived of his Instruments and Books &c. by an accident) the projection of the Sphere, according to the Orthographic and Stereographic Principles; Fortification, Gunnery, and Astronomy; Sir Isaac Newton's Laws of Motion; the Mechanical Powers viz. The Balance, Lever, Wedge, Screw and Axes in Peritrochio explained, Being not only an Introduction necessary to the more abstruse Parts of Natural and Experimental Philosophy, but also to every Gentleman in Business". Carroll truly tells us what he taught!

Table 2.1 (Continued)

1766	"Geometry, Trigonometry, and their application to Surveying, Navigation, Geography, and Astronomy"	Alexander Power[29]	Philadelphia	Seyb p.29
1770	"Writing and Arithmetic"	Lazarus Pine	Philadelphia	Seyb p.23
1770	"READING, WRITING, and ARITHMETIC, VULGAR and DECIMAL;. . . [30]"	Robert Kennedy, John Maxfield, and David Kennedy	Philadelphia	Seyb p.27
1770	"READING, WRITING, ARITHMETIC, and ACCOUMPTS"	Matthew Maguire	Philadelphia	Seyb p.25
1771	"Arithmetic, geometry, trigonometry, algebra, book-keeping, surveying, leveling, gauging, mensuration, dialing, geography, spherics, conics, navigation, astronomy,	Christopher Colles	Philadelphia	Seyb p.28

[29] See also at 1772.
[30] ". . . BOOK-KEEPING METHODIZED; the ELEMENTS of GEOMETRY and TRIGONOMETRY, with their application to NAVIGATION, SURVEYING, DIALLING, &c. ALGEBRA, with the Application of it to a Variety of PROBLEMS in ARITHMETIC, GEOMETRY AND TRIGONOMETRY, CONIC SECTIONS and STEREOMETRY. With the several methods of solving and constructing EQUATIONS of the higher kind."

Table 2.1 (Continued)

1771	"Reading, Writing and Arithmetic"	Ebezener Dayton	Newport RI	Seyb p.23
1772	"WRITING, ARITHMETICK, NAVIGATION or any other Branch of the MATHEMATICKS"	Charles Shimmin	Salem, MA	Seyb p.29
1772	"theory of pendulum [and] the construction of logarithms"	John Wilson	Philadelphia	Seyb p.28
1774	"Book-keeping after the Italian Manner, or double entry"	Peter Dunworth	Salem, MA	Seyb p.26
1774	"common and mercantile arithmetic"	John Feffernan	Philadelphia	Seyb p.24
1774	"logarithms"	John Feffernan	Philadelphia	Seyb p.28
1774	"book-keeping in the Italian method, by double entries"	Gollen and Mountain	New York	Seyb p.26
1776	"reading, writing, and arithmetic"	William Payne	Boston	Seyb p.23
1777	"reading, writing, and arithmetic"	Thomas Wiley	New York	Seyb p.22
1781	[see footnote[31]]	Mr. Davis	New York	Seyb p.64

Table 2.1 (Continued)

1782	[see footnote[32]]	Mr. Davis	New York	Seyb p.64
1782	"method of Making Logarithms to any Number of Places"	J. Mennye	New York	Seyb p.28

This table systematizes most of the mathematical references found in the New England newspapers during the 18th century. In early America all mathematics was *applied* mathematics. A large proportion of the quotes above contain references to surveying or related endeavors.

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[31] Mr. Davis went out of his way to impress the readers of his advertisement (see also the next footnote):

"Where is taught Reading, a grace of the schools,
Writing, Arithmetic by easy rules,
Book-keeping, Geometry, too very plain,
And Navigation to steer o'er the main:
Surveying and Mensuration as well,
With rare Algebra to make you excell.
All those—and more he has got in his plan,
To rouse the genius, and furnish the man.

The pupils may depend on an easy, elegant, perspicuous explication of things, being the most conductive to rouse the genius, and invigorate the thought, or to inspire the mind, with a true and lively sense of what is taught, which cannot fail to enrich it with fruitful ideas; and as they shoot will not only be cherished, but made to flourish".

[32] To the above verses, are added:

"These lively fields pure pleasure do impart,
The fruit of science, and each useful art,
Which forms the mind, and clears the cloudy sense,
By truth's powerful pleasing eloquence.
Ye hopeful youths, be sensible of this,
O! mark the fleeting time and profer'd bliss,
The only time when learning makes its way,
Thro' dark ignorance brightning into day:
Bright'ning into day, you'll in knowledge shine,
Full orb'd with wisdom to the human mind
Ye hopeful youths, come learn what he has told,
Exalt your Minds, and be what you behold;
While Genius soaring, great Heights explore,
And grace your Talents with true Beauties o'er,
Till ornamented with the flowers of Truth,
Ye shine bright patterns for [the] unlearned Youth.

CHAPTER 3

CONCLUSION

In the Preface of this thesis I set out to investigate a few questions pertinent to the historical relationship in early America between land surveying and mathematics instruction.

The sources underlying this research (newspaper advertisements and surveying manuals) show that surveying grew from the planning of small settlement towns[33] to measuring and mapping large tracts of newly forayed territory. Mirroring this growth, the mathematical instruction of the future surveyors went from being provided in a dual master/apprentice relationship based on the master's experience and instructional materials to more organized forms provided by special geometry and trigonometry courses taught in colleges and universities, and based on textbooks that had gained wide acceptance. In their programmatic statements, the authors of the printed materials I inspected offer somehow contradictory assessments of the level of mathematics they presented.

While different authors often solved the same practical problems in similar ways, one might consider such instruction to be part of basic "principles" necessary to the surveyor while another considered it to be a practical application of principles. Most of the mathematical content of the surveying manuals widely circulated and used in America prior to the middle of the 19th century was equivalent to the geometry and trigonometry taught today in high schools with excellent

[33] New Haven was planned in 1638 by John Brockett "the first surveyor of record." See Chronology.

mathematics teaching. But solid geometry and spherical trigonometry have completely disappeared from curriculum.

In early America surveying was a profession offering prestige, and a springboard to careers in business and politics. Its practitioners had a broad education that included fundamental mathematical notions and applications, as well as knowledge of the English (later American) law. Gaining such instruction was impeded by the absence of public funding, by the scarcity of well-trained mathematics teachers, and by the apparent incompetence of some of those who did teach.[34] By the mid 19th century, however, American universities responded to the need of the rapidly expanding nation by hiring (mainly) European-trained professors and by reprinting frequently well-reputed surveying textbooks.

[34] Occasional evidence for such occurrences appears indirectly in newspaper notices that mention that a "master" known for offering classes in surveying and similar trades had passed or failed to pass certification procedure established by the local authorities.

CHAPTER 4

CHRONOLOGY

The following is a reverse chronology of relevance to the history of mathematics education and surveying in colonial America and the Unites States.

1975 Metric Conversion Act recommends again adopting the European decimal system, to little effect (Dupree 2001).

1901 U.S. Congress establishes the National Bureau of Standards.

1875 Treaty of the Meter, of which U. S. is a signatory, leads to American Scientists adopting the European metric system of measurement.

1863 National Academy of Science founded.

1821 John Quincy Adams, then Secretary of State, publishes *Reports upon Weights and Measures*.

1807 Jefferson establishes the United States Coast Survey.

1807 Pike's expedition ends.

1806 Lewis and Clark expedition ends.

1785 The Land Ordinance sets the land grid westward of Ohio.

1783 A Committee of the Confederate Congress retains Jefferson's proposal for adopting a rectilinear grid for land measuring but replaces his suggestion for using a decimal system of measures and implements, instead, the use of the English mile.

1777 Thomas Jefferson surveys and maps Albemarle County in Virginia (Bedini 2002, p. 19-20).

1638 John Brockett, "the first surveyor of record" lays out "with impressive accuracy the original nine squares which later became the center of New Haven" (Bedini 1975, p. 63).

1584 Thomas Harlot, a "mathematician" (Dupree 2001), uses the English customary measures in the colonial settlement at Roanoke.

APPENDIX

To put the content of mathematical instruction in context, I find it useful to transcribe fully a few of the many newspaper advertisements from the eighteenth century which contain references to mathematics.

Transcriptions of tutoring advertisements in old newspapers:

Samuel Scammell, "Formerly a Teacher of the Gentlemen Volunteers in His Majesty's royal Navy," advertised in 1737 that "At the North End of Boston, in the Fore Street, near the Sign of the Red Lyon, are taught the Mathematical Sciences, viz. Arithmetick, Geometry, Algebra, Fluxions, Trigonometry, Navigation, Dialing, Astronomy, Surveying, Gauging, Fortification, Gunnery, The use of Globes, also other Mathematical Instruments, likewise the Projecting of the sphere on any Circle, &c. with other parts of the Mathematicks"[35].

Thomas Berry advertised the services of Isaac Greenwood this way: "Such as are desirous of learning any Parts of the Mathematicks whether THEORETICAL, as the demonstrating [of] Euclid, Appolonius, &c or PRACTICAL, as Arithmetic, Geometry, Trigonometry, Navigation, Surveying, Gauging, Algebra, Fluzions &c. Likewise any of the branches of NATURAL PHILOSOPHY, as Mechanics, Opticks, Astronomy &c. [] at the Duke of Malborough's Arms in King-

[35] *Boston Evening Post*, November 21, p. 2, 1737.

Street over at the Golden Fleuce, Boston; where Attendance is given from 9 to 12, AM, and 3 to 6, P.M."[36].

A kind of 'certification': "John Miller formerly Advertised the Publick he had set up a Mathematical School, at the House of Mr. Peter Barbour opposite to the North side of the Town House, was on Friday examined in the several Mathematical Arts and Sciences he Professed, by two Gentlemen (desired to make such an Examination, by the Select Men of this Town) and was by them Judged to be sufficiently Skilled for an Instructor therein. N.B. The said Miller gives due Attendance at the House of the said Mr. Barbour"[37].

Thirty-five years later Miller, now experienced, had moved to Connecticut and was teaching in better conditions: "John Miller, Acquaints the Public, that on Monday the 16th Inst. He Opens his School at Mr. Meloy's House, (in a spacious and eleganmt room) where for the future, he will take Scholars that are to be taught Writing and Arithmetic, for 8d. per Week, and for spellers and Readers, 6d. per Week. Those who are pleas'd to encourage said School, may depend on being faithfully serv'd, their Children carefully instructed, and treated in the Tenderest manner. Private Education will be given by him, to those who are desirous to further improve themselves in Writing, Arithmetic, &c. &c."[38].

"Mills of various Kinds, and other Hydraulic Engines, designed and constructed according to the true Principles of Mechanics and Hydrostatics – Land surveyed and Levels taken for the Conveyance of Water – Buildings of several Kinds

[36] *Boston Gazette*, March 26, p. 4, 1739.
[37] *Boston Gazette*, February 5, p. 4, 1733.
[38] *Connecticut Journal*, May 27, p. 4, 1768.

ornamented in the Grecian and Roman manner, designed and superintended on reasonable Terms, by CHRISTOPHER COLLES, ENGINEER AND ARCHITECT. Said Colles will engage to instruct young Gentlemen, at their Houses, in the different Branches of the Mathematics and natural Philosophy". Colles was on hard times, though; as the advertisement continues: "Any Gentlemen, in or near the City, willing to employ him, will be waited upon, and Letters (Post paid) directed to the Care of Robert Bell, bookseller, at the late Union Library, in Third Street, Philadelphia, will be answered"[39].

"Writing, Arithmetick, Vulgar and Decimal fractions, &c. Merchant Accompts the true Italian Method by double Entry, Dr. and Cr. Navigation in all its Parts, both in Theory and Practice, &c. Also Spherical Trigonometry, great circle Sailing, Astronomy, Surveying, Gauging, &c. and compleat Method to keep the Ship's Way at Sea, called a Journal, whereby I teach in my School, to find the Longitude at Sea every Day at Noon, by true Proportions; as sure as the Latitude by Observations of the Sun; I have the original Journal to produce, in which it will appear the Plan is like a Chain, the first Link of which being fixed to the Port departed from; each Day's work is a new Link joined to the other, till the last Link is fixed to the Port arrived at; each Day's Work being truly wrought, the journal is compleat. My Journals from England to Cape-Henlopen (or Cape James) in America; and from thence to the Lizard (near 140 Degrees of West Longitude) as appears in my Journals to be produced, with others of the like Sort, and are good Proofs of my Principles; although Sun and Stars should disappear for several Days and Nights, my Plan will find both Latitude and Longitude at Noon every Day, or any other Hour; it is a Rational Plan, and founded upon great and long Experience at Sea, both on board the Royal Navy, and Merchant

[39] *Pennsylvania Chronicle*, August 19, p.3, 1771.

Ships. Sailors take Care you be [ineligible: prepared?] by Land men pretending to this Plan. N.B. [ineligible] taught Navigation, and kept a Journal above 40 Years, the Scheme is new, and never was in printed Books, and has been approved of by proper Judges, &c. Your Long-line must be 50 Feet between each Knot, and Glass just 30 Seconds; or your Long-line must be 48 Feet between each Knot, and Glass just 29 Seconds. I give due attendance in my School in Front Street at John Johnston's, Tallow chandler, next door to Mr. Richardson, Goldsmith, up the Alley. And teach both Day and Night School, or waits on any Gentlemen at his Chamber, &c. ANDREW LAMB"[40].

[40] *Pennsylvania Gazette*, October 23, p.2, 1755.

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