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GALILÆANA

Studies in Renaissance and Early Modern Science

Galilæana is an international scientific journal, which publishes blind peer-reviewed research articles in the history of Renaissance and early modern science. The journal focuses on topics relating to the life, scientific work, achievements, and legacy of Galileo. The journal also welcomes submissions that, while not directly pertaining to Galilean studies, will be of interest to historians engaged in research on science and culture in early modern Europe.

Galilæana also hosts other forms of contribution, from historical and bibliographical notes to invited papers and essay reviews.

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GALILÆANA

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GALILÆANA XXIII, 2 (2026)

– FOCUS –



KNOWLEDGE IN USE.

PRACTICES AND PRACTITIONERS IN THE RENAISSANCE
AND EARLY MODERN PERIOD (14TH–17TH CENTURIES)

edited by Francesco Brusori and Raffaele Danna



Introduction

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Abstract

This Focus section explores how knowledge and skill emerged in direct dialogue with practice, from the late Middle Ages to the early modern period. It seeks to create a space in which historians of science and economic historians can recognise common research questions and establish a conversation. The contributions in this section share an interest in how practitioners' works, their knowledge, and craft expertise contributed to both socio-technical and scientific change. To do so, they explore how the expertise of artisans, artists, engineers, instrument makers, surgeons, and other skilled workers took form "in use." These pages introduce the first papers published under this 'Knowledge in Use' label. Other papers will be published in the Focus section published in the forthcoming volume of *Galileana*. Early drafts of these studies were discussed in a workshop held in February 2026 at the Sant'Anna School of Advanced Studies in Pisa, within the research activities of the FIS WorkKnow project. Taken together, this and the forthcoming Focus section show how taking practitioners' own words seriously is to see knowledge developing hand in hand with material practice.

Keywords

practical knowledge, practitioners, historiographical approaches

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We thank the participants of the Knowledge in Use workshop, held in February 2026, for sharing their expertise across disciplines and engaging with the themes of this Focus session. We also thank all the authors, anonymous peer reviewers, and editorial staff of *Galileana*, for making this collection of papers possible.

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This Focus section brings together contributions exploring the emergence of knowledge and skill in direct dialogue with practice, from the late middle ages to the early modern period. Historians of science have long recognised the role of so-called “practitioners” in the making of early modern science, at least since Edgar Zilsel’s pioneering work of 1942; yet a sustained engagement with sources written by practitioners themselves – rather than about them – is a comparatively recent development in the field. At the same time, economic historians have grown increasingly attentive to knowledge and skill as key drivers of long-run economic change, stressing the role of labour and craft expertise in the development, application, and transfer of innovation and technology. The papers gathered here sit at the crossing point of these two strands of scholarship, asking how the knowledge and skill of artisans, artists, practically-minded humanists, engineers, instrument makers, surgeons, and other skilled workers developed through their very application – that is, how knowledge took shape “in use.”

Under this framework, contributors were invited to reflect on the practices, channels, and constraints that shaped the production and circulation of practical knowledge across physical and social spaces. The resulting essays published in this volume examine: how we can approach sources that emerged from the world of late medieval and early modern practitioners; the circulation of practical knowledge across institutional and social borders, focusing on the extent to which abacus mathematics circulated beyond the abacus school; the role of writing as both a tool of practice and a medium for medical theory in the day-to-day activity of surgeons and barbers; how a close examination of an unpublished abacus manual reveals practical texts as active sites of knowledge production rather than passive repositories of technique; the relationships between artesanal experience, technical practice, and written knowledge through the writings of mathematical practitioners engaged with surveying and military techniques at a crucial moment of change in European warfare technology; the emergence and politics of technical expertise through a comparative analysis of handbooks of water management and hydraulics in early modern Europe; the entwinement of theory and technology through an analysis of the uses and conceptualisations of the *camera obscura*.

Owing to the number and length of the contributions, the papers of this Focus section will appear across two issues of *Galilæana*: the present issue and the forthcoming one, which will present a wide range of further themes and cases. Earlier versions of these papers were first presented and discussed at a workshop held in February 2026 at the Sant’Anna School of Advanced Studies in Pisa, organised within the framework of the project *WorKnow – Working Knowledge: the Emergence of Practitioners in Late Medieval and Early Modern Europe*, funded by a FIS (Fondo Italiano per la Scienza) Starting Grant of the Italian Ministry of University and Research, with the collaboration of the Museo Galileo in Florence. We are grateful to the workshop’s participants and discussants, and to the Museo Galileo, for their generous contribution to the discussions from which these papers have benefited.

We hope that, taken together, these essays will offer readers a fresh sense of the fascinating diversity and richness of these sources, and show how taking practitioners' own words seriously lets us see how knowledge developed hand in hand with material practice – thereby contributing to the broader transformations of science, technique, and the economy in the Renaissance and early modern period.



Knowledge in use: Books of the mechanical arts as objects and sources of knowledge in late medieval and early modern Europe

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Abstract

The paper offers a historiographical reflection on how scholars can approach sources that emerged from the world of the mechanical arts in the late medieval and early modern period. It situates these sources within scholarly discussions on the history of science, economic history, and the history of technology. Drawing on historical epistemology, the social history of science, and philological studies of primary sources, the paper elaborates on how standard interpretative frameworks apply poorly to these texts, and suggests possible approaches to understand them. The conclusion reflects on how these sources can interrogate our own practice of historical research.

Keywords

practical knowledge, mechanical arts, historiographical approaches

How to cite this article

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I am grateful to the participants of the Knowledge in Use workshop held in Pisa in February 2026, as well as the authors of the papers gathered in this and the forthcoming Focus section of *Galilæana*, for the many insights on the core themes of this volume. My thanks to the two anonymous reviewers are not a formality, as they provided an attentive and constructive reading of my first draft, significantly contributing to strengthening the paper.

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1. Introduction: approaching practical sources

A century ago, historians tended to explain the relationships between social, economic, and scientific change in terms of linear narratives. Their accounts, later labelled “externalist” and “internalist,” traced causation either from the social and economic context to the sciences, or from the internal logic of scientific ideas and methods to the development of science, which was treated as largely autonomous from its context. Today, scholars seek to offer more nuanced perspectives that reconstruct the complex interrelations between social, economic, and scientific layers. Given its intermediate role between the techniques and the abstract sciences, the world of the mechanical arts is particularly important for exploring these connections. As stressed by Pamela Smith, in the late medieval period an increasing number of actors belonging to the world of the mechanical arts used the written word to give a tangible form to their own knowledge and expertise.¹ Liliane Hilaire-Pérez, Paola Bertucci, and Smith have shown the importance of understanding the works of these actors on their own terms.² As Lissa Roberts, Simon Schaffer, and Peter Dear have noted, our “modern” conceptions of the relationship between science, technology, and the economy can in fact impose anachronistic conceptual frameworks when applied to the rich interdependencies between these spheres in the late medieval and early modern period.³ This inevitably raises a number of questions, such as: how should we approach these sources? How should we understand the knowledge that they attest? Should we understand it as knowledge at all? And if not, how should we describe it?⁴

In the pages that follow, I offer a methodological reflection on the possibility of approaching these texts with a “controlled” degree of anachronism – by which I mean a self-aware use of interpretative tools, with their advantages and limitations.⁵ My aim is to provide a reflection on how to read these sources with an awareness of the historical distance that separates us from them, and of the extent to which we choose to translate their meanings into our own conceptual categories. Rather than taking a stance on which approach, or which terminology, would be most appropriate, I will seek to present a range of possibilities, stressing their respective advantages and limitations, and raising questions

¹ Smith, *The Body of the Artisan*; Smith, *From Lived Experience to the Written Word*.

² Hilaire-Pérez and Verna, “Dissemination of Technical Knowledge in the Middle Ages and the Early Modern Era”; Hilaire-Pérez, “Technology as a Public Culture”; Bertucci, *Artisanal Enlightenment*; Smith, *From Lived Experience to the Written Word*.

³ Roberts, Schaffer, and Dear, eds., *The Mindful Hand*, ix–x.

⁴ The present author is obviously not the first to raise similar questions. For a recent overview, see Smith, *From Lived Experience to the Written Word*, 21–42. See also Dubourg Glatigny and Vérin, eds., *Réduire en art*.

⁵ I am borrowing the concept of “controlled anachronism” from Schneider, “Productive Anachronism.”

for the reader to consider. As I will argue in the conclusion, this methodological reflection is also an opportunity to interrogate our own work as practising historians. As the mechanical arts appear to have produced pivotal sources for reconstructing the co-evolution of epistemic and socioeconomic practices, reflecting on how we can approach these texts is not just a matter of antiquarian curiosity, but rather a necessary premise to deepen our understanding of this transformative period. While the essays collected in this volume offer a number of illuminating case studies to explore the internal dynamics of these processes, the present paper provides a methodological premise.

To develop this reflection, I will weave separate strands of scholarship. Specifically, I draw on historical epistemology, the social history of science, the history of technology and economic history, and philological studies of primary sources. As we will see, recent historical literature offers key conceptual tools to think about these texts, and philological studies provide crucial evidence regarding their composition and transmission. Because of the research experience of the present writer, the majority of the examples will be drawn from the tradition of practical arithmetic, but the arguments presented in this paper can arguably be applied to works of the mechanical arts more broadly. A key premise to my argument is that it is possible to consider late medieval and early modern works written by actors of the mechanical arts as a largely coherent group of texts. While my argument is built on common features among these sources, I should immediately clarify that these commonalities occurred amid a high degree of local variation.

2. The mechanical arts at the intersection of historical debates

The roots of the debate on the relations between theory and practice can be traced all the way back to ancient philosophy. However, the late medieval and early modern period is a particularly significant case for investigating these connections because of the epochal changes in science and technology that occurred in these centuries, which have attracted the attention of generations of scholars. The second International Congress of the History of Science and Technology held in London in 1931 provides an effective starting point to explore this debate, because it exposed the political and philosophical positioning that lay behind the understanding of this relationship in a foundational period of contemporary historiography.⁶ In the disconnection between the interventions of Western and Soviet scholars we can observe something of broader consequence: how one conceives the relationship between science and the economy in the late medieval and early modern period carries significant implications for the interpretation of longer-term historical transformations. More specifically, this conception shapes how we understand the epochal shifts in both intellectual and material production that characterised the early

⁶ Bucharin, ed., *Science at the Cross Roads*.

modern period – the transformations conventionally designated the “scientific” and the “industrial revolutions.”

Joseph Needham recalled that, in the immediate aftermath of the Great Depression, Boris Hessen’s presentation on “The social and economic roots of Newton’s *Principia*” was received as “almost a sacrilegious act, in any case culpable of lèse-majesté” by the conventional wisdom of the audience.⁷ At the time, the majority of historians of science referred to narratives of the development of knowledge – later labelled “internalist” – according to which social and economic forces played a minimal role in scientific enquiry. In these narratives, science was primarily the result of the intellectual acumen of isolated geniuses.⁸ While most of the Soviet delegates were to meet a tragic fate during the Stalinist era, internalist narratives of science continued to be challenged by some receptive members of the Congress. For example, John Desmond Bernal and Needham attentively considered the interventions of the Soviet delegation, and later referenced them as sources of inspiration.⁹ In 1938, Robert K. Merton also mentioned Hessen’s “provocative essay” in his landmark *Science, Technology and Society in Seventeenth Century England*, remarking that Hessen’s methodology “if carefully checked, provides a very useful basis for determining empirically the relations between economic and scientific development.”¹⁰ In 1942, Edgar Zilsel used a sociological approach to argue that the emergence of science was rooted “in the period of early European capitalism.”¹¹

These remained marginal narratives at the time,¹² as most historians of science did not give centre stage to economic or technological factors in their narratives. Authoritative models such as George Sarton’s *The History of Science and the New Humanism* (1931) and Alexandre Koyré’s *From the Closed World to the Infinite Universe* (1957) – which were deemed “externalist” accounts by some of the most sterling “internalists” of the time – mainly focused on religious and philosophical influences.¹³ Nevertheless, more sociologically inclined approaches continued to be pursued, for example in the works by Eva Taylor – who introduced into the historiographical debate the concept of “mathematical

⁷ Foreword by Joseph Needham. *Ibid.*, VIII.

⁸ Examples of such accounts include, in varying degrees, the works by George Sarton, Alexandre Koyré, and Eric Temple Bell.

⁹ Needham, *A History of Embryology*, xvi; Bernal, *The Social Function of Science*, 406. For historiographical perspectives, see Ienna and Rispoli, “Boris Hessen at the Crossroads of Science and Ideology”; Cozzoli, “John Desmond Bernal and ‘Bernalism.’”

¹⁰ Merton, *Science, Technology and Society in Seventeenth Century England*, 502, n. 24.

¹¹ Zilsel, “The Sociological Roots of Science,” 936.

¹² Zilsel’s essay has found currency in recent historiographical debates under the namesake of the “Zilsel thesis.” See for example Long, *Artisan/Practitioners*; Cormack, “Handwork and Brainwork.”

¹³ Sarton, *The History of Science and the New Humanism*; Bell, *Men of Mathematics*; Koyré, *Études galiléennes*; Koyré, *From the Closed World to the Infinite Universe*.

practitioners” – and Paolo Rossi.¹⁴

In parallel, the philosophy and sociology of science provided new societal awareness and conceptual frameworks to think about science.¹⁵ Among others, the works of the “second” Ludwig Wittgenstein, Bruno Latour and Harry Collins were essential in the emergence of the so-called “practical turn.” Science increasingly appeared as a practice: as an activity carried out by specific individuals, active in specific times and places, in contact with specific people, and using specific technologies.¹⁶ One reason for the appeal of this approach was that it allowed scholars to overcome the internalist/externalist debate, as the study of scientific practices implied focusing on matters – such as experiment – that cut across that divide. Simon Schaffer and Steven Shapin were among the most influential historians to bring this approach into the history of science.¹⁷ Galileo started to appear not just as an extraordinarily talented scientist, but also as a developer of instruments, a cunning engineer, and a strategic navigator of early modern society.¹⁸ Similarly, scholars recognised that, although Newton’s interests were primarily theoretical, the evidence on which he grounded his *Principia* depended on the imperial networks of seventeenth-century England.¹⁹ Lorraine Daston and other scholars working at the Max Planck Institute in Berlin have studied the emergence of epistemological concepts in their expanded social setting, seeking to understand what were usually considered as universal ideas as themselves the product of historical processes.²⁰

This change in approaches meant that the range of practices and actors that is today encompassed by the history of science has expanded considerably. In the case of individual scientists, this has implied focusing on interests and activities which had seemed difficult to reconcile with their depiction as heralds of linear progress – such as Newton’s biblical and prophetic interests.²¹ Together with studying a broader set of fields through which humans interacted with nature – including alchemy and astrology²² – scholars have increasingly fo-

¹⁴ Taylor, *The Mathematical Practitioners of Tudor & Stuart England*; Rossi, *I filosofi e le macchine*; Taylor, *The Mathematical Practitioners of Hanoverian England*.

¹⁵ Two pivotal studies are Carson, *Silent Spring*; Kuhn, *The Structure of Scientific Revolutions*. For an overview of these shifts in the historiography, see Smith, “Science on the Move.”

¹⁶ Wittgenstein, *Philosophical Investigations*; Collins, *Changing Order*; Latour and Woolgar, *Laboratory Life*; Latour, *Science in Action*.

¹⁷ Shapin and Schaffer, *Leviathan and the Air-Pump*; Shapin, *Never Pure*.

¹⁸ Biagioli, *Galileo, Courtier*; Valleriani, *Galileo Engineer*.

¹⁹ Schaffer, “Newton on the Beach.”

²⁰ See for example Daston, *Classical Probability in the Enlightenment*; Dear, *Discipline and Experience*; Wise, ed., *The Values of Precision*; Daston, “The Nature of Nature in Early Modern Europe”; Daston and Galison, *Objectivity*.

²¹ Iliffe, *Priest of Nature*.

²² See for example Debus, *The Chemical Philosophy*; Grafton and Newman, eds., *Secrets of Nature*; Moran, *Distilling Knowledge*; Kassell, *Medicine and Magic*; Grafton, *Magus*.

cused not only on isolated scientists, but also on a broader social spectrum of actors. Following in the footsteps of Zilsel and Taylor, Pamela Long and Smith have stressed the key contributions of artisans and practitioners in the emergence of new forms of knowledge.²³

Applying Peter Galison's concept of "trading zones" to the early modern period, Long has stressed the key role of settings such as workshops, schools, and arsenals in the encounter of different actors and bodies of knowledge, whose combination made possible new forms of quantification, experimentation, and theorisation.²⁴ Even the history of such a seemingly abstract field as mathematics has been influenced by these approaches, with scholars focusing on the social status of mathematicians and on situating mathematical procedures in their historical contexts.²⁵ William Eamon's pathbreaking studies on books of secrets started to illuminate the richness of texts written by late medieval and early modern practitioners.²⁶ Bertucci has shown the importance of focusing on the sources written by practitioners themselves to understand their strategic use of the written word and the originality of their epistemologies up to the age of the Enlightenment.²⁷ Smith has noted how an increasing number of practitioners took to the written word starting from the late Middle Ages, and the implications of this transition in the processes of knowledge making.²⁸ The act of writing appears as a non-neutral process, and the written word as a transformative tool for both scientific and social change, which was used by a broad range of actors, from intellectuals to manual labourers.

Economic history and the history of technology followed a somewhat similar and entwined trajectory. During the Cold War period, historians tended to think that the industrial revolution owed little to science.²⁹ While not unchallenged,³⁰ this view reflected the main narrative of the history of science of the time that centred on isolated individuals. The possibility of intersections between economic and scientific change became increasingly apparent once scholars started to think about the development of science as the outcome of incremental and collective processes. For example, Carlo Cipolla was among the

²³ Smith, *The Body of the Artisan*; Long, *Artisan/Practitioners*.

²⁴ Long, "Trading Zones in Early Modern Europe."

²⁵ See for example Westman, "The Astronomer's Role in the Sixteenth Century"; Biagioli, "The Social Status of Italian Mathematicians"; Wagner, *Making and Breaking Mathematical Sense*; Chemla, "Cultures of Computation and Quantification in the Ancient World"; Morel, *Underground Mathematics*.

²⁶ Eamon, *Science and the Secrets of Nature*; Eamon, "How to Read a Book of Secrets."

²⁷ Bertucci, *Artisanal Enlightenment*.

²⁸ Smith, *The Body of the Artisan*; Smith, *From Lived Experience to the Written Word*.

²⁹ Hall, "What Did the Industrial Revolution in Britain Owe to Science?"

³⁰ An early example is the influential pamphlet on the "stages" of economic growth by the economist Walt Rostow, in which Rostow distinguished between "pre-" and "post-Newtonian" countries, and considered only the latter as promising candidates for industrial development. See Rostow, *The Stages of Economic Growth*.

first to interpret the industrial revolution as a long-run process rooted in an incremental rise in average literacy among the European population, and Edward Musson and Eric Robinson focused on technological breakthroughs that required scientific insights.³¹

Joel Mokyr's work was influential in shifting the debate among economic historians. Mokyr argued that the industrial revolution was characterised by the emergence of a consequential complementarity between so-called "propositional" and "prescriptive" knowledge.³² Whereas Mokyr first focused on Enlightenment intellectuals, the debate has progressively moved on to include other actors in this explanation of the industrial revolution. Roberts, Schaffer, and Dear argued that material and intellectual production, rather than two independent phenomena, constituted "a single, hybrid affair" in the early modern period.³³ Elspeth Whitney discussed how the mechanical arts rose to intellectual legitimacy in the classifications of knowledge during the Middle Ages, and Hélène Vérin examined the transition from artisanal knowledge to technical expertise in the early modern period.³⁴ Maxine Berg illustrated the key role of skilled artisans, workers, and women in the development of new techniques of production.³⁵ Hilaire-Pérez and Alessandro Nuvolari, among others, showed that the world of the mechanical arts had an underappreciated openness that made it possible for knowledge and techniques to be shared and developed.³⁶ Maarten Prak, Jan Luiten van Zanden, and Stephen Epstein focused on the development of skills and technology, opening a debate on the role of guilds and apprenticeship which is still ongoing, for instance, in the works of Sheilagh Ogilvie and Patrick Wallis.³⁷ Morgan Kelly, Mokyr, and Cormac Ó Gráda argued that the eighteenth-century British labour force was comparatively highly skilled, and included a large group of watch- and instrument-makers, who arguably provided essential skills and techniques in the run-up to industrialisation.³⁸ Building on this perspective, Kelly and Ó Gráda have recently argued that it is indeed possible to think about the scientific and the industrial "revolutions" as two deeply entwined processes.³⁹

³¹ Cipolla, *Literacy and Development in the West*; Musson and Robinson, *Science and Technology in the Industrial Revolution*.

³² Mokyr, *The Gifts of Athena*.

³³ Roberts, Schaffer, and Dear, eds., *The Mindful Hand*, x.

³⁴ Whitney, *Paradise Restored*; Vérin, *La Gloire des Ingénieurs*; Whitney, *Medieval Science and Technology*.

³⁵ Berg, *The Age of Manufactures*; Berg, "The Genesis of 'Useful Knowledge.'"

³⁶ Nuvolari, "Collective Invention during the British Industrial Revolution"; Hilaire-Pérez and Verna, "Dissemination of Technical Knowledge in the Middle Ages and the Early Modern Era"; Hilaire-Pérez, "Technology as a Public Culture."

³⁷ Prak and van Zanden, eds., *Technology, Skills and the Pre-Modern Economy*; Ogilvie, *The European Guilds*; Wallis, *The Market for Skill*.

³⁸ Kelly, Mokyr, and Ó Gráda, "Could Artisans Have Caused the Industrial Revolution?"

³⁹ Kelly and Ó Gráda, “Connecting the Scientific and Industrial Revolutions.”

3. The pitfalls of “modern” frameworks

As anticipated above, texts that emerged from the world of the mechanical arts often defy the frameworks through which we tend to think about textual sources. Smith has stressed how today’s notion of “author” can mislead our understanding of how natural knowledge developed in the late medieval and early modern period. This is because we tend to think about written sources and authors through distinctively “modern” lenses:

Reliance by historians on written records and on identifiable individuals (whose papers or works are still extant) living in the recent human past has had the effect of misleading us about the collective and distributed nature by which all knowledge, and especially knowledge of our natural environment, is produced.⁴⁰

The “artisan writers” of the late medieval and early modern period, instead, often did not produce texts in the way we tend to think. Smith noted that their writings often “signaled a departure from the traditional modes of producing and ways of conceptualizing textual knowledge.”⁴¹ While our notions of “author” and “textual knowledge” are commonly associated with individual agency, these texts often reflect collective and incremental processes of experimentation. As noted by Smith, this group of emergent writers comprised both famous individuals such as Leonardo da Vinci and Benvenuto Cellini and a broad spectrum of lesser-known individuals, including merchants, architects, skilled artisans, ship pilots, engineers, instrument makers, gunners, mariners, and dancing masters.⁴² In many cases, we do not know the names of these actors, as their works survived in anonymous form, and were often the result of a series of interventions by different writers. Rather than groundbreaking breakthroughs and individual geniuses, these works reflect collective processes of knowledge making, in which texts were cumulatively tweaked, updated, and repurposed.⁴³ We may describe as “weak authoriality” this lack of an authoritative model to reproduce faithfully and this evolution through incremental developments and collective agency.

The manuscript II.IX.57 of the Biblioteca Nazionale Centrale of Florence provides a compelling example of this collective and incremental nature. This relatively compact (c. 215×150mm) manuscript of 188 folios includes a practical arithmetic manual – a so-called “libro d’abaco” – from the early fourteenth century that covers a particularly broad set of subjects. The manuscript includes sections dealing with the fundamental arithmetic operations, several sections on the practical uses of arithmetic, such as problems of

⁴⁰ Smith, *From Lived Experience to the Written Word*, 9.

⁴¹ *Ibid.*, 91.

⁴² *Ibid.*, 91.

⁴³ Danna and Morel, “Arithmetic Manuals as Crystallization of Mathematical Practices.”

conversions between units and moneys, problems of exchange, alloying, interest rates, discounting, barter, and division of profits and losses according to shares. The core of these texts is the so-called *Trattato di tutta l'arte dell'abaco* attributed to the Florentine abacus master Paolo dell'Abaco.⁴⁴ However, rather than providing a tidy copy of a coherent text, the manuscript comprises a number of sections that do not add up to a cohesive structure. Besides including subjects that usually do not feature in a work on practical arithmetic – such as medicine and astronomy/astrology – the manuscript was clearly written by different hands, and its sections, even if broadly coherent in themes, do not follow the clear organisation of a systematic treatise.⁴⁵

The recent codicological analysis by Irene Ceccherini has shown that the manuscript is made up of quires that likely circulated at first as independent documents, and were bundled together only at a later stage.⁴⁶ These small booklets probably circulated within Paolo dell'Abaco's school in the second quarter of the fourteenth century, where they were used as teaching tools. According to this reconstruction, the various hands that appear in the manuscript would correspond to the generations of abacus masters active in that school. Between the end of the fourteenth and the beginning of the fifteenth century, these masters bound the booklets together, giving the manuscript its present form. The manuscript II.IX.57, then, reflects a collective authorship, and is the result of the additions, amendments, and cumulative contributions of generations of readers who incrementally reshaped previous texts, and adapted them – even in a material sense: from a collection of independent booklets to a single volume – to the needs and interests of a Florentine abacus school.⁴⁷ The so-called book by Michael of Rhodes provides a very similar example. This manuscript was written in the 1430s by a seaman – probably a native of Rhodes – who started his career as an oarsman in the Venetian navy and rose through the ranks until he reached the highest positions attainable by non-nobles. It combines personal notes with texts on practical arithmetic, shipbuilding, astronomy and astrology, as well as information on ports and harbours. Michael often selected this textual material from other sources, rearranging and repurposing it according to his own interests and needs.⁴⁸

These texts do not neatly fit common dualities such as “pure/applied,” “theoretical/practical,” and “head/hand.” While many historians and sociologists of science would be inclined to argue that these dualities are not effective to describe how knowledge has *ever* been produced, these categories are particularly inadequate to describe the transforma-

⁴⁴ For a discussion of this manuscript in its socio-economic context, see Danna, “Una scienza per la rinascita.”

⁴⁵ On the history of this specific manuscript, see Murano, “Nella invenzione della quale molto pensai.”

⁴⁶ Ceccherini, “Come nasce un libro d'abaco.”

⁴⁷ See also Papi, “Crafting Practical Mathematics: The Making of an Abacus Manual,” in this volume.

⁴⁸ Long et al., eds., *The Book of Michael of Rhodes*.

tions in the production of knowledge that are reflected in these sources.⁴⁹ This is because the mechanical arts had a dynamic relationship with both the world of the theoretical sciences – based on more or less coherent theoretical systems – and the world of the crafts – often based on repetition and routine. The camera obscura provides an effective example of this entwinement of conceptualisation, codification, and mechanical use, as discussed by Jip van Besouw.⁵⁰ Daston has recently framed the role of the mechanical arts in the late medieval and early modern period as that of “the middleman, betwixt and between the necessary universals of the sciences and the happenstance particulars of the crafts.”⁵¹ The mechanical arts provided the experimental space for exchanges between “the head and the hand, understanding and dexterity,” for previously separated practices and bodies of knowledge to converge and hybridise: “poised between universals and particulars, the tacit and the explicit, the rules of the arts occupied a fulcrum position, always see-sawing back and forth between the two.”⁵² In the philosophical terms of the time, the justification for this intermediate status was that the mechanical arts involved both forms (the realm of theory and universals) and matter (the world of practice and particulars). As exemplified by the manuscript IL.IX.57, the written word could function as a medium of this intermediate function.

4. Historiographical descriptors

How should we describe these texts? The word “manual” is attractive because it provides an actors’ category that appears in some of these sources. Moreover, it carries with it the notion of texts that needed to be “at hand,” and could be used like tools. However, at least in the tradition of practical arithmetic, “manual” is not the main term employed by historical actors. More common are the terms “book” (as in “libro d’abaco” or “libro di ragioni”) and “trattato” (as in the *Trattato di tutta l’arte dell’abacho*), but one finds these texts being described in late medieval Italy with expressions such as “zibaldoni” (notebooks or jumbles), “ricordanze” or “memoriali,” “libri di segreti” (books of secrets), “trattati” (treatises), and “ricettari” (recipe books). Examples of these texts include Cennino Cennini’s *Libro dell’arte*, the commercial/mathematical text titled *Zibaldone da canal*, the *Memoriale* by Francesco Bentaccordi, the thirteenth-century *Books of Secrets* spuriously attributed to Albertus Magnus, the collection of recipes of Caterina Sforza, and the widely circulated

⁴⁹ Roberts, Schaffer, and Dear, eds., *The Mindful Hand*; Shapin, *Never Pure*; Long, *Artisan/Practitioners*.

⁵⁰ See van Besouw, “Projecting and Painting: Codifications of the Camera Obscura, 1568–1711,” in this volume.

⁵¹ Daston, *Rules*, 77.

⁵² *Ibid.*, 78.

Secreti by the pseudonymous Reverendo Alessio Piemontese.⁵³

“Book” and “treatise” may appear as rather neutral descriptors to us, but we need to remind ourselves that these texts emerged in a time in which the very appearance of the mechanical arts in written form was anything but obvious. When artisan-writers decided to describe their texts as “books” or – even more – as “treatises,” they appropriated a terminology that carried notions of epistemological and social prestige. The notion of “art” is highly common in practical sources from across western Europe, with descriptions such as “arte dell’aritmetica” or “arte dell’abaco,” “art de l’arithmétique” or “pratique des nombres,” “künstliche Rechnung,” and “the mathematicalls” or “arte of numbers.” The advantage of describing these texts as manuals or handbooks is that we bring to the fore the practical nature of these sources, but it means using a category that, even if it belonged to historical actors, was possibly not the most common way in which these texts were referred to. Using the term “books of art” may more closely reflect the language of the time; however, it has the drawback of being easily understood in anachronistic terms, and therefore requires clarification, as both the term “book” needs to be qualified, and the concept “art” must be understood in the specific sense of *mechanical* art, rather than in the broader or modern meaning of the word.

How should we describe the kind of knowledge attested in these texts? Scholars have used a variety of historiographical labels that highlight different aspects of their contents. A brief reflection on these aspects is useful to employ these terms with a “controlled” degree of anachronism. Mokyr’s influential definition of “useful knowledge” centres the complementarity of “propositional” and “prescriptive” knowledge,⁵⁴ but – as it is based on a Baconian interpretation of the Enlightenment – it may prove an anachronistic framework when applied to other settings. Moreover, if used irreflexively, Mokyr’s category of “usefulness” can be misleading (useful for what and for whom? Who gets to define this “usefulness?”).⁵⁵ Historians of science and technology including Sebastian Felten, Michael Friedman, and Smith have used the expressions “artisanal knowledge,” “craft knowledge,” and “embodied knowledge” to stress the dimension of embodied skill that underpinned the development of new techniques and tools.⁵⁶ These definitions are close to the distinc-

⁵³ Eamon’s *Science and the Secrets of Nature* includes an appendix with a list of books of secrets published in Italy 1520–1643. Raffaele Danna’s catalogue of manuals of practical arithmetic is published at <https://zenodo.org/records/20055076>. See Eamon, *Science and the Secrets of Nature*; Ray, *Daughters of Alchemy*; Brambilla and Hayez, eds., *Il tesoro di un povero*; Danna, *The Craft of Indo-Arabic Numerals*; Danna, “Dataset for The Craft of Indo-Arabic Numerals.”

⁵⁴ Mokyr, *The Gifts of Athena*; Mokyr, *A Culture of Growth*.

⁵⁵ Berg, “The Genesis of ‘Useful Knowledge’”; Morel, Parolini, and Pastorino, eds., *The Making of Useful Knowledge*.

⁵⁶ Smith, *The Body of the Artisan*; Smith, *From Lived Experience to the Written Word*; Felten, *Money in the Dutch Republic*; Friedman, *On Joachim Jungius’ Texturae Contemplatio*.

tion between “tacit” and “explicit” knowledge introduced by Michael Polanyi and further discussed by Harry Collins.⁵⁷

From a historical perspective, the works written by actors of the mechanical arts do not just document a form of knowledge that also implied an important “tacit” component, but they also attest the emergence in explicit form of bodies of knowledge that, until the late medieval period, had mostly not been codified in written records. This is an important social phenomenon that characterised the late medieval and early modern European period, and went hand in hand with the social emergence of the mechanical arts.⁵⁸ To bring to the fore the essential role of practice in the development of this knowledge, Bertucci and Smith have used the category of “practical knowledge.”⁵⁹ One could also argue that the very category of “knowledge” is inadequate to describe what emerged from the world of the mechanical arts, and that terms such as “competence,” “skill,” “expertise,” and “dexterity” may be more appropriate. However, while these terms may be useful to stress the hands-on nature characterising much of the knowledge of the mechanical arts, they can obscure – if used irreflexively – the fact that the authors of these texts themselves made claims to knowledge, challenging the borders and semantics of the terms *ars* and *scientia*. In the case of practical arithmetic, this is attested from the very emergence of the tradition in the late medieval Mediterranean, as Fibonacci described the mastery of his mathematics in terms of a “scientia artis.”⁶⁰ The expression “knowledge in use” can be considered as yet another in a long list of historiographical labels. Contrary to the less anachronistic “books of the mechanical arts,” this expression is not an actors’ category, but it has three desirable features. It highlights the hands-on nature of the knowledge of the mechanical arts; it brings to the fore how it evolved in a dialectical relationship with practice and application, without implying a hierarchy between the two poles; and it stresses how notions of utility, effectiveness, and usefulness need to be firmly attributed to historical actors.

⁵⁷ Polanyi, *The Tacit Dimension*; Collins, *Tacit and Explicit Knowledge*.

⁵⁸ Smith, *From Lived Experience to the Written Word*, 91–116. Raffaele Danna has recently described the emergence of this body of knowledge in terms of a transition from an “implicit” to an “explicit” form. See Danna, *The Craft of Indo-Arabic Numerals*, 18–20.

⁵⁹ Smith, *The Body of the Artisan*; Bertucci, *Artisanal Enlightenment*; Smith, *From Lived Experience to the Written Word*.

⁶⁰ “Ubi ex mirabili magisterio in arte per novem figuras Indorum introductus, *scientia artis* in tantum mihi pre ceteris placuit, et intellexi ad illam, quod quicquid studebatur ex ea apud Egyptum, Syriam, Greciam, Siciliam et Provinciam cum suis variis modis, ad que loca negotiationis postea peragravi, permultum studium et disputationis didici conflictum.” See Giusti and D’Alessandro, eds., *Leonardi Bigolli Pisani Liber Abbaci*, 4. Italics added by the author.

5. Writers and readers

As mentioned above, “standard” concepts of authoriality are not effective for understanding the emergence and circulation of late medieval and early modern practical texts. The fact that these texts tended to be reproduced with varying degrees of manipulation reflects the fact that the knowledge of the mechanical arts developed through adaptation, stratification, and assimilation. Unlike literary, legal, or religious texts, these works were not painstakingly reproduced with the aim of preserving an authoritative original, but rather with the aim of providing tools that met the interests and needs of their users. The concept of “emulation” may be used to frame this process in between faithful reproduction of a canonical model and the claims of radical departure typically associated with ideas of invention and innovation. “Emulation” has indeed been used to describe several inventive processes through adaptation and trial and error, from competing strategies in political economy to the emergence of mechanical calculation.⁶¹ The so-called “*pratiche di mercatura*” (or merchant notebooks), which appeared from the thirteenth century, are a paradigmatic example of this selective reproduction and adaptation. This tradition is characterised by a few particularly thorough texts, such as the *Libro di divisamenti di paesi e di misure di mercatantie* (also known as *Pratica della mercatura*). This text was written in the 1330s and 1340s by Francesco Balducci Pegolotti, who worked for one of the most important Florentine merchant-banking firms of the time: the *Compagnia Bardi*. While Pegolotti’s work provides information about trade across the Mediterranean, most copies of his text only report a selection of this evidence, following the needs and interests of their users.⁶²

This argument does not only apply to manuscript sources, as printed practical works also reveal cases of hybridisation, manipulation, and blurred authorship. For example, in 1495 the printer Johann Winterburg published in Vienna an *Algorismus / Opus algorismi jocundissimum*, which reported as its author the name of Georg von Peuerbach.⁶³ Peuerbach, who had died several decades prior (1423–1461), was a key figure of Viennese humanism, and a major astronomer, mathematician, and instrument maker. In just six folios, the *Opus algorismi jocundissimum* covered most of the standard subjects of a practical arithmetic manual, such as numeration, operations, progressions, the rule of three, and the division of profits and losses. Interestingly, the section on progressions closed with the

⁶¹ Reinert, *Translating Empire*; Jones, *Reckoning with Matter*.

⁶² Bocchi, ed., *Pratiche di mercatura toscane del Trecento*, 27–34; Locatelli, “Between the Decameron and the Bill of Exchange.” See also the results of Locatelli’s ongoing project, EduMoney: <https://cordis.europa.eu/project/id/101106709/it>

⁶³ For a digital copy of the work, see <https://daten.digitale-sammlungen.de/0008/bsb00082254/images/>

following annotation: “finis algorismi magistri Georgij de Peurbach.”⁶⁴ This suggests that the subsequent practical sections may have been added to a standard *algorismus* attributed to Peurbach. These sections may be attributed to an unidentified author or to the printer himself, who also published other popular works, such as almanacs and prognostica in both Latin and the vernacular. Peurbach’s name, which features prominently on the title page of the work, may have been used as a marker of authority for a carefully designed assemblage of texts. This operation was probably rather successful, as the *Algorismus / Opus algorismi jocundissimum* was reprinted over ten times.⁶⁵

The so-called *Tractatus de mercatura, seu mercatore* by Benvenuto Stracca, first published in 1553, provides a similar example from a later period and a different field. Stracca’s text, which is one of the first treatises on commercial law, was reprinted several times until the seventeenth century, often in editions that combined the *Mercatore* with other texts on similar subjects, such as the *Tractatus de assecurationibus et sponsionibus mercatorum* by Pedro de Santarém.⁶⁶ Other manuals went through several versions in both manuscript and printed form. A clear example is the so-called *Rossarzneibuch*, a German text on the care and medicine of horses attributed to a master Albrecht, who was supposedly active as stall marshal to Emperor Friedrich II in the thirteenth century. This text survives in over 200 manuscripts, was printed in eight incunable editions, and continued to be reprinted until the eighteenth century. Across these copies and editions, the text was translated, adapted, and updated.⁶⁷ Given these examples, the well-known cases in which Luca Pacioli appropriated other authors’ texts without credit appear as particularly acute instances of a rather common practice.⁶⁸

In philological terms, this means that standard understandings of textual filiation apply poorly to practical texts. If these writers reproduced their models selectively and on the basis of their needs and interests, traditional word-by-word comparisons can reveal links between specific texts, but may miss a range of interpolations with other sources and even intentional departures from previous models. As noted by Andrea Bocchi, a useful level of analysis is to focus on the structure of these texts, because the choice of the subjects

⁶⁴ *Algorismus / Opus algorismi jocundissimum*, f. 6r.

⁶⁵ The work was published under varying titles and was sometimes bound together with other works. The expression “Opus algorismi jocundissimum” appears in the incipit of the 1503 edition. The editions were: Johann Winterburg (Vienna, 1495); Johann Winterburg (Vienna, 1498); Johann Winterburg (Vienna, 1500); Martin Landsberg (Leipzig, 1503); Martin Landsberg (Leipzig, 1507); Johann Winterburg (Vienna, 1510); Martin Landsberg (Leipzig, 1510); Hieronymus Viator (Vienna, 1515); Martin Landsberg (Leipzig, 1517); Johann Singriener (Vienna, 1520); Josef Klug (Wittenberg, 1534); Giovanni Antonio Nicolini da Sabbio sumptu Melchiorre I Sessa (Venice, 1538).

⁶⁶ Hoock, Jeannin, and Kaiser, *Ars Mercatoria*, 240–243.

⁶⁷ Smith, *From Lived Experience to the Written Word*, 162.

⁶⁸ Ulivi, “Luca Pacioli: una biografia scientifica.”

and their organisation can yield precious evidence on the interests and the needs of their writers.⁶⁹

The readership and circulation of practical texts show a high degree of variation. Disputing the common association of science with openness and technology with secrecy, Hilaire-Pérez has shown how the early modern mechanical arts were often characterised by open practices.⁷⁰ Long has questioned the fixed definitions of “openness” and “secrecy” and discussed how their meanings were entwined in the late medieval and early modern crafts.⁷¹ In this varied landscape, it may be useful to conceptualise the circulation of practical texts in terms of a spectrum. At one end of the spectrum, we find texts that had a distinctively public circulation. At the other end, we find texts whose readership was highly restricted. Examples of works that circulated openly are provided by texts used within schools, as was often the case with practical arithmetic and geometry manuals. Like today’s schoolbooks, these texts offered interesting opportunities for printers because of their relatively predictable demand, which was tied to school curricula. The inclusion of these texts in school curricula and their consequent publication in large numbers arguably gave schoolbooks a circulation among a remarkably large readership, which often cut across social layers.

Other kinds of practical texts had various degrees of openness. Starting from the sixteenth century, printed works engaged with a variety of readers, reflecting and promoting their values, as discussed by Samara Greenwood.⁷² At first glance, books of secrets may appear as works whose circulation was restricted to a limited number of individuals, but this was not necessarily the case. Studies on ownership have revealed that books of secrets circulated in several different settings, and the analyses of marginalia have shown that printed books of secrets were probably a rather popular genre that reached a diverse readership.⁷³ *Pratiche di mercatura* are a genre of texts with a rather restricted readership, as these texts were often compiled and circulated within commercial firms, where they were probably used as instructional material for apprentices and as repositories of business information.⁷⁴ Even in the case of texts whose circulation was limited within an organisation, manuals worked as vehicles for the transmission of information across time and space. Even Bocchi’s recent reading of these texts as “testaments,” which underlines the restrictive aspects of their circulation, recognises the heir/pupil as “the true and only recipient of the text,” stressing their role in the intergenerational transmission of knowledge.⁷⁵

⁶⁹ Bocchi, ed., *Pratiche di mercatura toscane del Trecento*, 34–57.

⁷⁰ Hilaire-Pérez, “Technology as a Public Culture.”

⁷¹ Long, *Openness, Secrecy, Authorship*. See also Cialesi, “Crossing Institutional Boundaries: Abacus and Scholastic Knowledge in Fourteenth-Century Italy,” in this volume.

⁷² Greenwood, “Practical Mathematical Knowledge in Early Modern Verona,” in this volume.

⁷³ Leong and Rankin, eds., *Secrets and Knowledge in Medicine and Science, 1500–1800*.

⁷⁴ Spufford, “Late Medieval Merchants’ Notebooks.”

⁷⁵ Bocchi, “Nomina nuda,” 342–343.

The handbooks of water management and hydraulics discussed by Santiago Gorostiza, Maria Antònia Martí Escayol, Davide Martino, and Caroline E. Murphy provide another example of this intermediate circulation: closed enough to secure the delimitation of a field of expertise, public enough to establish personal and professional prestige among patrons and employers.⁷⁶ At the other end of the spectrum – i.e., works with highly restricted circulation – we may find texts that were apparently intended for personal use, such as notebooks and commonplace books. However, the circulation of these texts could also have been more articulated than may appear at first. In several cases, for instance, these materials were shared among people.⁷⁷

6. Pedagogy and epistemology

Methodological reflections are also useful for approaching the epistemology of these sources, as can be easily shown through an example from one of the earliest texts to emerge from the world of the mechanical arts. The anonymous *Livro de l'abbecho* provides a paradigmatic example of the distinctive features of these works, as is made clear from the first lines of the text:

Quisto è-ne lo livro de l'abbecho secondo la oppenione de
maestro Leonardo de la chasa degl figluogle Bonaçie da
Pisa. Lo p(r)imo capitolo è-ne de le reg(o)le d(e) le tre chose.
Se ce fosse dicta alchuna ragione e · lla q(ua)-
le se proponesse tre chose, sì devemo m(ultip)licare
quilla chosa che noie volemo sap(er)e (contra) q(ui)lla
che non è de quilla medessme, a pa(r)ti(r)e nell'altra.

Voglovo dare l'asenpio a la dicta reg(o)la e voglo dire chu-
sì: «3 ravignane vaglono 5 cortonese, que va(r)ronno gle
7 ravignane?». Deie fare chusi: m(ultip)lichare 7 fiade 5, che fon-
no 35, e pa(r)tire p(er) t(er)ço, che ne viene denare 11 2/3, e chusi fa' le
semeglante ragione.⁷⁸

Written around 1290, the *Livro* is a typical example of a practical arithmetic manual. The text is written in the vernacular of Perugia, making it possible to hypothesise that the

⁷⁶ Gorostiza et al., “Writing, Transmission, and the Politics of Knowledge in early modern Handbooks of Water Management and Hydraulics,” in this volume.

⁷⁷ Smith, *From Lived Experience to the Written Word*, 165–166.

⁷⁸ Bocchi, ed., *Lo libro de l'abbecho*, 163.

anonymous author may have been an abacus master active in that city. As shown in the passage above, this text is rather different from what we would today expect to find in a work of mathematics.

The introduction is limited to the first two lines of text, which make a vague reference to the works of Leonardo Pisano (Fibonacci). This is immediately followed by a formulation of the rule of three. Despite the initial reference to the works by Leonardo Pisano, this formulation of the rule of three is not taken from his *Liber abaci*: while Fibonacci's definition is lengthy and mathematically thorough, the wording of the *Livro de l'abbecho* prioritises synthesis and memorability over theoretical rigour.⁷⁹ The rule is just given in a simple and memorable formula, without telling the reader (or the listener) why it works this way. Similar formulations of the rule are found in several other abacus manuals.⁸⁰ In line with the above considerations on the weak authoriality of these texts, these variations reflect a form of "professional memory" among abacus masters, rather than a chain of faithful reproduction of an authoritative model.⁸¹

Instead of giving a demonstration of the rule of three, the anonymous author immediately follows with a worked example ("asenpio"). The rule is applied to a problem of monetary exchange, presented in the form of a hypothetical dialogue. The writer wears the hat of the master, and directly addresses the reader: "3 coins from Ravenna are worth 5 coins from Cortona. How much will 7 coins from Ravenna be worth?" The writer/master takes the reader/pupil by the hand: "you need to do this" ("deie fare chusi"), and applies, step by step, the procedure outlined in the formulation of the rule of three introduced a few lines above. The text then continues with a long list of similar worked problems, arranged by domain of application, such as monetary exchange, equivalences between units and measures, the alloying of metals, interest rates, discounting, the division of profits and losses, and miscellaneous problems. Practical texts are often mainly dedicated to long lists of worked examples, arranged according to their domain of application. This structure reflects the pedagogical model of the time, which was based on repetition. Instead of understanding the reasons why the rule of three works the way it does, the learner was supposed to assimilate – to almost literally "absorb" – the solution method by working their way through hundreds of

⁷⁹ Giusti and D'Alessandro, eds., *Leonardi Bigolli Pisani Liber Abbaci*, 141.

⁸⁰ See, for instance, the so-called *Tractatus algorismi* by Jacopo da Firenze (Florence, Biblioteca Riccardiana, Ricc. 2236 and other copies), Paolo Gherardi's *Liber habaci* (Florence, Biblioteca Nazionale Centrale, Magl. Cl.XI.88), the *Trattato di tutta l'arte dell'abacho* attributed to Paolo dell'Abaco (Florence, Biblioteca Nazionale Centrale, Fond. Naz. II.IX.57, and other manuscripts), and Piero della Francesca's *Trattato d'abaco* (Florence, Biblioteca Medicea Laurenziana. Ash 359 (291)).

⁸¹ I am taking the expression "professional memory" from Bocchi, ed., *Lo libro de l'abbecho*, 65.

examples.⁸² The pedagogy of these texts, in other words, follows a pragmatic model that is akin to artisanal apprenticeship.⁸³ Rather than as a deductive science, practical mathematics was taught in terms of a craft: as a set of tools (rules) – learned through memorisation – and skills – learned through repetition – that the pupil acquired to solve emergent problems.

Since they primarily report long lists of worked examples, practical texts are more akin to recipe books than to systematic treatises. Indeed, recipe books provide paradigmatic examples of this kind of text.⁸⁴ Instead of developing coherent theoretical systems, the mechanical arts just stated their rules, without providing an explanation or theoretical justification. Their validity was instead “corroborated” by their extensive use to identify the solution of practical problems. Rather appropriately for texts with a recipe-like structure, Veronica Field has described this form of legitimisation with the expression “the proof of the pudding is in the eating.”⁸⁵ It is indeed common to find in these texts expressions such as “this is how it’s done,” “if you want to get this, then *do* so and so,” “*si fa così* ... / you do as follows.” Rather than on the demonstration, the attention is clearly focused on the effectiveness of the application. We could think of this use of the written word in terms of a tool, and of these procedures as a form of “quasi-experimental proof.”

The recipe-like arrangement of the subjects, the lack of theoretical explanations, the attention to action, and the direct engagement of the reader are features that characterise many texts of the mechanical arts. For example, the first chapter of the so-called *Trattato dell’arte della seta* follows a very similar stylistic and didactic model:

Cap. I – Dello incannare

Adunque volendo imparare a incannare, piglia questa via: arrecati il fuso nella tua mano ritata, e fa’ che la punta di detto fuso aggiunga per insino al dito mignolo e non lo passi. E detto dito serra con quello che gli è allato, a modo che se tu volessi porre 200 per abbaco alle mani. E così fatto, posa detto fuso in su le due dita dinanzi, e fa’ che dette dita sieno adattate a uso d’uncini, e mena la mano facendo balzare detto fuso in su dette due dita dinanzi, tenendo

⁸² Again, Fibonacci’s *Liber abaci* exemplifies this pedagogical model: “Unde qui per eum huius scientie praticam bene scire voluerint, oportet eos continuo usu et exercitio diuturno in eius praticis perstudere; quod scientia per praticam versa in habitum, memoria et intellectus adeo concordent cum manibus et figuris, quod quasi uno impulsu et anelitu in uno et eodem instanti circa idem per omnia naturaliter consonent; et tunc cum fuerit discipulus habitudinem consecutus, gradatim poterit ad perfectionem huius facile pervenire.” See Giusti and D’Alessandro, eds., *Leonardi Bigolli Pisani Liber Abbaci*, 3.

⁸³ Bocchi, ed., *Lo libro de l’abbecho*, 51.

⁸⁴ Leong, *Recipes and Everyday Knowledge*; Basile, “Recording Medical Recipes: Surgeons and Barbers in Early Modern Italy (c. 1450–1600),” in this volume.

⁸⁵ Field, “The Unhelpful Notion of ‘Renaissance Man,’” 197.

bene istrette quelle di dietro acciò non passi la punta di sotto.⁸⁶

The anonymous author of this *Trattato* arranged the subjects into domain-specific sections (which, in this case, correspond to stages and processes of silk production), addressed the reader in the second person, and called to action with imperative verbs. The writer did not explain the technical vocabulary used in the text, and instead provided step-by-step instructions whose validity was not grounded in an explanation, but rather in a call to experience, and to verify – quite literally “first hand” – that the procedures work: “piglia questa via.”

To a certain degree, the memorisation of rules through repetition can be compared to the mechanical application of an algorithm. In this sense, the books of the mechanical arts can be understood as the social tools that secured the codification and transmission of fundamental skills for the world of production. However, describing these texts just as carriers of algorithms – which they undeniably were – obscures the fact that the process of repetition of worked examples implicitly trained very different, but equally important, skills. By working their way through hundreds of analogical examples, the learner did not just assimilate procedures, but was also trained to recognise analogies. This made it possible to repurpose the method first used in a specific domain to solve different kinds of problems. In other words, the assimilation of these algorithms did not just teach the learner to execute procedures, but also to recognise patterns and similarities, and to experiment with the uses of (mathematical) procedures through a sort of “analogical expansion” of their domain of application.⁸⁷

Daston has compared this attitude to the naturalists’ classifications of the living world into species and genera.⁸⁸ Just as naturalists used their taxonomies to make sense of the natural world, this ability to classify taught practitioners the essential skill to identify, among the infinite variability of the world of practice, the method best suited to tackle the specific problem at hand. While these analogies did not produce general or systematic knowledge, they taught a practical epistemology founded on an attitude towards generalisation and an attention towards identifying solutions. Practical arithmetic manuals described their problems as *ragioni* (“reasons,” in the plural) which, while they did not add up to produce a systematic theoretical edifice, provided rational tools to understand and act in the world of practice. As Daston put it: “this was a form of generality better suited to a world of problems to be solved rather than theorems to be proven – especially one in which the problems, like the world, were too unpredictable and particular for universal

⁸⁶ Gargioli, ed., *L'arte della seta in Firenze*, 5. This text is discussed in detail in Lassalle, “L’Arte della seta a Firenze.”

⁸⁷ Bocchi, ed., *Lo libro de l’abbecho*, 51, n. 38.

⁸⁸ Daston, *Rules*, 98. See also Chemla, “Le paradigme et le général.”

generalizations to gain much purchase.”⁸⁹ In other words, the assimilation of algorithms among people rather than machines did not just produce the mechanical replication of rules, but also implicitly trained the analogical repurposing of rational procedures.

7. *A reflexive conclusion*

The texts stemming from the world of the late medieval and early modern mechanical arts may appear familiar only at first glance, because several methodological reflections are necessary to approach them through a “controlled” degree of anachronism. As discussed above, standard conceptions of “author,” “text,” “written work,” and indeed “knowledge” can be misleading when applied to these works. These sources were often the result of a collective and incremental authorship. They were not reproduced with the aim of preserving an authoritative original text, but of crafting tools that responded to and engaged with local interests and needs. Their reproduction and transmission were deeply entwined with processes of emulation, adaptation, stratification, and assimilation of previous models. Indeed, the codification of practical knowledge in written form can be thought of as the crystallisation of a fluid process of incremental development of practices.⁹⁰ While this codification only provides a partial view of the development of this knowledge, the very fact that in the late medieval and early modern period a growing number of practitioners started writing down their knowledge is in itself an important phenomenon, which was non-obvious and non-neutral.⁹¹ These practitioners used the transformative agency of the written word to challenge the hierarchies of society and of knowledge. Their texts reveal a distinctive form of epistemology, which differs from “standard” conceptions of what it means to express knowledge in written form. With their hastening to experience, their unsystematic collections of procedures, and their lack of theoretical elaboration, these texts reflect the emergence of a form of generalisation suited to the solution of emergent problems – a form of context-sensitive, or field-specific, generality. In a nutshell, these texts allow us to study the emergence of a form of knowledge that co-evolved with practice.

Ultimately, these considerations can also be used to interrogate our own practice of historical research. Isn’t it peculiar that “standard” historiographical frameworks apply so poorly to texts that several strands of scholarship increasingly recognise as pivotal sources for understanding the emergence of the “modern” world? Isn’t this indicative of how the emergence of “modern” socio-economic frameworks went hand in hand with narratives that reframed and concealed the inner workings of “modernity”? What does this say about the worldview of the interwar and Cold War period in which many of our “standard” con-

⁸⁹ Daston, *Rules*, 102.

⁹⁰ Danna and Morel, “Arithmetic Manuals as Crystallization of Mathematical Practices.”

⁹¹ Bertucci, *Artisanal Enlightenment*; Smith, *From Lived Experience to the Written Word*.

ceptual frameworks emerged? Isn't it peculiar that many of our linear and hierarchical narratives of the relationship between science and technology were shaped in the decades in which the interdependency between these spheres revealed its tragic and unprecedented potential?⁹²

To get closer to our own work as practising historians, isn't it interesting that we, as professionals who need to write texts to progress in our careers, need much methodological reflection to approach a world in which texts were clearly used more as tools than as authoritative models, and in which people exploited the flexibility of the written word as one of the many instruments at their disposal? Are we not the first to move beyond the passive reproduction of textual content, engaging with books instead for a wide array of strategic, practical, and leisure purposes?

Aren't "standard" or "traditional" understandings of the production of knowledge and linear models of the relationship between theory and practice inadequate to describe the way in which even we – as scholars – produce new knowledge? While these models provide polished ways of portraying and conveying our work, they reveal as much as they conceal of the inner mechanisms of the research process. Aren't these understandings of disembodied texts misleading about the ways in which we – as scholars – actively exploit the agency and performativity of texts that we *want* (or *need*) to be perceived as authoritative? From this point of view, the manuals of the mechanical arts can give us a distinctively unfiltered mirror to reflect on the transformative agency of the written word, and the murky, tentative, and unsystematic nature of the dialectic of theory and practice.

⁹² James Secord has recently analysed how the concept of the "scientific revolution" was discussed in the United States in the early twentieth century. See Secord, "Inventing the Scientific Revolution."

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Crossing institutional boundaries: Abacus and scholastic knowledge in fourteenth-century Italy

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Abstract

This article examines the circulation of abacus mathematics within learned environments of late medieval Italy, drawing on broader historiographical debates on premodern scientific knowledge. Tempering an account that confines abacus mathematics to urban, practical schooling, it documents the presence of abacus knowledge within mendicant studia and learned circles, as well as abacus teachers within university arts faculties in the fourteenth century. Four kinds of evidence are discussed: (1) theologians writing on abacus mathematics; (2) archival evidence from Bologna, Siena, and Perugia; (3) references to convent libraries in abacus texts; and (4) abacus teachers' reports on non-practitioners engaged with abacus mathematics. The paper then examines whether philosophical knowledge informs abacus writings, focusing on scholastic traces in three case studies: Jacopo of Florence's *Tractatus algorismi*, Dardi's *Aliabraa argibra*, and an anonymous Genoese *Tractatus super practicam geometrie*. The article concludes that abacus mathematics was neither socially nor intellectually isolated but embedded within a common culture comprising scholastic knowledge.

Keywords

abacus mathematics, scholastic knowledge, medieval Italy

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1. Introduction: framing a new research question

This article arises from a research question concerning the interaction between philosophy and mathematics in premodern intellectual Europe. Recasting a well-known interrogation articulated by Jens Høyrup in his *In Measure, Number, and Weight* (1994),¹ the question may be formulated as follows: was philosophy merely an epiphenomenon in the historical development of mathematics, or did philosophical discourse contribute to mathematical innovation, perhaps providing an epistemic framework to mathematical practice? I suggest that this question finds a particularly fruitful testing ground in a specific historical and cultural context, namely, fourteenth-century Italy. At that time, cities such as Florence, Siena, Perugia, Bologna, Parma, Pavia, and Padua witnessed the rise and consolidation of a distinctive educational landscape. A unique intellectual atmosphere emerged from the coexistence of varied institutions: the studia associated with mendicant orders, the universities, and the pre-university schools, including abacus schools. This cultural configuration constitutes the principal case study of the present article, defining its chronological focus on the fourteenth century.

Once this context is chosen, the guiding question may be reformulated in more precise terms. One may ask, first, whether the material and institutional conditions for sustained exchanges between philosophical and mathematical domains were in fact present; and, second, whether such exchanges were intellectually meaningful and yielded outcomes of historical significance. The present article argues that the first condition is clearly met and proposes a preliminary exploration of the second, based on an initial analysis of the ways in which practical mathematical texts were framed and introduced. Furthermore, the article investigates how philosophical and mathematical knowledge were reciprocally put to use. More specifically, it asks whether abacus knowledge was mobilized within philosophically oriented contexts, and conversely, whether scholastic knowledge informed the teaching and conceptual frameworks of abacus mathematics. In other words, to what extent did abacus knowledge circulate within learned settings, and how far did university-based philosophical frameworks shape mathematical practice in abacus schools?

To pursue this line of inquiry, I adopt two historiographical perspectives that have proven influential in accounts of premodern scientific knowledge and learning: those of John Murdoch and Edgar Zilsel. Murdoch's position, articulated most programmatically in "From Social into Intellectual Factors: An Aspect of the Unitary Character of Late Medieval Learning" (1975), is directed against separatist interpretations of medieval intellectual life.² Murdoch argues instead that late medieval learning, especially in the fourteenth century, exhibited a fundamentally unitary character, both institutionally and intellectual-

¹ Høyrup, *In Measure, Number, and Weight*, especially Chapter 5, "Philosophy: Accident, Epiphenomenal, or Contributory Cause of the Changing Trends in Mathematics."

² Murdoch, "From Social into Intellectual Factors."

ly. Institutionally, this unity was secured by the medieval universities; intellectually, it was sustained by shared problems and analytical tools.

Within the university system, at least in Paris and Oxford, which are the focus of Murdoch's study, all advanced students – whether destined for law, medicine, or theology – were required to pass through the faculty of arts.³ This curricular structure ensured a common training in logic, natural philosophy, and mathematics (arithmetic and geometry). It was this common training that facilitated the transfer of methods and problems across disciplines and faculties. Such institutional unity enabled a reciprocal shaping of theology and philosophy in particular, but also of natural philosophy (physics) and mathematics: philosophical inquiry imported problems from theology and natural philosophy (for example, debates concerning the status of the infinite), while theology and natural philosophy relied on philosophical and mathematical tools to articulate and resolve their own difficulties (for example, the logical distinction between syncategorematic and categorematic terms in dealing with infinities).⁴ In this sense, the arts training furnished a shared analytical language that permeated multiple domains of learning, including the scientific one of physics. Murdoch's central conclusion is methodological as much as historical: for the historian, philosophy, theology, and science should not be treated as autonomous or insulated domains, but rather as interdependent components of fourteenth-century intellectual life.

Edgar Zilsel's contribution broadens the analytical horizon by shifting attention beyond the confines of the medieval university and advancing a sociological account of the emergence of modern science. In doing so, Zilsel partially challenges approaches – such as Murdoch's – that explain scientific rationality primarily through internal intellectual developments. In his seminal 1942 article, with the telling title "The Sociological Roots of Science," Zilsel argues that modern science could emerge only once entrenched social barriers between different categories of knowledge holders began to erode.⁵ Between approximately 1350 and 1600, the gradual weakening of rigid social and cultural divisions allowed for sustained interaction between elite, leisure-based learned groups and social strata oriented – so to speak – toward practical effectiveness.

As Zilsel emphasizes, late medieval and early modern Europe witnessed an increasing circulation of knowledge between university-trained scholars and humanists, on the one hand, and artisans, craftsmen, instrument-makers, and artists, on the other. Figures such as the sculptor Lorenzo Ghiberti (1377–1455) exemplify this mobility of knowledge across social and intellectual strata, binding 'manual and skilled labor' and 'rational thinking.' A

³ It is worth specifying that in the case of Italian universities, such as Bologna, the arts training was regarded as preparation particularly for medicine. See, for instance, Masuzawa, "Theology," 1279.

⁴ Hence the philosophical tendency to approach Aristotelian doctrines through a "quantifying lens," as emerges from Di Liscia and Sylla, eds., *Quantifying Aristotle*.

⁵ Zilsel, "The Sociological Roots."

crucial feature of this new configuration, according to Zilsel, was the growing prominence of quantification: measurement assumed a central role, and mathematics was increasingly deployed in an operational way. This development occurred within what Zilsel characterizes as an “early capitalistic society,” understood as an ensemble of economic practices, labor relations, and social structures that directly affected the production and circulation of knowledge. In such an urban, mercantile, and socially mobile environment, the traditional separation between pure scholars and practitioners weakened, thereby making possible the integration of theoretical reflection and technical practice, thus preparing the ground for the emergence of modern – or rather, post-medieval? – science.

At first glance, Murdoch’s and Zilsel’s perspectives may appear to stand in tension. Murdoch identifies a form of internal coherence *within* late medieval learned culture, whereas Zilsel emphasizes a bridge *between* learned and practical forms of knowledge beginning in the later Middle Ages. Framed in this way, Murdoch may be seen as accounting for the structural unity of medieval intellectual life from within a single milieu, while Zilsel explains why this unity of a single milieu did not yet culminate in modern science. Despite these differences, the two approaches function complementarily in the present study, serving as historiographical presuppositions that frame its central question.

From Murdoch, I retain the view of knowledge as porous rather than rigidly compartmentalized, a condition that allowed logical and mathematical tools to be mobilized across domains, including natural philosophy. From Zilsel, I adopt the insight that science is not an isolated intellectual achievement but a collective and socially situated enterprise, shaped by interactions among diverse cultural actors. From this combined perspective, the question of the interaction between mathematics and philosophy must first transform into a broader inquiry into the interaction between different communities of mathematical and philosophical actors, and ultimately into how the contributions of one discipline allow us to explain the mechanisms and notions of the other.

Building on these premises, the article is structured in two main parts. The first section establishes the material and institutional conditions that made exchanges between mathematical and philosophical actors not only possible but structurally plausible in fourteenth-century Italy. In line with Zilsel’s attention to the circulation of knowledge across social and institutional boundaries, I show that abacus teachers (and the mathematical knowledge they transmitted) were present and operative in settings that were not confined to abacus schools. These include theological studia of mendicant orders and the university arts faculties.

The second section shifts the focus from institutional settings to the structure of mathematical practice as expounded in abacus texts. Although scholarship tends to minimize the role and importance of university knowledge in shaping the work of mathematical practitioners – and with solid reasons – the available evidence invites a more nuanced assessment, as scholastic doctrines surface at various points in these writings. Drawing on

Murdoch's account of the permeability and unity of late medieval learned culture, this section proposes to look at abacus mathematics in light of the shared philosophical training that informed both university and mendicant intellectual environments.

2. *The shared paths of philosophical and mathematical actors*

As stated in the previous section, central-northern Italian cities of the fourteenth century constitute a particularly apt case study for addressing the first strand of the overarching research question, namely, the existence of shared contexts in which historical actors operating within philosophical and mathematical domains could interact. Late medieval Italian cities such as Florence, Siena, Perugia, Bologna, Parma, Pavia, Padua, and Venice were vibrant intellectual environments in which the activities of three institutional settings devoted to the education of young adults were closely interlaced within the urban life: the university – comprising, on the one hand, the faculties of arts and medicine, and, on the other, the faculty of law; the studia associated with mendicant orders, broadly comparable to theology or divinity schools; and the abacus schools, which provided instruction in practical mathematics to the offspring of the emerging mercantile class.

Philosophy – understood here as the constellation of doctrines derived from Aristotle in logic, natural philosophy, metaphysics, and moral philosophy – was formally taught within the institutional framework of the faculty of arts.⁶ The same contents also entered the foundational education of friars, insofar as theological study presupposed familiarity with philosophical tools and distinctions.⁷

Theoretical foundations of mathematics, including issues that might today be classified under the philosophy of mathematics, such as the ontology of numbers, were also imparted within the faculty of arts as an essential component of quadrivial instruction in arithmetic, geometry, astronomy, and music – with astronomy often occupying a particularly prominent position.⁸ Core texts included Boethius' *De arithmetica*, so-called al-

⁶ See Bianchi and Randi, eds., *Filosofi e teologi*; and Pedersen, *The First Universities*.

⁷ To frame the kind of knowledge imparted within learned mendicant circles, I refer to Roest, *A History of Franciscan Education*, especially 137–146, where the arts and philosophy curriculum is considered.

⁸ Studies shedding light on mathematical instruction at European universities, most prominently the university of Paris, include Beaujouan, “L'enseignement de l'arithmétique”; Rommevaux, “Un exemple de *Question*”; and Rommevaux, “L'enseignement de la géométrie.” By contrast, our knowledge of the mathematical teaching at Italian universities before the fifteenth century is comparatively uneven. Useful information is scattered across studies devoted to individual institutions. For instance, for the curriculum of mathematical teaching at the university of Padua, see Siraisi, *Arts and Sciences*, especially 67–77; for the university of Pavia, see the concise note in Azzolini et al., “La facoltà di arti e medicina,” 518; and for the university of Bologna, Rashdall, *The Universities of Europe*, 249–250.

gorism treatises introducing operations with Hindu-Arabic figures (such as that by Alexander of Villa Dei, despite documented contextual resistance), Euclid's *Elements* mostly in Campanus of Novara's Latin version, Campanus' *Theorica planetarum* – among others. For analogous reasons, quadrivial fundamentals also formed part of the educational curriculum within mendicant studia.⁹

Abacus schools, by contrast, specialized in practical mathematics, offering instruction primarily in practical arithmetic, algebra, and practical geometry, with a strong emphasis on commercial applications and a secondary focus on recreational problems, astronomy and calendrical knowledge, and systems of weights and measures.¹⁰ A concrete sense of the range of knowledge circulating within such schools can be obtained from a typical abacus textbook, such as the one produced within the Florentine school – or *bottega* – of Santa Trinita, where Paolo dell'Abaco was active, and preserved in manuscript Florence, Biblioteca Nazionale Centrale, II.IX.57.¹¹ The contents of this manuscript are diverse and not limited to practical mathematics: alongside Paolo dell'Abaco's *Regoluzze* and the *Trattato di tutta l'arte dell'abaco*, collections of commercial and numerical problems involving procedures for finding unknown quantities, it also includes astronomical and astrological materials, as well as medical texts and preparations of remedies.

It is thus evident that the knowledge circulating within an abacus school was not exclusively mathematical: in the case of Santa Trinita, it appears to encompass medical materials, albeit framed in a markedly practical orientation. This broader intellectual profile is corroborated by an important contemporary testimony, Giovanni di Pagolo Morelli's *Ricordi*, which describes the education of Florentine merchants around 1393. Therein, Giovanni explicitly attributes to schools the reading of classic authors (Vergil and Seneca), major poets (Boethius and Dante), rudiments of rhetoric (Cicero), and elements of philosophy (Aristotle). Supplemented by biblical instruction, this curriculum leaves little room – says Giovanni – for the addition of further, non-superfluous content.¹² Giovanni thus seems to outline what may be described as a proto-humanist education for young

⁹ For mathematical knowledge within mendicant contexts, I refer to Chandelier and Robert, eds., *Savoirs profanes*.

¹⁰ Danna, "Figuring out," especially 13–14 and 47; Høyrup, "Abacus Geometry."

¹¹ This textbook has recently been the subject of detailed analysis by Ceccherini, "Come nasce un libro d'abaco"; cf. Danna, "Una scienza per la rinascita."

¹² Giovanni di Pagolo Morelli, *Ricordi*, 226: "E di poi ài aparato, fa che ogni in dì, un'ora il meno, tu istudi Vergilio, Boezio, Senacha o altri autori, chome si leggie in ischuola [...]. Tu ti potrai istare chon Boezio, chon Dante e chogli altri poeti, chon Tulio che t'insegnierà parlare perfettamente, chon Aristotile che tti insegnierà filosofia: chonoscierai la ragione delle chose [...]. Istara'ti cho' santi profeti nella Santa Iscrittura, legierai e studierai la Bibia [...]; e da questa virtù della scienza tu sarai tanto bene amaestrato e 'nsegnato che non bisognerebbe dire più avanti, ché tutto è di soverchio."

adults.¹³ The reference to Aristotle is particularly noteworthy, as it is associated with the unveiling of the nature of things, which in vernacular reads “la ragione delle cose”¹⁴ – an expression that may simultaneously evoke genuinely Aristotelian explanatory aims and concrete abacus procedures oriented toward finding the unknown.

Having outlined the richness of the educational landscape of some Italian cities, I now turn to the question of whether there are positive grounds for assuming intersections among actors traditionally associated with one or another of these institutions – or, at the very least, the possibility that individual actors inhabited multiple contexts, carrying their expertise with them and possibly rearticulating it within new educational environments. Evidence for such intersections can be drawn from mathematical works authored by non-practitioners (§2.1), formal documentary transcriptions relating to city and university life, including salary and payment records (§2.2), and indirect reports by abacus teachers themselves (§2.3).

2.1 Non-practitioners’ mathematical works: Grazia dei Castellani and Leonard of Pistoia in Florence

The first type of source on which I focus concerns two Florentine figures: the Augustinian friar Grazia dei Castellani (d. 1401) and the Dominican friar Leonard of Pistoia (*fl.* 1338–1342), both active in Florence in the fourteenth century. The former has already received sustained attention from the historian of mathematics Elisabetta Ulivi, while the latter’s mathematical expertise has been examined by Gino Arrighi and Raffaella Franci. I begin by outlining Grazia dei Castellani’s intellectual profile on the basis of Ulivi’s survey.¹⁵ Grazia dei Castellani was a theologian active at the convent of Santo Spirito of the Hermit friars, which he entered between 1356 and 1358 and where he was ordained in 1361.¹⁶ During the 1390s, Grazia served as a professor of theology at the Florentine university: in 1391 and 1392, he was appointed lecturer on Peter Lombard’s *Sentences* and Augustine’s *De civitate Dei*; whereas in 1394, he was further authorized to lecture and comment on the *Apocalypse* in vernacular, at the church of Santo Stefano al Ponte.¹⁷

In line with these appointments, sources attest to Grazia’s authorship of theological works such as the *Lectiones theologicae* and the *Quaestiones super libros Sententiarum*. These writings should have been preserved within the library of Santo Spirito, but are no longer listed in the convent library catalogue of 1450 and may therefore be lost – it remains pos-

¹³ This is how Aurélien Robert defines it; Robert, *Le monde mathématique*, 55.

¹⁴ See footnote 12.

¹⁵ Ulivi, “Su Maestro Grazia.”

¹⁶ *Ibid.*, 114.

¹⁷ *Ibid.*, 121; Garfagnini, “Lo studio a Firenze,” here 116. The establishment of Florence’s university was not a linear process, for the *studium* had been re-established several times prior to Grazia’s appointment. See Zorzi, “Lo studium nel XIV e nel XV secolo.”

sible that they survive among the Conventi Soppressi holdings of the Biblioteca Nazionale in Florence.¹⁸ Be they lost or hidden, these are the kind of texts that demanded of their author not only theological preparation, but also to engage with deeply philosophical issues.

Beyond this already substantial activity as theologian and lecturer, further evidence points to Grazia's involvement in scientific and mathematical production closely connected to the abacus tradition. To begin with, Grazia is mentioned in Giovanni Gherardi's (1362–1442) *Paradiso degli Alberti*, a collection of novellas inspired by Boccaccio's *Decameron* that offers vivid insights into the Florentine intellectual milieu. There, Grazia is explicitly described as “theologian and mathematician,”¹⁹ alongside another major contemporary figure at the intersection of philosophy and mathematics, Blasius of Parma (1347–1416).

More decisive evidence of Grazia's mathematical expertise is provided by a group of texts attributed to him that fall squarely within the domain of what may be termed business mathematics. These writings are incorporated into two fifteenth-century treatises on practical arithmetic, preserved in Florence, Biblioteca Nazionale Centrale, Pal. 573, and Vatican City, BAV, Ottob. lat. 3307. They include *chasi del chatain* (a discussion of the rule of double false position used to approximate solutions to first- and second-degree equations), *chasi sopra compagnie*, *chasi notabili al meritare e scontare* (dealing with interest, discounting, and partnership problems), as well as a vernacular translation of a treatise on practical geometry, *De visu*.²⁰

The content and form of these texts clearly situate them within the abacus teaching milieu. According to Ulivi, however, these writings were not intended for direct pedagogical use; rather, they may reflect Grazia's own early education in an abacus school prior to his entrance into the convent of Santo Spirito. Yet, they would have been composed after Grazia had been ordained. While there is no direct evidence that Grazia himself taught in Florentine abacus schools during his time at the convent, a significant indirect testimony is provided by a Florentine abacus teacher, possibly Benedetto di Antonio and surely a disciple of Domenico Vaiaio. In his *Practicha d'arismetricha* (ca. 1460–1463), Benedetto explicitly states that he acquired insight into particularly subtle mathematical matters

¹⁸ Negri, *Istoria degli scrittori fiorentini*, 315. Gutiérrez, “La biblioteca di Santo Spirito.”

¹⁹ Giovanni Gherardi, *Il Paradiso degli Alberti*, III, 7–9, 164–165: “Similmente ancora per simile modo ci era maestro Biagio da Parma, universal filosofo e metamatico più che altro che quella età si avesse. [...] Eraci ancora il preclaro e famoso teologo e metamatico maestro Grazia, non meno d'ingegno divino che umano.” To give a further sense of Grazia's embeddedness within Florence's cultural scene, I will here recall that Santo Spirito was chosen by Boccaccio, according to his will, as a repository for his texts after his death. The Santo Spirito friar Martino da Signa, who was appointed executor of Boccaccio's will, also witnessed Grazia's religious vows.

²⁰ One of these texts from the Pal. 573 has been edited in Maestro Grazia de' Castellani, *Chasi sopra chonpagnie*.

(“chasi sottili”) precisely from our Grazia, alongside other renowned abacus teachers.²¹

Leonard of Pistoia's life is less documented. Nevertheless, Silvana Vecchio's entry in the *Dizionario biografico degli italiani* provides sufficient details to situate him within the Dominican convent of Santa Maria Novella. Leonard appears to have served as lecturer in logic in the Dominican convent in Cortona in 1338, before moving to Lucca in 1339 to pursue further studies in philosophy, and eventually settling in Florence at the Dominican *studium generale* of Santa Maria Novella, where he completed his theological training around 1340.²² His career clearly places him within the same scholastic framework as Grazia: he emerges as a theologian with a strong grounding in philosophy and logic, as reflected in his cursus.

Leonard is the author of several theological works, including the *De praescientia et praedestinatione divina* – long attributed to Thomas Aquinas until the nineteenth century – the *Speculum Christianae religionis* (a compendium on Christian doctrine closely aligned with Aquinas' *Summa theologiae* and *Summa contra gentiles*), the *Tractatus de decem praeceptis*, and the *Super oratione dominica* (a study of the act of praying and an exegesis of the *Our Father*).

His intellectual production, however, is not confined to theology. Leonard also authored a series of mathematical texts: four short treatises corresponding to the traditional quadrivial disciplines – arithmetic, geometry, music, and astronomy – transmitted under the collective title *Mathematica* in the manuscripts Florence, Biblioteca Nazionale Centrale, Conv. soppr., J.V.7, and Biblioteca Riccardiana, ms. 1169.²³ Although the *Mathematica* aligns with the scholastic tradition of quadrivial teaching, it also reveals notable influences from algorism and abacus traditions, particularly in his treatment of arithmetic and geometry. This combination led Arrighi to rank Leonard of Pistoia among the most significant mathematicians of the fourteenth century.²⁴

Remarkably, the arithmetic and geometry sections of the *Mathematica* do not present purely speculative taxonomies of natural numbers or geometrical shapes. Instead, they of-

²¹ Arrighi, “Il codice L.IV.21,” 155, where a transcription of Benedetto's mention of Grazia is provided. Cf. Ulivi, “Su Maestro Grazia,” 122; and Black, *Education and Society*, 368. On Benedetto di Antonio, Ulivi concludes that he is likely the same author of the arithmetical and geometrical works transmitted in manuscripts Florence, BNC, Pal. 573 and 577, Siena, Biblioteca degli Intronati, L.IV.21, and Vatican City, BAV, Ottob. lat. 3307. The *Practicha d'arismetricha* would have undergone four stages: it would have been composed before 1460, revised in 1460 in manuscript Pal. 573, revised again in 1463 in manuscript L.IV.21, and finally, in 1465, it would have been united with the *Praticha di geometria* (present in Pal. 577) within manuscript Ottob. lat. 3307. See Ulivi, “Benedetto da Firenze,” 59–60.

²² Vecchio, “Leonardo da Pistoia.”

²³ Gino Arrighi transcribed selected parts of the *Mathematica*. See Arrighi, *L'Arithmetica di fra Leonardo*; Arrighi, “Fra Leonardo da Pistoia”; and Arrighi, “La *Cosmimetria* di fra Leonardo.” See also Franci, “L'insegnamento dell'aritmetica nel medioevo,” 128–129.

²⁴ Arrighi, “Fra Leonardo da Pistoia,” 382.

fer practical procedures for computation and measurement – methods for operating with integers and fractions, as well as techniques for determining dimensions such as height, width, and depth through the use of instruments. In the arithmetic section, Leonard introduces the *ars numerandi*, explicitly identifying it with *algorismus* in its vernacular form; for Franci observes that this section also includes the extraction of cube roots.²⁵ Although Leonard’s *Mathematica* likely originated in a conventual teaching context, its practical orientation suggests connections with urban mathematical instruction. This line is further validated by the fact that, as will be recalled below in §2.3, Leonard’s treatment of integers and fractions was later taken up by the author of the *Practicha d’arismetricha*.

Grazia dei Castellani and Leonard of Pistoia thus emerge as friars, theology lecturers, and experts in abacus mathematics. The available evidence concerning their career and writings points to figures who operated across multiple intellectual contexts and contributed within each of them. In this respect, they exemplify the convergence of scholastic and practical mathematical traditions – much like later figures such as the Franciscans Mariotto Guiducci and Luca Pacioli, Grazia and Leonard stand at the intersection of the convent and the abacus school.²⁶

2.2 City- and university-life records in Bologna, Siena, and Perugia

If Grazia dei Castellani provides evidence of early abacus knowledge entering and being reworked within mendicant circles – albeit not with the aim of instructing others – other types of sources delineate a different, yet closely related, trajectory of knowledge transfer, namely, from the abacus school to the arts faculty (and back again). A small number of examples drawn from the Universities of Bologna, Siena, and Perugia will substantiate this claim. In what follows, I look at the *Rotuli dei lettori, legisti e artisti* for Bologna, at the university *Chartularium* for Siena, and the city statutes for Perugia.

The *Rotuli*, that is, the salary registers of the University of Bologna, record two cases that are particularly relevant for the present inquiry.²⁷ Beginning in the academic year 1387–1388, the faculty of arts appointed masters to lecture not on astrology, but explicitly “ad lecturam abbachi.” This designation recurs consistently in the payment records of the fourteenth century. In 1387–1388, the subject was taught by one Nicola Ottaviani (also referred to as de Abbacho or de Bononia) alongside Antonio Bonini Biliotti of Florence.²⁸

²⁵ Franci, “L’insegnamento,” 129.

²⁶ I refer to Papi, “Francescani e matematica”; and Ulivi, “Luca Pacioli.”

²⁷ Andrea Papi meticulously reconstructed the tradition of abacus teaching in Bologna up to Scipione Dal Ferro, covering the fourteenth century while focusing especially on the fifteenth, for which the documentary record is considerably richer. See Papi, “Prima di Scipione Dal Ferro.”

²⁸ *Rotuli dei lettori*, vol. 4, 14: “AD LECTURAM ABBACHI. M. Nicolaus de Abbacho cum salario librarum quinquaginta. M. Antonius Boninj Belliotti libras centum. Ita tamen quod predicti magistri non possint nec debeant diebus feriatis ire ad mensurandum, salvo quod dictus magister

Antonio was permitted to teach at the university while simultaneously holding a civic appointment granted by the city of Bologna, which involved supervising masonry, land surveying, and account auditing. The salary entry specifies that he alone was authorized to carry out such activities on non-teaching days (“diebus feriatis”).²⁹

What emerges from this notice is that Antonio’s activity was not confined to academic instruction but extended directly into the urban and administrative life of the city. Notably, during the same years in which Nicola Ottaviani and Antonio Bonini Biliotti lectured on abacus mathematics (“ad lecturam abbachi”) – that is, between 1387 and 1393³⁰ – the arts faculty also counted among its members one of the most prominent figures in contemporary philosophy, teaching astrology and logic: Blasius of Parma.

A further instructive case appears in the academic year 1395–1396, when two teachers were again appointed “ad lecturam abbachi”: Antonio Bonini Biliotti, who continued to combine university teaching with civic duties, and Jacopo of Betania. The *Rotuli* describe Jacopo’s appointment in particularly revealing terms:

AD LECTURAM ABBACHI [...] Magister Iacobus de Betania electus ad dictam lecturam sceu docendum Abbachum ... et teneatur publicas retinere scollas et abbachum docere in dicta civitate Bononie ac videre et chalchullare ac in saldum reducere rationes, nec non mensurare et assagiare res quaslibet ad commune Bononie spectantes et reactare herologium communis et accedere ad videndum laboreria et hedificia communis Bononie que videri et revideri expediens foret et que oppoteret reparari et eiam de novo fieri in quacumque parte quociens et quandocumque foret opportunum.³¹

This document makes clear that, in 1395, the boundaries between university teaching, civic service, and pre-university mathematical education were far from rigid. Jacopo was appointed as a university lecturer in mathematics, yet his duties explicitly included calculating and settling accounts, maintaining the city clock, inspecting workshops and public buildings and – crucially – continuing to teach abacus mathematics in the city of Bologna. In other words, the same individual was expected to operate simultaneously within the university, the communal administration, and the abacus school system. At that time, one of Jacopo’s teaching colleagues in the arts faculty was Angelo of Fossombrone, a master renowned for his command of the Oxford Calculators’ approach to natural philoso-

Antonius teneatur et debeat mensurare res spectantes ad commune Bononie et videre et calculare rationes dicti communis cum expediens fuerit, ut patet in litteris transmissis per dominos Antianos dicto magistro.” Cf. Mazzetti, *Repertorio di tutti i professori*, 46.

²⁹ Antonio Bonini Biliotti’s twofold investment was first mentioned by Ulivi, “Scuole e maestri d’abaco,” 124.

³⁰ *I Rotuli dei lettori*, vol. 4, 16.

³¹ *Ibid.*, 18. Bold here and in other quotations is always mine.

phy and sophismata (particularly as developed by William of Heytesbury).³²

Up to this point, I have deliberately used the generic expression “teaching mathematics” to describe the appointments of Antonio Bonini Biliotti, Nicola Ottaviani, and Jacopo of Betania despite the fact that their official designation was “ad lecturam abbachi” – sometimes being referred to simply as “arithmetic.”³³ Should this label be taken to indicate the formal establishment of a chair of practical mathematics proper at Bologna at the end of the fourteenth century? I do not wish to press this claim without nuancing it. For the statutes of the arts faculty of 1405 continue to organize mathematical instruction around distinct geometrical and astrological/astronomical speculative components.³⁴ More cautiously, however, the evidence does warrant a different take: specialists trained in practical mathematics – figures who elsewhere functioned as city abacus teachers – could and did lecture within the arts faculty. Also noteworthy is the case of Jacob the German (lit. *de Alamania*), who was appointed not only to lecture on arithmetic *and* astrology, *but also* on moral philosophy.³⁵

A closely comparable situation can be documented at the arts faculty of the University of Siena, and at an even earlier stage, that is, in the first half of the fourteenth century. From the 1320s, abacus teachers appear to have been embedded within university teaching, hired explicitly because of their mastery and expertise (“ars et doctrina”).³⁶ More specifically, the university *Chartularium* reveals that between 1328 and 1341 the teaching of mathematics within the arts faculty was entrusted to two masters trained in the abacus tradition: Giovanni di Puccio (also called Morroccho) and Lapo di Neri (or di Ranieri) from Florence – and Tommaso di Davizo from Florence, at the passing of the latter.³⁷

Giovanni di Puccio was appointed in 1328, with an annual salary of 25 lire, paid in two semiannual installments. This salary remained stable until the final year of his service in

³² Ibid., 19.

³³ For instance, *ibid.*, 11, where Antonio Bonini’s activity is defined as “ad lecturam arismetrice.”

³⁴ *Statuti delle università*, 276: “In astrologia in primo anno primo legantur algorismi de minutis et integris, quibus lectis, legatur primus geometrie Euclidis cum commento Campani. Quo lecto, legantur tabule Alfonsi cum canonibus. Quibus lectis, legatur theorica planetarum. In secundo anno primo legatur tractatus de sphaera, quo lecto, legatur secundus geometrie Euclidis, quo lecto legantur canones super tabulis de linerijs. Quibus lectis, legatur tractatus astrolabij Mes[sa]chale. In tertio anno, primo legatur Alkabicius, quo lecto legatur Centiloquium Ptolomej cum commento haly. Quo lecto legatur tertius geometrie, quo lecto, legatur tractatus quadrantis. In quarto anno primo legatur quadripartitus totus, quo lecto, legatur liber de urina non visa. Quo lecto, legatur dictio tertia almagestj. Dictis annis completis, et completis dictis libris in dicto termino, fiat circulus, et redeatur ad lecturam primj anni postea ad lecturam secundi anni, et sic per ordinem.” Cf. Rashdall, *The Universities of Europe*, 249–250.

³⁵ *I Rotuli dei lettori*, vol. 4, 11.

³⁶ See below the reference to Giovanni di Puccio’s teaching for the year 1329.

³⁷ Zdekauer, *Lo studio di Siena*, 14–15; Moscadelli, “Maestri d’abaco a Siena,” 208. Cf. Ulivi, “Scuole e maestri d’abaco,” 126.

1342. The records further indicate that Giovanni occasionally placed his expertise at the disposal of the city: in 1336 and again in 1340, he is recorded as acting as a surveyor. Of particular relevance for the present argument is the consistency with which Giovanni is designated as “magistro abbaci” and remunerated for teaching abacus, abacus geometry, and arithmetic within the arts faculty. A selection of salient entries from the *Chartularium* is reproduced below – the year of reference and emphasis are my additions.

- [1329] Die lune XVI. novembris. Item XII. l., X. s. magistro Iohanni Pucci, vocato Magistro Morroccho, **Magistro abbaci**, pro suo salario **occasione sue artis et doctrine**, pro tempore sex mensium inceptorum in kalendis maii proxime preteritis, ad ratione viginti quinque l. in anno, ut apparet per eius stantiammentum.³⁸
- [1330] Item Magistro Iohanni Pucci, magistro abbachi, pro salario VI. mensium, per instantiammentum dominorum Novem – XLVI l., X s.³⁹
- [1336] Die lune VIII. decembris. Item I. l. magistro Morroccho de albaco, pro mensurando murum communis porte Montis Guatiani qui fuit XLVII. cannis et quarto.⁴⁰
- [1339] Mezzedima XXX, di giugno. [...] Anco a maestro Giovanni di Puccio chiamato Morocho, maestro in **giometria d'albacho**, per suo salario di sei mesi cioè da chalende giennaio passato fino al di d'oggi, come apare per stanziamento fatto per mano di ser ... – XII. l., X. s.⁴¹
- [1340] Maestro Giovanni di Puccio, **maestro in arismethica**, de' avere per suo salario di detti sei mesi – XII. l., X. s.⁴²
- [1341] Maestro Giovanni Pucci Mochi, die avere, e' quali dodici l., diecie s. furo per lo suo salario di sei mesi **per insengiare l'abacho** – XII l., X. s.⁴³
- [1342] Maestro Giovanni detto Morroccho, **dottore et maestro in arismetica et geometria**, per li nostri sei mesi – XII l., X. s.⁴⁴

Alongside Giovanni, another abacus teacher such as Lapo di Neri operated at the arts faculty between 1330 and 1339, the year of his death, under more favorable economic conditions: he received an annual salary of 42 lire. Lapo belonged to a Florentine family of abacus practitioners, his father being Maestro Chiaro Neri (or Ranieri).⁴⁵ According to the *Chartularium*, Lapo was appointed to teach abacus and geometry and, like Giovanni,

³⁸ *Chartularium Studii Senensis*, vol. 1, 381.

³⁹ *Ibid.*, 419.

⁴⁰ *Ibid.*, 420. Cf. *ibid.*, 483.

⁴¹ *Ibid.*, 468.

⁴² *Ibid.*, 490.

⁴³ *Ibid.*, 494.

⁴⁴ *Ibid.*, 503.

⁴⁵ Black, *Education and Society*, 227.

Lapo combined university teaching with service to the city of Siena.⁴⁶ Of particular importance is a record from 1334 documenting his parallel activity at the university and in urban abacus schools during the year 1333. For six months (October–April) Lapo would have lectured (“lettura e ’nsegnatura”) on mathematics at the arts faculty; and for a further, partially overlapping six-month period (January–June), he would have taught in the city’s abacus schools – the university appointment being more generously remunerated.

- [1334] Maestro Lapo del maestro Ranieri de ll’abaco die avere per **lettura e ’nsegnatura la detta scientia per VI. mesi**, e’ quali si finiscono in kalende aprile MC-CCXXXIII – XV. l. **E die avere per le scuole del detto abaco per VI. mesi**, e’ quali cominciano in kalende gennaio MCCCXXXIII – VI. l.⁴⁷
- [1339] Anco a maestro Lapo del maestro Ranieri da Fiorenza, **maestro in geometria dell’abacho**, per suo salaro di quattro mesi cioè da chalende otobre anno mille trecento trenta otto in fino a chalende febraio anno detto per ciò che allora passò di questa vita, a ragione di quarantadue l. l’anno, come appare per stanziamento fatto per mano di ser ... – XIII l.⁴⁸

At the death of Lapo di Neri, Tommaso di Davizo, another “abacus and arithmetic teacher” from Florence, took on the mathematical teaching at the faculty of arts, serving between 1339 and 1341, for 25 lire per semester.

- [1340] Maestro Tomagio del maestro Davizo da Fiorenza, **maestro d’abacho e arismeticha**, per suo salario detti sei mesi – XXV. l.⁴⁹

A brief remark on the nomenclature of Giovanni’s, Lapo’s, and Tommaso’s teaching is in order. In Giovanni’s case, as in Lapo’s, the subject of instruction is variously designated as abacus, abacus geometry, and arithmetic; similarly, Tommaso is recorded as teaching both abacus and arithmetic. This fluctuation – also attested for other abacus masters ac-

⁴⁶ In 1330, for instance; see *Chartularium*, vol. 1, 387.

⁴⁷ Ibid., 402.

⁴⁸ Ibid., 468.

⁴⁹ Ibid., 490. This information is confirmed in the entry from the Archivio di Stato di Siena (Concistoro 1, c. 42r) reported in Ulivi, “I Davizzi-Corbizzi,” 56. The entry reads: “In nomine Domini amen. Anno Domini millesimo CCCXXXVIII, indictione VII, die XX mensis februarii. [...] Magister Thomasus Magistri Davizi de Corbizis de Florentia, magister theoricus et practicus in arte iometrie et arismetrice, nuper venit ad Civitatem Senarum causa docendi in dicta civitate in facultate et scientia supradicta, et audita fama laudabili sue doctrine et scientie in utraque facultate supradicta, et volentes eidem causam dare ut residentiam faciat in dicta civitate ad docendum in facultatibus supradictis, et super dicta materia tenentes colloquium et tractatum.”

tive within the arts faculty, such as Bartalo di Morroccho (years 1343–1345 and again in 1357),⁵⁰ Manno di Boccoccio (years 1344–1348),⁵¹ Pietro Parutino da Montepulciano (years 1349, 1351–1352),⁵² and Leonardo del Bianco (year 1354)⁵³ – suggests that, at the University of Siena, the term *abacus* gradually gained a foothold in the designation of mathematical teaching. The most plausible explanation for this semantic shift lies in the sustained presence of abacus practitioners within a university milieu that had previously been dominated by specialists trained primarily in the classical traditions of speculative arithmetic and geometry.⁵⁴

A comparable development can be observed at the faculty of arts of the University of Perugia. In this case, the evidence derives from municipal statutes regulating the organization of the university, which, although less specific regarding individual masters and salaries, nevertheless provide insight into both the nomenclature of mathematical teaching and the qualifications expected of instructors. For instance, in 1389, when the number of professors and masters was to be determined, the statutes prescribed the appointment of a single master to teach “arithmetic or geometry or abacus,” as the following passage indicates:

In **arimetrica seu geometria vel abbacho** eligatur et eligi possit unus ad legendum et docendum in dicto Studio quantumcunque doctoratus insignis non sit pollens, dum tamen sit sufficiens et expertus.⁵⁵

The provision further specifies that, unlike masters in other disciplines, teachers of abacus (as well as of grammar) were not required to hold a doctorate, but solely to be “sufficient and expert” in their field – a point also emphasized by Stefania Zucchini.⁵⁶ The municipal

⁵⁰ *Chartularium*, vol. 1, 506, 509–510, and 556. Bartalo, Giovanni di Puccio’s son, would also serve the city of Siena as a surveyor in 1345, alongside his colleague Manno di Boccoccio. See *ibid.*, 512.

⁵¹ *Ibid.*, 511–532 *passim*.

⁵² *Ibid.*, 533, 536–537. Cf. Denley, *Teachers and Schools*, 133.

⁵³ *Ibid.*, 540. Cf. Denley, *Teachers and Schools*, 123.

⁵⁴ It is perhaps worth mentioning here another significant piece of evidence from Tuscany, more precisely from Florence and the bottega of Santa Trinita. As argued by Ulivi and recalled by Høyrup, abacus master Giovanni di Bartolo (1364–1440) also taught astrology at the Florentine studium. See Ulivi, “Benedetto da Firenze,” 39, n. 41; and Høyrup, *The World of the Abbaco*, 232, n. 299. Further details on Giovanni di Bartolo are in Arrighi, “Il codice L.IV.21,” 156.

⁵⁵ Bellini, *L’università a Perugia*, 71 (III, Scons 1389.3). Cf. Bellini, *L’università a Perugia*, 77 (VIII, Scons 1389.8): “Predicta tamen non vendicent sibi locum in magistris gramaticalibus et magistro abbaci quoquo modo qui possint eligi licet non sint doctores et salarium consequi ordinatum.”

⁵⁶ Zucchini, *Università e dottori*, 103.

statutes additionally indicate that such a master could receive a salary of up to fifty gold florins.⁵⁷ Despite this relatively favorable remuneration – higher, for instance, than that of grammar masters – the position appears to have been difficult to fill: as Zucchini notes, the chair of abacus at Perugia remained vacant during the final decades of the fourteenth century.⁵⁸

A preliminary conclusion of this section is therefore that abacus teachers circulated within university settings to the point of reshaping the terminology used to designate mathematical instruction. Within the arts faculties, they appear to have taught alongside masters of astrology/astronomy – sometimes prominent figures, such as Blasius of Parma in Bologna – likely contributing foundational training in arithmetic and geometry that prepared university students for more advanced, philosophically engaged study of astrology/astronomy. The question of the language of instruction – whether Latin or vernacular – remains open.⁵⁹ What is clear, however, is that these teachers, operating alongside colleagues lecturing on Aristotle, Peter Lombard, and logical texts, embody in concrete terms the institutional permeability and cross-domain circulation of knowledge emphasized by Zilsel.

2.3 Indirect reports by abacus teachers: between Florence and Venice

Additional evidence further attests to exchanges between learned settings and abacus schools. Abacus teachers themselves occasionally refer to libraries within convents that preserved mathematical works, as well as to learned individuals who, although not formally recognized as abacus masters, engaged with problems characteristic of practical mathematics.

A particularly instructive case is provided by a Florentine abacus teacher, the above-mentioned disciple of Domenico called Vaiaio. Although the *Practicha d'arismetricha* dates from the middle of the fifteenth century – thus slightly beyond the chronological scope of the present study – it draws extensively on earlier abacus traditions. In particular, it makes use of works by figures discussed above (§2.1) as non-practitioners, such as Grazia dei Castellani and Leonard of Pistoia.⁶⁰ At the conclusion of a section devoted to arithmetic, the author recommends consulting Boethius and Euclid, alongside Leonard of Pistoia, “whose works are available at the library of the Santa Maria Novella con-

⁵⁷ Bellini, *L'università a Perugia*, 93 (XVI, Scons 1389.16): “Item uni magistro eligendo per conservatores monete Studii sapientes ad legendum abbacum pro suo salario anno quolibet, solvi possint et debeant usque in summam quinquaginta florenorum de auro.”

⁵⁸ Zucchini, *Università e dottori*, 104.

⁵⁹ Cf. Papi's take in Papi, “Prima di Scipione Dal Ferro,” 236.

⁶⁰ See Arrighi, “La matematica a Firenze”; and Arrighi, “Nuovi contributi.” Both articles are reprinted in Arrighi, *La matematica*, respectively at 209–222 and 161–194.

vent.”⁶¹ This reference is significant for two reasons. First, it indicates that abacus teachers engaged directly with writings produced within mendicant and scholastic contexts when these were deemed mathematically relevant. Second, and more importantly, it suggests that the contents of conventual libraries – at least in the case of Santa Maria Novella – were accessible to abacus practitioners. The fact that the author of the *Practicha d'arismetricha* confidently directs his readers to such a repository implies not only familiarity with its holdings but also the practical possibility of consulting them.

A further instructive testimony, also preserved in the *Practicha d'arismetricha*, concerns a figure from fourteenth-century Venice: Marco Trevisano (d. 1378). Although not a friar but a lay nobleman, Trevisano appears to have been deeply influenced by Franciscan intellectual culture, as is evident from his *De macrocosmo*. In this treatise, theological and mathematical concerns – such as the eternity of the world and the status of unity as a number – intersect with questions of natural philosophy, including the atomic constitution of matter.⁶²

Trevisano also seems to have maintained contacts with Florentine abacus circles. According to the report transmitted by Vaiaio's disciple, in 1372 a certain “Marcho Trevigiano” addressed a mathematical problem to a group of Florentine teachers, requesting its solution.⁶³ The problem, which belongs to the domain of recreational mathematics, concerns the measurement of the Earth's circumference and presupposes familiarity with procedures for summing the sequence of natural numbers and their corresponding cubes.⁶⁴

What makes this testimony particularly significant is the profile of Trevisano himself. As a learned layman operating within a scholastic and Franciscan intellectual horizon, he nonetheless turned to practitioners of abacus mathematics to resolve a technical problem. This episode, thus, points to the use of mathematical knowledge beyond

⁶¹ Arrighi, “Nuovi contributi,” 165, where the passage from the *Practicha d'arismetricha* (preserved in manuscript Florence, Biblioteca Nazionale Centrale, Pal. 573, f. 29v) is transcribed: “Chome ò detto, molte altre nature et misterj che ànno e' numerj potrei trattare; ma, se di ciò vuojo bene essere 'sperto, leghasi Boetio et Uclide e 'l frate Lionardo pistoiese frate predicatore; e lle sue opere sono in Sancta Maria Novella.”

⁶² Robert, *Le monde mathématique*, chapters 3 and 5.

⁶³ Arrighi, “Nuovi contributi,” 165; Ulivi, “Masters, Questions and Challenges,” especially 658 (there, Trevisano is acknowledged as an abacus teacher from Treviso); and Robert, “Les mathématiques franciscaines,” 142–143.

⁶⁴ The problem is preserved in manuscript Florence, Biblioteca Nazionale Centrale, Pal. 573, f. 138r, and is the following: two individuals depart from the same point on the Earth, proceeding in opposite directions with velocities that increase constantly according to a given proportion; the question posed by Marco Trevisano concerns the time required for them to meet again at the point of departure. An English translation of the problem is provided in Ulivi, “Masters, Questions and Challenges,” 658.

strictly pedagogical settings and highlights a concrete instance of interaction between learned culture and practical mathematical expertise.

3. *Abacus mathematics and scholastic knowledge*

Having established that abacus knowledge was not confined to the institutional premises of abacus schools, but that its actors were in contact with – and at times active within – arts faculties and mendicant circles, the groundwork is now laid for the next analytical step. This section draws explicitly on Murdoch’s characterization of medieval learning as porous, in order to examine how abacus mathematics can also be situated within a shared scholastic epistemic framework. To this end, I analyze three cases in which philosophical notions and doctrines are demonstrably present within abacus texts, thereby revealing a permeability between mathematical and philosophical domains. The first is drawn from Jacopo of Florence’s *Tractatus algorismi*, the second from master Dardi’s *Aliabraa argibra*, and the third from a geometric treatise by an anonymous Genoese teacher.

Very little is known about Jacopo of Florence. He is the author of one of the earliest extant abacus textbooks, the *Tractatus algorismi*, composed around 1307. Its editor, Jens Høyrup, places Jacopo between the late thirteenth and early fourteenth centuries and has suggested that he may have traveled to Montpellier to deepen his knowledge of abacus mathematics.⁶⁵ A closer examination of the prologue of the *Tractatus* allows us to identify the epistemic framework within which abacus mathematics was situated – one plausibly shaped by the intellectual environments of convents and universities. This line of inquiry is further supported by Høyrup’s observation that Jacopo’s *Tractatus* appears to originate from “an environment where scholars and mathematical practitioners were in contact.”⁶⁶

Signs of this intellectual provenance are evident in the introduction to the *Tractatus*, where Aristotelian distinctions are invoked and treated as shared background knowledge. Particularly emblematic is the distinction between natural and scientific knowledge, described respectively as “senno naturale” and “scienza accidentale”: the former depending on divine grace, the latter on human reason.

Conciossia cosa che tucte quelle cose che la humana generatione de questo secolo sanno et possono sapere, si fanno per duy principale vie, le quale vie sonno queste. La prima si è senno, et la seconda si è la scienza. E ciascheuna di queste due vie si à secho duy gentile et nobile compagne. L’una si è gratia di Dio. Et l’altra si è cognoscenza per ragione. [...] È vera cosa che l’omo po nominare lo senno et la scienza, l’uno senno naturale, et l’altro scienza accidentale.⁶⁷

⁶⁵ Høyrup, *Jacopo da Firenze*, 7; cf. Ulivi, “Scuole e maestri d’abaco,” 133.

⁶⁶ Høyrup, *Jacopo da Firenze*, 6 and 47.

⁶⁷ Jacopo of Florence, *Tractatus algorismi*, 1.2, in Høyrup, *Jacopo da Firenze*, 193–194.

The distinction between knowledge acquired naturally and knowledge acquired contingently is characteristic of scholastic epistemology. Rather than indicating direct dependence on a specific author, it reflects a widely shared conceptual framework. A close parallel can be found, for instance, in the work of the Florentine Dominican Remigius dei Girolami, a contemporary of Jacopo. Having studied in Paris during the years of Thomas Aquinas and later taught theology at Santa Maria Novella, Remigius authored the *Divisio scientie*, a text belonging to the genre of introductions to, and divisions of, philosophy.⁶⁸ Composed at the very end of the thirteenth century, likely for the Dominican studium, the *Divisio* reflects the scholastic culture transmitted from the Parisian university milieu.⁶⁹

In this work, Remigius rejects certain common classificatory schemes – such as the division between science of things and science of signs, or between speculative and practical science – and instead proposes a more fundamental distinction between knowledge derived from God and knowledge that is properly human. Philosophy and its branches, including mathematics, belong to the latter category and depend on human reason.⁷⁰

Such parallels point not to direct influence of Remigius on Jacopo, but to a shared pool of scholastic doctrines from which abacus practitioners could draw and within which abacus mathematics could be situated and understood. The broader division of knowledge thus functions as a received epistemic framework that legitimized mathematical practice. Its relevance is further confirmed by its recurrence in later abacus writings: Giovanni dei Danti di Arezzo, in his algorism treatise of 1370, adopts a comparable distinction, as does the anonymous author of the *Libbro delle ragioni d'abacho* (Florence, Biblioteca Nazionale Centrale, Conv. soppr., G.7.1137) at the end of the fourteenth century.⁷¹

A second case illustrating the presence of scholastic knowledge within abacus contexts is provided by another master, Dardi, and more precisely by his treatise entirely devoted to algebra, composed in vernacular around 1344 and translated into Hebrew by Mordecai Finzi in 1473.⁷² In the opening section of his *Aliabraa argibra*, Dardi introduces his treatise

⁶⁸ Panella, “Nuova cronologia remigiana” (online version: <https://www.e-theca.net/emiliopanella/remigio2/re1200.htm>); Gentili, “Girolami, Remigio de”; for Remigius within the conventual context of Santa Maria Novella, I refer to Pegoretti, “Lo ‘studium’ e la biblioteca,” especially 110–111.

⁶⁹ The *Divisio scientie* is edited in Panella, “Un’introduzione,” 27–126.

⁷⁰ Remigius dei Girolami, *Divisio scientie*, 2–3, in Panella, “Un’introduzione,” 83–85.

⁷¹ The text of Giovanni dei Danti di Arezzo is preserved in manuscript Florence, Biblioteca Medicea Laurenziana, Plut. 30.26. Jens Høyrup identified eight additional manuscripts from the fifteenth century that reproduce the same distinction, based on Jacopo’s introduction. These are not considered here, as they fall outside the chronological scope of the present study; see Høyrup, *Jacopo da Firenze*, 46.

⁷² Further details to situate Dardi can be found in Van Egmond, “The Algebra”; Franci, “The History of Algebra,” especially 182–185; and in the edition of Dardi’s work, that is, Maestro Dardi, *Aliabraa argibra*, 1–21.

tise by indicating four facets (*respettij*) of it: the title of the book, the author, the subject matter, and the utility.

Perché ongni libro che è fatto de' essere fatto per 4 respetti k primo sie lo titulo del libro, lo sicondo la intentione di coluj che chonpone, lo terso la materia dela quale elli tratta, lo quarto e ultimo l'utilità che seghue dell'opera.⁷³

While Jens Høyrup has plausibly connected these four elements to the four Aristotelian causes,⁷⁴ they are equally intelligible within the long-established tradition of the *accessus ad auctores* – the prefatory framework in which the title, author, subject matter, and utility of a text were discussed before its contents, a convention whose Latin lineage runs roughly from Boethius onward.⁷⁵ Besides this way of introducing his mathematical work, Dardi made his connection with the scholastic milieu clear when explicating the utility of his work, namely, to become a good geometer and arithmetician, whose speculative guises, he says, are ultimately part of natural philosophy.

L'utilità che seghue del libro, la quale utilità sie che quellj che intenderà bene le suoe regole sinprici e conposte sarà buon arismetico et etiandio geometro le qual cose specchulativamente sono parte di filosofia naturale.⁷⁶

While the inclusion of mathematical disciplines within natural philosophy does not find any direct correspondence in any scholastic divisions of philosophy, it is nevertheless meaningful that Dardi felt the need to specify that our understanding of nature, or rather, natural philosophy itself, encompasses mathematics.

The final case that spotlights the import of scholastic doctrines within abacus texts is the anonymous author of the *Tractatus super practicam geometrie*. Composed in Latin by a Genoese teacher and later translated into the vernacular, the text circulated in the fifteenth century through figures such as the Milanese Luca de Nigris, who was active in Genoa in 1455.⁷⁷ The introductory section of the *Tractatus* is particularly revealing, as it mobilizes a series of scholastic doctrines to frame the discipline of geometry. Four examples may be briefly highlighted.

First, geometry is defined as the science of static magnitudes, a formulation that clearly echoes Boethius' fourfold division of the mathematical sciences, in which geometry

⁷³ Maestro Dardi, *Aliabraa argibra*, 37.

⁷⁴ Høyrup, *The World of the Abbaco*, 231–232.

⁷⁵ For an overview of this practice, see Quain, “The Medieval *Accessus ad Auctores*.”

⁷⁶ Maestro Dardi, *Aliabraa argibra*, 37.

⁷⁷ Giusti, “Un trattato,” here 213–214 and 217 for the translation. Giusti provides the transcription of the text preserved in manuscript Vatican City, BAV, Vat. lat. 4606.

concerns immobile magnitudes, in contrast to astronomy, which studies magnitudes in motion.⁷⁸

Second, the treatise presents the objects of geometry and its specific kinds of magnitudes – lines, surfaces, and solids – as capable of being considered in two ways: either as embedded in matter or as abstracted from it. This distinction presupposes an Aristotelian conception of mathematical properties as subsisting within material things and of mathematics as a science grounded in abstraction, that is, in the cognitive process by which material entities are considered under their quantitative aspects alone.⁷⁹ Such a view, widely disseminated in university and mendicant contexts – as exemplified by Remigius dei Girolami's *Divisio scientie*⁸⁰ – can be understood as the received epistemic framework within which mathematical practice was situated. The Genoese author integrates this Aristotelian account with the Boethian classification of mathematical sciences in order to distinguish between two branches of geometry: a theoretical one, concerned with magnitudes insofar as they are abstracted from matter and motion, and a practical one, concerned with magnitudes as embodied and thus subject to change.⁸¹

A third doctrinal element concerns units of measurement. The smallest unit is identified with the atom, described as an indivisible corpuscle comparable to fine dust visible in a beam of light. While this description draws on ancient atomistic imagery, the insistence on the impossibility of actual division aligns with the prevailing Aristotelian rejection of atomism and resonates with scholastic discussions of *minima naturalia*.⁸² For the atom, specifies the Genoese, cannot be divided “in act,” and hence it can serve as the smallest unit of measure.⁸³ The atom, thus, functions not as a physical constituent in a

⁷⁸ *Tractatus super practicam geometrie*, in Giusti, “Un trattato,” 220 (hereafter *Tractatus*): “Geometria est sciencia figurarum immobilis magnitudinis secundum se, ad differenciam astrologie sive astronomie, que est sciencia de motibus magnitudinis mobilis.” Cf. Boethius, *De institutione arithmetica*, I, 1, 4, 7.

⁷⁹ On Aristotelian abstraction and its early reception in the Latin-speaking world through Boethius, see Crialesi, “The Status of Mathematics.”

⁸⁰ Remigius dei Girolami, *Divisio scientie*, 9, in Panella, “Un’introduzione,” 89–90: “Cum enim ars [mathematica] existens in materia sensibili abstractibilis tamen ab ea per considerationem sit quantitas [...] oportet quod mathematica sit de quantitate.”

⁸¹ *Tractatus super practicam geometrie*, in Giusti, “Un trattato,” 220–221: “Et quia contingit magnitudinem, scilicet lineam, superficiem et corpus dupliciter considerari, scilicet prout sunt in materia et prout intelliguntur abstracte sine materia, propter hoc geometria dividitur in theoreticam et practicam, quia secundum quod abstrahuntur sunt immobilia et de hiis determinat theoricam. Sed prout sunt in materia sunt mobilia, quia tactu variabilis rei permutatur Boetio testante, et de hiis determinat practica quia sensibilia sunt.”

⁸² I refer to Zambiasi, “The Doctrine of *minima naturalia*.”

⁸³ *Tractatus super practicam geometrie*, in Giusti, “Un trattato,” 222: “Hinc inde quatuor modi sive principales gradus sunt mensurandi terras et agros, videlicet attomus, punctus, uncia et pes. Quorum attomos indivisibilis est et dicitur ab a quod est sine et tomos quod est divisio, et sine

strict sense, but as a conceptual limit for measurement.

Finally, the treatise invokes methods of geometrical reasoning derived from Galen's *Tegni*: analysis (*resolutio*), synthesis (*compositio*), and dissolution of the definition (*diffinitiva*).⁸⁴ This reference suggests familiarity with the epistemological frameworks associated with the arts faculty, where such methods were discussed in commentaries on Galen.⁸⁵

The density of these scholastic references in the opening of the *Tractatus super practica geometrie* led its editor, Enrico Giusti, to question whether its author should be understood primarily as an abacus teacher well versed in scholastic learning or as a scholar engaged in geometrical inquiry typical of abacus circles. In either case, the text offers clear evidence of an attempt to frame abacus geometry within a structured epistemic context shaped by scholastic thought. Significantly, this framework was not retained in later transmission: the vernacular translator chose to omit the introductory section altogether, thereby setting aside its explicit philosophical grounding.

4. Conclusions

Returning to the initial research question, it is now possible to assess both the material reality and the intellectual significance of the exchanges under consideration, and to situate them within broader historiographical narratives concerning premodern scientific knowledge.

The evidence presented here shows that abacus teachers operated within learned environments traditionally associated with philosophical and theological training, thereby creating concrete sites of interaction rather than merely hypothetical points of contact. Particularly instructive are the cases of Jacopo of Betania at the arts faculty of the University of Bologna and of Lapo di Neri at the University of Siena. Both were authorized – and remunerated – to teach abacus mathematics at the university level while remaining active in urban pre-university abacus instruction. These examples indicate that abacus practitioners were not only integrated into academic settings but were also capable of preparing students for more theoretically oriented forms of mathematical learning within the arts curriculum.

divisione in hoc quod ponitur pro mensura, qui atomos est ad instar minimi pulveris seu sintirule qui consideratur in spera solis fulgente per fenestram. Et talle corpus nunquam potest actu dividi, quia igitur atomus appellatur.”

⁸⁴ Ibid., 222: “Et quia mensura recta et iusta est sub ordine et ratione et similiter omnis doctrina iuxta et recta, ut testat Galienus in principio *Tegni* cum dicit: Tres sunt omnes doctrine que ordine habentur, scilicet compositiva, resolutiva et diffinitiva; unde similiter modus triplex est, scilicet compositio, resolutio et diffinitio. Unde modus processus in hoc opere continetur sub aliquo istorum trium, sicut patebit inferius.”

⁸⁵ Ragland, “Knowing Diseases,” 172–173 and 183; see also Agrimi and Crisciani, “Medicina e logica.”

Alongside these figures stand individuals who were not primarily identified as mathematical practitioners but nevertheless contributed to the transmission of abacus knowledge. References to convent libraries and to mathematical works authored by friars point to such forms of interaction. Leonard of Pistoia, a Dominican at Santa Maria Novella, authored a *Mathematica* accessible to abacus practitioners through the convent's library, while Grazia dei Castellani, an Augustinian friar at Santo Spirito, produced a series of texts in abacus mathematics taken up by Vaiaio's disciple in the following century. Grazia, in particular, exemplifies the convergence of mathematical, philosophical, and theological interests, emerging as a figure operating at the intersection of multiple institutional and intellectual contexts: the university studium, the mendicant convent, and the abacus school. Such configurations give concrete expression to Zilsel's account of the erosion of social and epistemic boundaries in the late Middle Ages, enabling knowledge to circulate beyond its traditional domains. The emergence of abacus training and nomenclature within university settings is itself indicative of this process.

A closer examination of abacus texts further confirms that this tradition was not intellectually isolated. Its practitioners were aware of the scholastic culture of their time, and their works reflect this context. It is therefore neither incidental nor negligible that texts such as Jacopo of Florence's *Tractatus algorismi*, Dardi's *Aliabraa argibra*, and the *Tractatus super practica geometrie* incorporate Aristotelian and other philosophical elements. Jacopo articulates a division of knowledge that closely parallels widely accepted scholastic frameworks, such as that presented in Remigius dei Girolami's *Divisio scientie*. This interconnection – consistent with Murdoch's account of the porosity of late medieval learning – becomes even more pronounced in the Genoese geometrical treatise, where Aristotelian, Boethian, and Galenic doctrines inform the treatment of geometry, its objects, units of measurement, and methods of reasoning. Dardi, for his part, frames the contents of his algebraic treatise within the long-established philosophical practice of the *accessus ad auctores*.

Taken together, these elements suggest that philosophical resources were not external to abacus mathematics but could be mobilized to interpret and legitimize its procedures. The interaction between philosophical and mathematical knowledge in fourteenth-century Italy thus appears as a feature grounded in both the institutional configurations and the shared intellectual frameworks of the period. Abacus mathematics functioned as a form of *knowledge in use* within the university setting, acting as a hinge between practical training and more advanced, theoretically oriented disciplines such as astronomy/astrology. At the same time, scholastic knowledge was not merely external to this practice but actively mobilized by certain abacus teachers, who, at least in the fourteenth century, framed their subject matter through established philosophical and epistemological categories.

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Recording medical recipes: Surgeons and barbers in early modern Italy (c. 1450–1600)

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Abstract

The early modern period witnessed a notable rise in publications dedicated to learned surgery, yet manuscript evidence of surgeons' day-to-day practice remains scarce. The five manuscripts examined here offer fresh insight into the practice-based activities of Italian surgeons between roughly 1450 and 1600, highlighting an understudied aspect of their work: the recording of recipes and use of medications. After discussing the practical functions and tentative categorization of these surgical manuscripts, the essay explores the centrality of recipe collection as both a tool of practice and a medium for medical theory. It also analyses the types, forms, and purposes of remedies recorded, the epistemic domains they reflect, and their connections to contemporary pharmaceutical literature. Finally, the manuscripts' linguistic features reveal important clues about the sociocultural status of surgical practitioners. What emerges from the analysis is the centrality of pharmaceutical knowledge in surgical expertise and a variegated picture of early modern surgical practice, shedding light on actual knowledge-in-use across a diverse range of practitioners.

Keywords

surgeons, recipe collections, Italian manuscripts

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Recording recipes is an integral feature of early modern vernacular medical practice, and recipe collections represent by far the most prevalent type of manuscript medical sources. Yet this material has long been kept, as it were, in the “dungeons” of Italian libraries and archives, bespattered with “mould and dust” – to use Poggio Bracciolini’s outraged words in describing the pitiful state of the Quintilian manuscript he discovered in Saint Gall.¹ Only with the recent material and practice-oriented turn in the history of science have these documents begun to come to the limelight as windows to the tangible realities of healthcare practices in early modern Europe.² While progress has been made in mapping some of these collections, notably outside Italy,³ scholars continue to be daunted by their unwieldy profusion, wide dispersal, and frequent palaeographic impenetrability. As with other practical or artisanal manuals, handbooks, or *zibaldoni* discussed in this special issue,⁴ the absence of clear generic labels to encompass these medical manuscript sources has further complicated efforts at cataloguing or inventorying them.⁵ As a result, such materials are often misclassified, displaced, or simply absent from archival records. Two additional complications arise. Most of these sources are anonymous and/or undated, which prevents social historians of medicine from making precise, contextualized observations about situated medical practice. Only patience and chance occasionally yield epiphanic discoveries, such as the one below (Fig. 1):

¹ “plenum tamen situ, et pulvere squalentem ... in teterrimo quodam et obscuro carcere.” Poggio Bracciolini, letter to Guarino Guarini (d. 1417). Poggi, *Epistolae*, 29.

² Interest in medieval and early modern recipe-books has increased significantly in the last decades, but a comprehensive understanding of the recipe-book genre is still warranted. On this limited understanding, see Crisciani, “Ricette e medicina: tre zibaldoni nel Quattrocento,” 11–12; Cifuentes, “El receptari mèdic,” 105–107; Lacanale, “Le ricette per gli occhi nel ms. 1408 della Biblioteca Statale di Lucca,” 287–309, (esp. 287–288).

³ The most substantial corpus-based research to date has been conducted on British materials. For an overview, see Leong and Rankin, *Secrets and Knowledge in Medicine and Science*, and the essays in Leong and Rankin, “Testing Drugs and Trying Cures.” For recent works on women’s central role in early modern health, see Strocchia, “Introduction: Women and Healthcare in Early Modern Europe,” and Rankin, *Panacea’s Daughters*. See also Leong, *Recipes and Everyday Knowledge*. However, Italian collections have yet to receive comparable systematic attention. For a bibliography on edited Italian *ricettari*, see Crisciani, “Ricette e medicina: tre zibaldoni nel Quattrocento,” 26–28, and Lemme, “Ricettari medici: il caso del ms. 215 della Biblioteca Classense di Ravenna,” 125–137, (esp. 127–128).

⁴ On this written technical literature, circulating in manuscript and print since the late fifteenth century, see Smith, *From Lived Experience to the Written Word*, esp. 91–116. See also Long, *Artisan/Practitioners and the Rise of the New Sciences, 1400–1600*, and Morel, *Underground Mathematics*.

⁵ In Italian archives and libraries, the catch-all label used is “ricettario” or “segreti” without distinguishing epistemic category (technical, alchemical, medical, etc.) or any other typological or generic criteria.

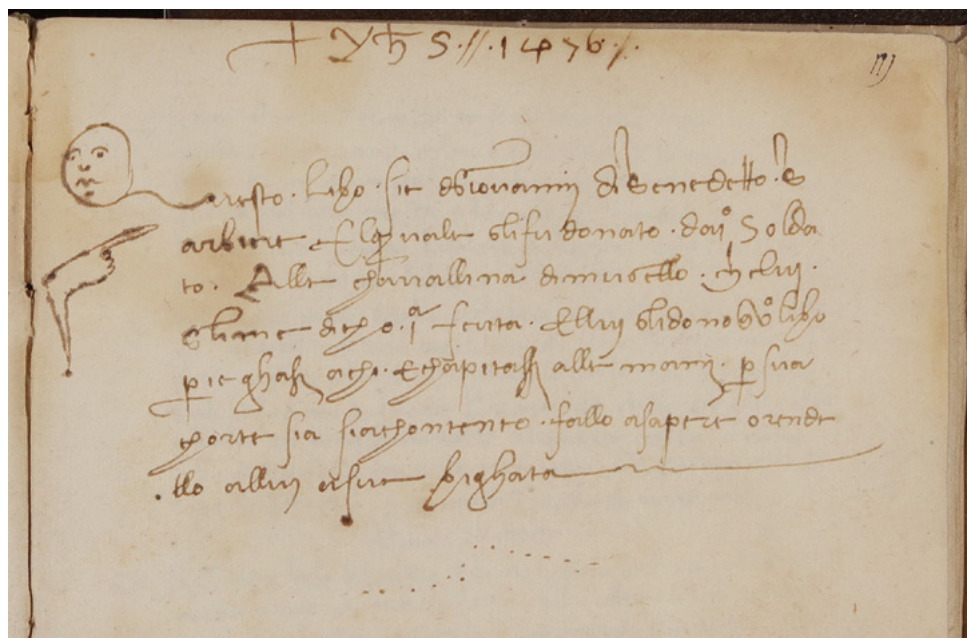


Fig. 1 – BNCF, Magliabechiano XV 76, flyleaf indicating ownership and date. Courtesy of the Biblioteca Nazionale Centrale di Firenze, Ministero della Cultura.

Questo libro fu di Giovanni di Benedetto barbiere el quale gli fu donato da un soldato alla chavalina di Mugello, che lui gli medicò una ferita [...]⁶

(This book belonged to Giovanni di Benedetto, a barber, to whom it was given by a soldier at the Cavalina of Mugello, whose wound he treated.)

The possession note in what has otherwise been catalogued as an anonymous manuscript is a promising finding: it shows that this collection was kept and presumably used by a rural barber in the Mugello region outside Florence.⁷

⁶ Biblioteca Nazionale Centrale di Firenze (hereafter BNCF), Magliabechiano (hereafter Mag.) XV 76 (flyleaf).

⁷ The possession note in mercantesca script appears after the initial folio (which bears only the inscription “ricettario” and “anon.”), making it likely that the identity of the owner should go unnoticed. The catalogue likewise indexes the manuscript as “ANON., *Diverse ricette di medicamenti et Segreti Alchimici, Cosmetici, superstiziosi etc.* ac. A. 1468” (Targioni Tozzetti, *Catalogo generale*, vol. 5, 116).

Findings such as this are rare, but not altogether exceptional.⁸ This chapter examines this and four other sixteenth-century vernacular handbooks authored or owned by surgeons and barbers, exploring how recipes and cures were recorded and how these texts functioned as operational artifacts in early modern medical practice, particularly in treatment and medication. Surgeons represented a broad category of practitioners who operated within, outside, or on the margins of guild structures in early modern Italy. Specializing in external conditions such as sores, wounds, fractures, and dislocations, and the treatment of specific ailments, their work was integral to healthcare provision. While more attention has been granted to surgery in the last years, concrete evidence of surgeons' day-to-day practices remains profoundly scarce.

The documents presented here, in this preliminary analysis, resist being subsumed under a coherent genre or typology but are nonetheless invaluable as evidence of surgeons' situated practice. For lack of a better category, I refer to them as surgeons' books or notebooks, although each represents a *unicum* in terms of its pragmatic, functional, and discursive features. This variety reflects, as I will argue, the heterogeneity and fluidity of the category of "surgeon" in early modern Italy – not only in terms of professional credentials and knowledge-in-use, but also of training and social standing. Despite their diversity, the recording of medical recipes is a common denominator across all the manuscripts, whether as full, self-contained collections or as hasty marginal notes. This points to the centrality of medication within surgeons' diversified range of practices and raises questions about the articulation and adaptation of medical theory and practice.

Early modern surgery and surgeons' writings

Viewed as the third instrument of medicine, alongside diet and medication, as Tomaso Garzoni explains in his *Piazza Universale*, surgery required the use of the hand ("col mezzo della mano") on the body.⁹ In early modern Italy, however, the title of surgeon encompassed "very different kinds of practitioners," including barbers, bonesetters, empirics, specialist operators, and academically trained physicians, as Paolo Savoia notes in the case of Bologna.¹⁰ This diversity reflects the broader configuration of the field. As Sharon Strocchia observes, surgery "spanned a wide array of people, practices, and institutions,"

⁸ Stolberg has discussed a handful of cases drawn from his research in forty archives across Austria, Germany, and Switzerland (Stolberg, "Surgical Training and Practice"), as well as the Bohemian physician Georg Handsch's notes (Stolberg, "Empiricism in Sixteenth-Century Medical Practice.") Examples of casebooks in British collections have likewise been examined; see, for instance, Beier, "Seventeenth-Century English Surgery," and Kassell, "Casebooks in Early Modern England." For Italy, the only study of which I am currently aware is Strocchia, "Notes from the Front."

⁹ Garzoni, *Piazza Universale*, f. 50r.

¹⁰ Savoia, "Skills, Knowledge, and Status," 27–54 (esp. 33).

ranging from university-educated practitioners to barbers, bathhouse attendants, and specialists treating conditions such as hernias, fractures, or cataracts.¹¹ While apprenticeship remained a central mode of training, the later sixteenth century saw increasing competition for professional standing between empirically trained practitioners and those seeking advancement through academic medicine.¹²

At the same time, the boundary between surgery and learned medicine remained fluid.¹³ As Kristy W. Bowers remarks, “the boundary of physic and surgery was indeed a moving target.”¹⁴ Historians have therefore cautioned against treating the two as rigidly separate domains, especially in the sixteenth century. In the Venetian context, for example, Richard Palmer showed in a pioneering study that “the divisions between physicians and surgeons have been exaggerated,” emphasizing instead “the close connexion between the two branches of the profession in daily medical practice.”¹⁵ Recent studies have highlighted interactions and tensions between surgeons and “anatomists, physicians, and natural philosophers.”¹⁶ Surgery was both a craft transmitted through apprenticeship and part of the broader tradition of learned medicine, requiring theoretical knowledge alongside practical skill.¹⁷ Meanwhile barbers continued to provide primary care in urban and rural settings,¹⁸ and itinerant specialists – *cursores* or *restauratores* – performed major operations such as cataract couching or hernia repair,¹⁹ often populating the ranks of so-called “char-

¹¹ Strocchia, “Notes from the Front,” 10.

¹² On the early academic teaching of medicine in Italian universities, see Siraisi, *Medieval and Early Renaissance Medicine*, 153–158; and McVaugh, *The Rational Surgery of the Middle Ages*. On the image of the learned surgeon in early modern Italy, see Savoia, “Skills, Knowledge, and Status,” 33–35. For the complex relationship between barbers and surgeons, extending to actual terms used to describe them, see Decamp, *Civic and Medical Worlds in Early Modern England*, 7–19.

¹³ On the sixteenth-century Italian *Protomedicati* and Colleges of Physicians and their (only partially successful) attempts to enforce a threefold partition of the medical professions – graduate physicians, apothecaries, and barber-surgeons, see Savoia, “Skills, Knowledge, and Status,” 31, and Gentilcore, “All That Pertains to Medicine,” 121–142 (esp. 123–127). On *matricolati* surgeons in Florence, see Cipolla, *Public Health and the Medical Profession*, 70–73.

¹⁴ Bowers, *Renaissance Surgeons*, 1.

¹⁵ Palmer, “Pharmacy in the Republic of Venice,” 460. On the relationships between physicians and surgeons, see Cavallo, *Artisans of the Body*, esp. 16–18. For the multiple career paths for surgeons, see Bartolini, “On the Borders: Surgeons and Their Activities in the Venetian State (1540–1640),” 83–100.

¹⁶ Bertoloni Meli and Klestinec, “Renaissance Surgery,” 4.

¹⁷ McVaugh, “When Universities First Encountered Surgery,” 19.

¹⁸ See Garzoni, *Piazza Universale*, (“De’ Barbieri” Discorso CXL, ff. 369r–370r), who lists among the barber’s tasks “la politezza del corpo,” “cavar sangue a gli amalati,” “mettergli le ventose,” “medicarle le ferite,” “far le stoppate,” “cavare i denti guasti et simile altre cose” (f. 369v); on “malicious” barbers, see also f. 262v.

¹⁹ Bertoloni Meli and Klestinec, “Renaissance Surgery,” 3.

latans,”²⁰ a phenomenon that illustrates the wide range of contexts in which surgical expertise circulated.²¹ The sixteenth century witnessed great mobility of surgical practitioners across technical and scholarly domains, as well as guild-regulated and informal settings.²²

The early modern period also saw a marked increase in publications devoted to learned surgery, including well-known medieval Latin manuals, vernacular translations, and new practical texts, many of which reached print.²³ However, manuscript records documenting surgeons’ actual practice remain remarkably scant.²⁴ The five manuscripts presented here shed new light on the practice-based dimension of a range of early modern Italian surgeons, illuminating a largely unexplored aspect of their profession: the record of recipes and medication.²⁵ As will be discussed below, these manuscripts do not easily fit into a single, coherent category. Some bear a loose resemblance to the late sixteenth- and seventeenth-century “casebooks” examined by Kassell – broadly defined as “serial records of practice,”²⁶ modeled on “practices of keeping diaries, commonplaces and observations, testimonials, or administrative registers”²⁷ – as well as to the late-Renaissance genre of *ob-*

²⁰ See Gentilcore, (*Medical Charlatanism*, 98) who notes that in Florence’s Guild of Physicians, Apothecaries, and Grocers, physicians, surgeons, barbers, apothecaries, and charlatans were registered alongside painters, comic actors, ballad-singers, mask-makers, booksellers, chapmen, perfumers, haberdashers, and numerous other groups.

²¹ Bertoloni Meli and Klestinec, “Renaissance Surgery,” 2.

²² See Garzoni’s jarring remark on this phenomenon: “Non è vero, ch’essi talvolta da puri barbieri diventano dottori in Chirurgia?” (Garzoni, *Piazza Universale*, 70v).

²³ Traditional medieval surgical authors whose works were circulated and translated into the vernacular include Guy de Chauliac, Bruno da Longobucco, Guglielmo da Saliceto, Pietro d’Argellata, alongside sixteenth-century authors such as Berengario da Carpi, Giovanni de Vigo, Jean Tagault, Leonardo Fioravanti, and the Venetian surgeon Giovanni Andrea della Croce (1515–1575), who published Latin and vernacular texts. For these and other references, see Klestinec, “Translating Learned Surgery,” 36–39; McVaugh, “When Universities First Encountered Surgery,” 16–19; and Castiglioni, *A History of Medicine*, 470–484, for a full list of famous Renaissance surgeons and main publications.

²⁴ Cf. Strocchia, “Notes from the Front,” 3, who notes that “numerous casebooks kept by early modern physicians have come to light, but comparable sources penned by empirical surgeons remain few and far between.” Also, Stolberg, “Surgical Training and Practice,” 77, writes “first-person accounts by surgeons or their patients, practice journals, casebooks, patient lists, and similar sources... are hard to find”; Cavallo, “Learning to Dress Wounds,” 84, calls them “unfortunately a rare source.”

²⁵ As this essay was under review, the excellent volume *Learning to Cut*, edited by Donato, Leong, and Taape, has appeared. I warmly thank Sandra Cavallo for sharing a draft of her essay and for our discussion on the striking convergence of our conclusions, reached independently and simultaneously on different archival materials.

²⁶ See Kassell, “Casebooks in Early Modern England,” 600; Jalobeanu, “The Toolbox of the Early Modern Natural Historian.”

²⁷ Kassell, “Casebooks in Early Modern England,” 615.

servationes studied by Gianna Pomata.²⁸ However, unlike published or publishable “case-books” and *observationes* largely authored by physicians, the five manuscripts analyzed here attest to the *private* empirical and cognitive practices of a *broad spectrum* of surgeons, not limited to elite learned ones, and represent unvarnished, straightforward records of practice.²⁹ More precisely, some of them closely align with the long-standing traditions of recipe collections, *segreti*, and technical know-how literature, though not all fully conform to this genre either.³⁰ What unites them, however, is the centrality of recorded cures, which constitutes the key focus of this chapter.

In what follows, I address (1) the pragmatic functions of the individual manuscripts and the typologies of medical literature to which they can be assigned; (2) the recording of recipes as a central feature of surgical handbooks and a site for articulating medical theory and practice; (3) the types, modalities, and functions of recorded remedies, the key epistemic domains they represent, and their relationship to mainstream pharmaceutical literature; and (4) the linguistic features of the surveyed manuscripts as evidence of the broader sociocultural positioning of surgical practitioners.

Surgeon’s manuscripts: notebooks, handbooks, and recipe-collections

The selected manuscripts may be regarded as notebooks, handbooks, and/or recipe collections, depending on their most salient individual characteristics – although no single label applies to all of them.³¹ Two important features, however, bring them together: first, they were all authored, owned, or annotated by a practicing Italian surgeon; and second, they all contain medical recipes to varying degrees. Some of them even include precise

²⁸ See Pomata, “Sharing Cases,” 193–236 (esp. 194–199).

²⁹ See similar observations in Strocchia, “Notes from the Front,” 8, in reference to Nardi’s case-book, also included in this corpus.

³⁰ The recipe is a form of writing with ancient roots, commonly found in artisanal, alchemical, and medical texts. For a classification of medieval medical recipes, see Hunt, *Popular Medicine*, 16, updated by Zarra, *Il “Thesaurus pauperum” pisano*, 4–5. For a review of this genre, see Cifuentes, “El receptari mèdic baixmedieval i renaixentista,” 103–160, and Leong, *Recipes and Everyday Knowledge*. Gianna Pomata has proposed that late medieval and early modern recipes constitute an “epistemic genre,” a literary form that both embodies and shapes a “cognitive project” (Pomata, “Sharing Cases,” esp. 196–197). On the relationship between recipes and cases as epistemic genres, see Pomata, “The Recipe and the Case,” 131–154. On secrets literature and the rhetoric of secrecy in craftsmanship, see Eamon, *Science and the Secrets of Nature*, 16, and id., “How to Read a Book of Secrets,” 23–46; Smith, “What Is a Secret?,” 47–66, and id., *From Lived Experience to the Written Word*, 118–120.

³¹ On the complex typological or generic categorization of these texts spanning various dichotomies, theoretical/practical, pure/applied, mind/hand, learned and artisanal, see Roberts and Schaffer, *The Mindful Hand*, xiii–xv (“Preface”).

dates of composition or circulation; some provide the exact name of its author or holder. The latter is extremely rare, especially within the broader context of largely undated and unattributed medical collections in Italian libraries and archives.

The first manuscript, in approximate chronological order, is the one introduced by the possession note that opened this chapter: Magliabechiano XV 76 (hereafter Man. A). It is a late fifteenth-century collection of recipes owned by “Giovanni di Benedetto, barbiere,” who, as stated on the flyleaf, received it from a soldier whom he had treated for a wound.³² The collection consists primarily of herbal remedies, but also recipes containing animal products and minerals, as well as a number of alchemical recipes, incantations, and charms.

The second text, Palatino 1068 (hereafter Man. B) is a miscellaneous mid-sixteenth century manual of surgery and medicine, compiled for professional use and regularly updated.³³ Although it bears no identifiable name, the manuscript was unmistakably owned and annotated by a learned surgeon. It contains an apparently original core,³⁴ alongside material derived from contemporary authors. Later additions include marginal notes and medical recipes – some written in the vernacular – dated 1516.³⁵ The main text, largely in Latin, focuses on wounds, injuries, ulcers, and fistulas. After a general introduction, the work presents about seventeen unnumbered articles on surgical theory and practice. Early sections reflect influence from Pietro d’Argelata’s *Chirurgia*, first published in Venice in 1480. This original core sections concludes with appendices of practical notes and citations of late medieval surgical authorities. The rest of the manuscript includes snippets from Pietro d’Argelata’s *Chirurgia*, especially on the treatment of wounds, fractures, contusions, and skin diseases, accompanied by numerous recipes.³⁶ The rest of the manuscript transcribes sections from Michele Savonarola’s *Practica Maior* and Nicolò Falcucci’s *Elementi di Chirurgia*.³⁷

The third manuscript, Wellcome MS 174 (hereafter Man. C), is a surgeon’s handbook produced near Verona and consisting largely of medicinal recipes. The cover bears a pen-drawn coat of arms belonging to the author. Inside, an inscription records: “Questo libro sie di M^o Gasparo barbiro e ceroicho...,” identifying the writer as Gasparo, son of Maestro Antonio, from Legnago, and noting that the book was written on 15 August 1529. The manuscript contains numerous recipes, descriptions of diseases and treatments, and is illustrated with small marginal pen drawings of diseased organs and surgical instruments. Folios

³² BNCF, Mag. XV 76. The original composition date is 1468 (at f. 39v); the later 1476 date appears on the flyleaf.

³³ For a fuller codicological description, see Rambaldi and Saitta Revignas, *I manoscritti Palatini*, Vol. III. Fasc. 1, 73–76.

³⁴ BNCF, Palatino (hereafter Pal.) 1068, ff. 2–47v.

³⁵ The date 18 May 1516 appears after the incipit of a recipe “Aqua bona et oleum pro vulneribus et ulceribus.” BNCF, Pal. 1068, f. 50v.

³⁶ Ibid. ff. 53r–142r.

³⁷ Ibid. ff. 145r–172v and ff. 208r–219v respectively.

24v–32 include a Latin–Italian list of plant names. Family notes are also recorded: the birth and baptism of the author’s son, Zuan Antonio (1530, Verona), appear on the final leaf, while the inside cover mentions the birth of a daughter, Chatalina, on 14 November 1527.

The fourth manuscript, Magliabechiano XV 19 (hereafter Man. D), is a sloppy and difficult-to-read personal notebook belonging to a barber-surgeon from Montelupo, “Maestro Daniello di Biagio di Becossi,” as recorded on the flyleaf and dated 1576.³⁸ As archival records show, Becossi had been granted a license by the Florentine College of Physicians on 21 July 1571 to perform basic operations pertaining to a barber-surgeon.³⁹ Unlike the other manuscripts, this is a distinctly private notepad, containing an unsystematic profusion of annotations of all kinds. These include repeated notes on family matters, rudimentary genealogical sketches, transcriptions of contracts, *ricordi*, personal affairs, and miscellaneous jottings, all interspersed with medical recipes and brief therapeutic observations.

The fifth manuscript, Magliabechiano XV 142 (hereafter Man. E), belonged to Giovanni Battista Jacopo Nardi da Montepulciano, a surgeon at the Hospital of San Giovanni, known as “di Bonifazio,” in Florence.⁴⁰ Begun in 1582, the manuscript records personal observations, clinical cases drawn from Nardi’s practice in the hospital’s *medicheria*, and a wide range of medicinal recipes. It also includes various “secrets,” such as metallurgical procedures and instructions for the fabrication of military equipment. This manuscript has recently been studied by Sharon Strocchia, whose insightful analysis informs much of the discussion of this text.⁴¹

As this cursory review of the corpus suggests, these manuscripts resist classification within a single, clearly defined category. They fulfilled multiple functions, and each case presents its own specific configuration. Medical theory (*magisterium*) and practice (*ministerium*) are articulated in different ways across the manuscripts; overall, however, the practical dimension tends to prevail over the theoretical. Amid such functional and formal diversity, one shared feature stands out: all these manuscripts, to a greater or lesser extent, record medical recipes, with a notable predominance of prescriptions for external cures. While the recording of recipes constitutes a defining characteristic, these manuscripts also

³⁸ The word “montelupo” is inserted in the interlineal space between the third and fourth line on the flyleaf, but also reappears on folio 13v in what seems to be the transcription of a letter addressed to Cosimo I “serenissimo granduca” in 1568.

³⁹ Biblioteca Biomedica dell’Università degli Studi di Firenze. Registro del Collegio Medico A, f. 62r, dated 21 July 1571. The licence expressly notes the limited scope of surgical activities authorized to the candidate by the examining physicians: “mettere chane,” “cavare denti,” “trarre sangue con licentia del fisicho,” and “medicare ferite semplice.” On these examination procedures, see Ciuti, “Il Collegio dei fisici e l’Arte dei medici e speziali di Firenze,” 3–28 (esp. 22–23) and Baldanzi, “Regolamentazione tra professionisti medici e speziali,” 163–170 (esp. 164).

⁴⁰ On Nardi’s career, see Strocchia’s detailed account, “Notes from the Front,” 4–7.

⁴¹ Strocchia, “Notes from the Front,” 19–21. The author deals summarily with recipes in a final section.

serve a range of additional purposes, again to varying degrees. These include functioning as personal memoranda or *ricordanze*, sometimes indicating the place of professional activity as well as recording family or private matters (such as births and genealogies);⁴² documenting the date of composition or the provenance of the compilation, particularly in cases of inheritance or gift; preserving evidence of medical practice, for instance in the form of casebooks that register patients, symptoms, diagnoses, treatments, and outcomes; and transmitting medical and surgical knowledge through treatises or excerpts from learned sources. Finally, as will be explored below, these manuscripts also provide a platform for recording practical or “how-to” knowledge beyond what is typically regarded as “medical” (in our modern understanding). This includes, for example, the properties of herbs, elements of astrological and alchemical learning, and descriptions of distillation apparatuses – thus fulfilling a function closely aligned with that of *secreti* literature.

A wealth of recipes: format, typology, and scope of medical knowledge

Whereas recipes appear in all five manuscripts, the organizational criteria, distribution, and spatial arrangement vary significantly across the corpus. This diversity can be explained partly by the overlapping functional purposes described above. Manuscript A is the only one that can be straightforwardly described as a traditional “ricettario,” consisting exclusively of recipes for a wide range of medical conditions, not limited to surgical or external treatments. Sequentially recording recipes without a discernible pattern – whether by remedy-type, part of the body, disease or intended effect –,⁴³ the collection lacks any specificity. The fact that it was owned by a barber-surgeon may point to the broad range of competences expected of a rural practitioner who, in the absence of a physician, may have been called upon to offer general primary care.

Manuscript C, although primarily a collection of recipes, is more extensive and incorporates a wider variety of material. In order to enhance readability and facilitate consultation, it employs a number of paratextual devices, such as alphabetical tables and clearly marked recipe titles (“Tavola da trovare le infrascritte recete,” “Questi sono certi simplici et erbe,” “A trovare le recete del secondo libro”).⁴⁴ (Fig. 2) This not only suggests a high-level of literacy on the part of its compiler, but also reflects the influence of humanist

⁴² Most notably, Manuscript D, but also Nardi’s casebook (manuscript E) includes some personal *ricordanze* regarding purchases (ff. 78v–179r) and Manuscript C includes on the verso of the last leaf a note of the birth and baptism, in 1530 at Verona, of the author’s son “Zuan Antonio.” In the inscription inside the upper cover, the birth of a daughter “Chatalina” on 14 November 1527 is also mentioned.

⁴³ On the main organization criteria for pharmaceutical literature and recording of remedies, see Basile, “Recording Remedies,” 117–118.

⁴⁴ Wellcome MS 174, ff. 1r, 58, and 80, respectively.

educational practices and reading habits, which were rapidly disseminated through the advent of print.⁴⁵ Similarly, these features signal the manuscript as a consultation manual, both a repository of pharmaceutical knowledge and a *vade mecum* for therapeutic practice. A comparable strategy is adopted by Nardi in Manuscript E, where the contents are signposted at the end of the volume (“Tavola di tutto quello si contiene nel presente libro cominciando prima delle cure che verranno nello spedale”)⁴⁶ – which a later hand expanded with new entries recording recipes added to the original compilation.⁴⁷ (Fig. 3) Unlike Manuscript C, however, Nardi’s book has a more miscellaneous and impromptu character, often alternating patient records, recipes, and other medical material. In turn, the Veronese surgeon’s collection, bound in vellum with leather ties, exhibits the features of a more carefully structured compilation – one intended for sustained consultation and possibly for transmission as a kind of professional “testament” to subsequent generations (as the gifted Manuscript A). Whether in the form of a closed, final collection as Manuscript C or as an open notebook receptive to ongoing additions (Nardi’s book),⁴⁸ both manuscripts serve as practical manuals for surgeons, with a special focus on medication.

Manuscript D, in turn, records recipes in a seemingly random manner, often filling blank spaces between personal annotations – such as property deeds, records of payments, transcriptions of letters, and *ricordi* spanning several generations (Fig. 4). These recipes take the form of hasty, synoptic *aide-mémoires*, typically listing only a few ingredients without measurements or procedures. They appear without any evident organizational logic and only occasionally coalesce into more defined sections (e.g. “virtù di più olii”).⁴⁹ Manuscript B also fills up blank spaces with Latin recipes in a rather cursory way, but in most cases the latter serve as a form of an offhand “commentary” to the Latin surgical literature transcribed, often to complement the information in the body of the text.⁵⁰ (Fig. 5)

⁴⁵ See Basile, “Recording Remedies,” 113–144. On the rise of the index in the humanist milieu, see Enenkel and Nellen, *Neo-Latin Commentaries and the Management of Knowledge*, 54–57; and Blair, *Too Much to Know*, 144–152. For a discussion of the proliferation of tables and alphabetical indexes with printing, see Blair and Patton, “A Quantitative Study of the Paratexts in Erasmus-Froben Imprints,” 99–181, esp. 101–102.

⁴⁶ BNCF, Mag. XV 142, f. 172r and ff. 174r–175r.

⁴⁷ *Ibid.*, ff. 175r–178r.

⁴⁸ On this distinction, see Basile, “Recording Remedies,” 121, with bibliographical references.

⁴⁹ BNCF, Mag XV 19: “virtu di piu olii” (ff. 4v–5r); “unguento di cerusa,” “unguento rosato” (f. 7v), “al mal di poppe” (f. 9r); “per rompere un ferro in 2 ore” (f. 10v), “unguento da rogne” (f. 11r); “al mal caduto” (f. 12r); “cura del cancro,” “alla milza,” “per disicare le lacrime” (f. 21r).

⁵⁰ In various sections marginal commentaries are flagged with the phrase “Nota quod” (e.g., ff. 11r, 15v, 17v, 34r–v, etc.); various medical authorities are cited throughout: Galen (e.g., ff. 12r, 15r, 16v, 35r, etc.) Rasis (f. 48v), Montagnana (f. 41r), Dino del Garbo (f. 16r), alongside contemporary physicians, like Nicolus Florentis (f. 35v, 63v), Agustinus de Urbino (f. 49r), Bartolomeus de pisteria cirurgicus (f. 49r), Nicolaus Bastarius delporta (f. 76v), etc. While most

1065/48527

Tavela darrouaze le infza faire recete

Prima afa aqua da feride	achaz	.i.
Cezero p la rista	achaz	.i.
Cezero chapirali	achaz	.i.
Afaldaze una piaga	achaz	.2.
Al mal de uermi	achaz	.2. 3. 8. 11. 22. 41.
Aguarize le fudole et le uer	achaz	.2. 1. 8. 10. 20.
Al mal de fmitza	achaz	.2. 7. 11. 39.
A delie et mal frangoso	achaz	.2. 4. 12. 50. 61. 62.
Al mal de la pveda	achaz	.2.
Ali dizoni et le uer	achaz	.2.
Al mal de la fenza zin	achaz	.2.
A una delia	achaz	.2.
Ala rioma	achaz	.2.
A delie do corpo	achaz	.2.
Afaldaze una piaga	achaz	.2. 29. 3. 63. 65. 67. 8. 14. 16. 41. 1.
Al mal de corpo	achaz	.2.
Aguarize le fudole	achaz	.2.
Al mal dela cholicha	achaz	.3.
Adi auele mazgo chole unuoso	achaz	.3.
Adi auele la fela mazaia	achaz	.3. 5. 39. 42. 4.
Al mal deli odoi	achaz	.3. 7. 11. 40. 47. 75.
Al mal de uerui	achaz	.3. 44.
Al mal deli uerui	achaz	.3.
Al mal dela pveda	achaz	.3.

Fig. 2 – Wellcome Library, MS 174, no folio number. Beginning of the table of contents. Courtesy of the Wellcome Library.

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Tavola di tutto quello si contiene nel presente libro cominciando
 da prima delle cure & uerranno nello spedale
 Impresa adi 28 di Maggio 1582

una cancrena nel codrone car i	Donne
in finzioni _____	car i Sono di
fonte quattri una nella destra del	
otto laterale prepolacomm. Hum	car i Sono
et una dal altra banda	
una nella coliccola	
et l'altra alla fronte della	
parte destra _____	car i Sono
una cancrena ouer creste nel prepurio	car i Sono
una cancrena nella borsa et nel	
membr _____	car i Sono
due priumi _____	car i Sono
una fenta nel filo delle reni _____	car i Sono
una rottura di gotta _____	car i Sono
de taroli _____	car i Sono
doke di mel francese alla natura	car i Sono
doke galliche alla poppe _____	car i Sono
belke coeste _____	car 3 Sono cinque
duar empiuta _____	car 3
del Medico di S. Ruffinazione	
della flegma empiuta di S.	
auro d'empella flegma des	car 3 Sono
d'una rpa fredda nella gla	car 3 Sono

Fig. 3 – BNCF, Magliabechiano XV 142, f. 172r. Folio containing the beginning of the table of contents with corresponding page numbers. Courtesy of the Biblioteca Nazionale Centrale di Firenze, Ministero della Cultura.

tio procedente tñ p[er]sideratioe h[uius] sup[er]
 b[un]d[is]tis t[er]m[in]is. Iuxta i[n] fistula magis h[ab]et
 d[icitu]r f[er]a locu[m] est albu[m] cuius q[ui]s d[icitu]r albu
 m[us] ex p[er]u[er]is nudis. i[n] n[ost]r[is] m[ed]ic[is]
 n[on] d[icitu]r qualibet loq[ui] subiecti. et d[icitu]r n[ost]r[is]
 coloris et put[er]idinis. Cu[m] aut[em] sup[er] b[un]d[is]tis f[er]a
 locu[m] est albu[m] et molle q[uod] p[er]u[er]is q[uod] m[ed]ic[is] m[us]
 stula est aliquantulu[m] co[n]tra et albu[m] et molle q[uod]
 t[er]m[in]is. Si m[ed]ic[is] locu[m] linc[et] et t[er]m[in]is ad n[ost]r[is]
 d[icitu]r q[uod] d[icitu]r d[icitu]r et p[er]u[er]is linc[et] ut m[us]
 g[er]it. Si d[icitu]r color locu[m] co[n]tra et ibi p[er]
 tes et m[ed]ic[is] f[er]a et p[er]u[er]is co[n]tra et t[er]m[in]is
 Si n[on] illud q[uod] co[n]tra b[un]d[is]tis f[er]a sanguis t[er]m[in]is
 locu[m] rubet uene q[uod] co[n]tra et p[er]u[er]is et p[er]u[er]is
 sanguis co[n]tra f[er]a. Co[n]tra f[er]a q[uod] d[icitu]r m[ed]ic[is]
 p[er]u[er]is q[uod] d[icitu]r d[icitu]r ut p[er]u[er]is ut
 alie m[ed]ic[is] f[er]a p[er]u[er]is et si p[er]u[er]is f[er]a
 debilis q[uod] d[icitu]r ut p[er]u[er]is ut p[er]u[er]is
 p[er]u[er]is cu[m] m[ed]ic[is] q[uod] d[icitu]r t[er]m[in]is et p[er]u[er]is
 zuberis p[er]u[er]is et d[icitu]r p[er]u[er]is et p[er]u[er]is
 talis p[er]u[er]is f[er]a et p[er]u[er]is et p[er]u[er]is
 alie et p[er]u[er]is p[er]u[er]is p[er]u[er]is b[un]d[is]tis
 i[n] co[n]tra b[un]d[is]tis f[er]a. i[n] alie op[er]e
 co[n]tra i[n] p[er]u[er]is ut m[us] et b[un]d[is]tis alie
 ut una op[er]e q[uod] m[ed]ic[is] id q[uod] m[us]

Ad fistulas et ulcers d[icitu]r f[er]a m[ed]ic[is] p[er]u[er]is
 cap[er]is at m[ed]ic[is] p[er]u[er]is alie et p[er]u[er]is m[us]
 alie p[er]u[er]is m[us] et p[er]u[er]is p[er]u[er]is d[icitu]r
 b[un]d[is]tis m[us] alie et p[er]u[er]is m[us] b[un]d[is]tis m[us]
 f[er]a et si m[us] f[er]a p[er]u[er]is alie f[er]a alie
 f[er]a et p[er]u[er]is p[er]u[er]is et p[er]u[er]is f[er]a
 d[icitu]r f[er]a m[us] et p[er]u[er]is et p[er]u[er]is

qualitate remanet i[n] corpore q[uod] p[er]u[er]is Co[n]tra
 m[us] d[icitu]r p[er]u[er]is loq[ui] ut alie p[er]u[er]is
 m[us] d[icitu]r p[er]u[er]is m[ed]ic[is] q[uod] d[icitu]r p[er]u[er]is
 d[icitu]r p[er]u[er]is i[n] co[n]tra b[un]d[is]tis f[er]a
 q[uod] d[icitu]r alie op[er]e q[uod] d[icitu]r ut et p[er]u[er]is
 ut m[us] d[icitu]r Co[n]tra co[n]tra p[er]u[er]is m[us]
 zuberis cu[m] p[er]u[er]is d[icitu]r co[n]tra i[n] p[er]u[er]is
 p[er]u[er]is ut m[us] co[n]tra f[er]a f[er]a p[er]u[er]is
 co[n]tra ut alie f[er]a. Si m[us] f[er]a f[er]a
 co[n]tra p[er]u[er]is. De d[icitu]r co[n]tra localis
 Si f[er]a est p[er]u[er]is q[uod] localis co[n]tra f[er]a
 f[er]a m[us] co[n]tra. Quis p[er]u[er]is est ut f[er]a
 m[us] f[er]a et alie. Si f[er]a d[icitu]r et m[us]
 f[er]a. Co[n]tra n[on] est ut alie g[er]it f[er]a
 co[n]tra et f[er]a. Et f[er]a quid[am] m[us] f[er]a
 et alie f[er]a f[er]a f[er]a est ob[er]u[er]is
 Si quis p[er]u[er]is f[er]a f[er]a alie f[er]a f[er]a
 b[un]d[is]tis f[er]a f[er]a m[us] f[er]a f[er]a f[er]a f[er]a
 p[er]u[er]is p[er]u[er]is. Et f[er]a m[us] f[er]a f[er]a f[er]a
 q[uod] f[er]a m[us] et m[us] ut co[n]tra
 f[er]a alie co[n]tra ut m[us] q[uod] m[us] f[er]a
 ut m[us] alie ob[er]u[er]is. Et quid[am] alie f[er]a
 ut m[us] alie alie alie alie f[er]a f[er]a

M[us] m[us] ad f[er]a et alie p[er]u[er]is et alie
 p[er]u[er]is alie d[icitu]r. Co[n]tra f[er]a alie
 m[us] m[us] m[us] m[us] m[us] m[us] m[us]
 m[us] p[er]u[er]is m[us] f[er]a f[er]a f[er]a
 p[er]u[er]is co[n]tra m[us] f[er]a f[er]a f[er]a

Fig. 5 – BNCF, Palatino 1068, ff. 41v–42r. Latin recipe “ad fistulas” annotated at the bottom of both folios. Courtesy of the Biblioteca Nazionale Centrale di Firenze, Ministero della Cultura.

1. Types of recipes

In most of the surveyed cases, there is a clear prevalence of recipes intended to treat wounds and lacerations, as well as other topical remedies (e.g., *impiastro*, *cerotti*, *unguenti*, *aque*, *olii*), as expected of the surgeon's line of medical practice.⁵¹ These preparations can be classified according to their binding agents – oil, wax, pitch, or resin – and their resulting consistency.⁵² Waxes and unguents broadly correspond to what would now be described as creams or pomades. *Waxes* (*cere*) are thicker and harder; some liquefy upon contact with the skin. Both waxes and unguents are applied by rubbing or massaging them into the skin. *Unguents* are richer in lipids (vegetable oils or animal fats) and spread more easily. They may contain some wax, though not in sufficient quantity to prevent liquefaction on contact with the skin. *Plasters* (*empiastri*) are characterized by their strong adhesive properties, due to the presence of pitch or resin. They are used externally and applied without friction, forming a stable, continuous covering on the skin. Plasters were employed particularly by barbers and surgeons rather than by physicians.⁵³

This remedy-type organization is especially evident in Manuscript D, which contains several folios with recipes closely connected to surgical practice. The main remedy types

references derive from learned sources, there is also incidental reference to hearsay: “Quidam referunt quod” (f. 44r) or personal remedies: “aqua et oleum ex nostra inventione per ulceribus et vulneribus.”

⁵¹ The recipes are mostly unguents, plasters, powders, waters, or oils as expected from surgical practice. BNCF Mag. XV 19: e.g., “unguentum ad fistulas et ulceras” (f. 42r), “unguentum conferens in fistula lacrimali et omnia alia fistula” (f. 44v), “unguentum in fistula lacrimali” (f. 46r), “unguentum per emoroydibus” (f. 49v); “cerotum bonum quod dissolvit duritie molificat exsiccat et consolidat” (f. 50v), “aqua bona et oleum per vulneribus et ulceribus” (f. 50v); BNCF Mag. XV 76: “unguento a mulificare lo ventre “perfecto,” “empiastro apurgare lo ventre” (f. 3v), “polvere da verga rescaldada e infada” (f. 8r), “unguento fino ala verga” (f. 8v), “unguento fino ala fistula” (f. 9r), “Afare olio roxado perfetissimo” (f. 20r), “unguento dagambe provado” (f. 28v), etc. BNCF Mag. XV 142: from f. 15r to f. 22r lists a number of oils, powders, etc.; various *cerotti* (ff. 46r–48v); *empiastri* (f. 51r); *unguenti* (f. 56r); *acque* (f. 69r); Wellcome MS 174, “ceroto chapitale” (f. 1r–v); “aqua daguarire el membro” (f. 4v); “unguento da rhotura di peto” (f. 6r); “unguento da saldare” (f. 8r); “unguento da smilza” (f. 10v), etc.

⁵² On these remedy-types, see Bénézet, *Pharmacie et médicament*, 615–617.

⁵³ Distinctions between these remedy-types were not always consistent. On the fluctuating or erroneous terminology for topical remedies, especially ointments, plasters and waxes, see Bénézet, *Pharmacie et médicament*, 614. In the Giglio accounts, products described as *unguenti* (unguents) and *unzioni* (unctions) appear to be used synonymously. By contrast, the *Ricettario fiorentino* employs only the term *unguento*, clearly distinguishing it from *empiastro*. Plasters may be understood as a stiffer variety of ointment, made with gums and resins. Although ointments and plasters are presented in separate sections of the *Ricettario fiorentino*, J. Mesue's *Opera* (Venice, 1497) treats them as a single category, “de unguentis et emplastris.” On this, see Welch and Shaw, *Making and Marketing Medicine in Renaissance Florence*, 23, 100, 160, 165, 236, 253, 298.

used for surgical care include: *Diversi cerotti* (ff. 46r–48v); *Diversi empiastri* (f. 51r); *Diversi unguenti* (f. 56r); *Acque diverse* (f. 69r). At the same time, the manuscript also preserves more general medical material, such as a synopsis of the complexions and humours, the foundational concepts of Hippocratic–Galenic medicine.⁵⁴ Blank spaces in Nardi's casebook were later filled by subsequent users with alchemical recipes.⁵⁵ Later additions further include drawings of artillery shells for bombardments and the machinery used to launch them.⁵⁶ The collection also includes recipes explicitly marked as drawn from the Medicean foundry ("*cavate dalla fonderia segreta di S.A.S.*"), which are predominantly cosmetic in nature.⁵⁷

The manuscript also demonstrates the integration of *ad hoc* remedies into the treatment of patients at the hospital's *medicheria*, for instance, the case of a young man (*fanciullo*) with a dislocated clavicle.⁵⁸ The account explains how the patient was laid on his side, restrained by several assistants on a stretcher, and how the surgeon reset the clavicle ("*rimessi la clavicula al suo posto*"). After bandaging, a plaster was applied as recommended by the physician. Nardi writes,

Afterwards I removed the bandage and applied the plaster prescribed by my master, which is made in the following way:

Take:

Venetian turpentine, 4 drachms

Sealed earth

Dragon's blood (of each equal parts)

Armenian bole

Mix, and let them be made into very fine powders, and let a plaster be made according to art; and let it be applied over the affected place.⁵⁹

The treatment was subsequently replaced with a viscous plaster (*cerotto*) of Nardi's own formulation, combining Venetian turpentine oil, dragon's blood, and two medicinal clays.

⁵⁴ BNCF, Mag. XV 142, ff. 13r–14r.

⁵⁵ Ibid. ff. 26v–30v.

⁵⁶ Ibid. ff. 163r–165v.

⁵⁷ Ibid. ff. 127r–130v.

⁵⁸ Ibid. f. 10r.

⁵⁹ Ibid. Translation is mine. The recipe combines ingredients with complementary wound-healing properties frequently used in topical remedies. Venetian turpentine provides a protective, mildly antiseptic base. Terra sigillata and Armenian bole act as absorbent astringents, drying the wound. Dragon's blood aids coagulation and tissue repair. Together, they form a plaster applied to protect and heal the affected area. See Venieri, et al. "Bridging the Gaps: Bole and Terra Sigillata," 6–8; Basile, "Dragon's Blood or the Red Delusion," 1248–1250.

Nardi recorded this recipe in a formal, upright hand, deliberately imitating a physician's prescription – an eloquent indication of his professional aspirations. According to the account, the treatment proved highly successful. (Fig. 6)

2. Adaptation of recipes: the case of *unguento apostolorum*

Unguents were standard medicaments throughout Antiquity and the Middle Ages, constituting a traditional and well-established category of topical remedies. The *Ricettario fiorentino* of 1499 records 35 unguents; the updated 1576/97 *Ricettario* lists 40 unguents;⁶⁰ by contrast, the manuscript Mag. XV. 92 – the recipe collection belonging to the hospital of Santa Maria Nuova (1515) – records as many as 162.⁶¹

Manuscript recipe books often preserve multiple versions of the same prescription sometimes under slightly different names, with variations introduced through qualifiers, indications of use, authorship, or provenance.⁶² Some of these name-tags acquire grandiloquent or deliberately elaborate overtones, suggesting an underlying commercial or advertising strategy. Classification systems frequently emphasize use – either the condition to be treated or the part of the body to which the remedy should be applied. Compared to printed formularies, manuscripts tend to provide more detailed descriptions of procedures and the order of ingredients, occasionally supplemented by personal or experiential observations. In the surveyed surgical handbook, traditional remedies are reworked for practical use: ingredients are simplified or reduced to a strict minimum, quantities are not consistently provided, while greater attention is often paid to customized processes of manufacture and preparation. Evidence suggests that many of these external remedies were probably manufactured by the surgeons themselves.⁶³

A case in point is the traditional *unguento apostolorum* (also known as Apostles' Ointment or Ointment of Venus) a *dodecapharmacum* – that is, a compound made of twelve ingredients – attributed to Avicenna⁶⁴ but closely related to a kind of plaster found in various Late antiquity Greek recipes.⁶⁵ The standard formulation includes turpentine, white

⁶⁰ On the *Ricettario fiorentino* and other pharmacopeias, see Beck, “The *Ricettario fiorentino*,” 45–62. For a comparison of the various sixteenth-century editions of the *Ricettario fiorentino*, see Corradi, *Le prime farmacopee*, 1–64.

⁶¹ On this manuscript, see Henderson, *The Renaissance Hospital*, 297–335.

⁶² See Basile, “Medicinal Waters,” 117–126.

⁶³ Stolberg's discussion of German barbers indicates that being able to prepare external remedies was a condition to successfully pass the “master's exam.” Cf. Stolberg, “Surgical Training and Practice,” 85. Though less well documented, Cavallo speculates that this may have also been the case in Italy (Cavallo, “Learning to Dress Wounds,” 58). Jones, “Learning surgery from medieval manuscripts,” 126, shows that recipe collections were instrumental in the surgical practitioner training in seventeenth-century England.

⁶⁴ Avicenna, *Canon of Medicine* V.1.11 (533va).

⁶⁵ Asade and Druille, “The Syriac Christianization of a Medical Greek Recipe,” 11–38.

10

Venne il fanciullo il quale haueua cheato
 la sia destra et colli la zassetta in q^o
 modo et lodisti nel neltto a fauer
 et due pigliando nel mezzo d'uno sin
 golar et tenua bere tutta la vita et in
 gata bere a talche due altri ne erano
 et tenuano la gamba et colli mettolo
 y fianco et facendo tirare d'ambe
 due le parti in un medesimo tempo et
 d'accordo et in facendo l'operazione sia
 et le mani in metti la clauicola al suo
 luogo finalmente gli feci una strascina
 di buonissima fasciatura et colli sette
 di dicta et ordire fino in 8 giorni
 dopo lo sfascia et u. metti la il Cerotto
 di ordire del mio m.^o quale e in
 questo modo
 L'erebentina venetiana 5 q
 terra sigillata
 sangue d'orso an p. eq.
 Bolarme no
 m. et subtilissime sixt pulueres et sixt
 Cerotto S. A. et imporgat^{etur} sup locum
 affattura

Fig. 6 – BNCF, Magliabechiano XV 142, f. 10r. Case of a young boy with a dislocated clavicle, followed by a recipe for a plaster (*cerotto*) prescribed by Nardi. Courtesy of the Biblioteca Nazionale Centrale di Firenze, Ministero della Cultura.

wax, gum ammoniac, birthwort roots, olibanum (frankincense), bdellium, myrrh, galbanum, opoponax, verdigris, litharge, and olive oil/vinegar.⁶⁶ Widely used throughout the Middle Ages and profusely cited in medical, surgical, and pharmaceutical literature,⁶⁷ the unguent served as a topical remedy for bleeding wounds, valued for its healing, astringent, absorbent, and emollient properties.⁶⁸ By the sixteenth century, the *unguento apostolorum* had become a standard preparation in the antidotaries and civic pharmacopeias.⁶⁹ The surgeon's manuscripts, however, reveal a range of ad hoc adaptations.

Manuscript A, composed thirty years before the publication of the 1499 Ricettario fiorentino, contains nearly the same list of ingredients but notably excludes turpentine (present in Avicenna's formula).⁷⁰ The version transmitted in Manuscript A is very similar to Dino del Garbo's (1280–1327) recipe found in his "Compilatio emplastorum et unguentorum," a tract circulating in manuscript form before being printed as an appendix to his *Expositio Dini Florentini super tertia et quarta fen quarti Canonis Avicenne* (Venice, 1496).⁷¹ The Florentine physician – an important commentator on Avicenna's *Canon* – also omits turpentine,⁷² possibly in order to maintain the symbolic total of twelve ingredients rather than thirteen.⁷³ Evidence of borrowing from del Garbo's variation – whether directly or,

⁶⁶ *The London encyclopaedia: or Universal dictionary of science, art*, Vol. 2, 507. Also, Corradi, *Le prime farmacopee*, 42. Stannard, "Hans von Gersdorff and Some Anonymous Strassburg Apothecaries," 55–65 (esp. 62–63) states that the unguent "owed its name and perhaps its popularity as well, to a supposed connection between the number of apostles, the number of ingredients, and its twelve-fold efficacy." See recently Stolberg, "Surgical Training and Practice," 85–86, who discusses the use and preparation of these plasters and unguents in the Germanophone area.

⁶⁷ The unguent is mentioned in the surgery of Theodoric dei Borgognoni, Salicet, Guy de Chauliac, and Henri de Mondeville, among others. The list of ingredients oscillated between twelve and thirteen ingredients (even if the ointment was supposed to derive its name from the twelve apostles), and was also known as "unguentum veneris," "Cesareos (according to Mesue)," or "gratia dei." On this see Guy de Chauliac, *Inventarium sive chirugia magna*, 177.

⁶⁸ See Asade and Druille, "The Syriac Christianization of a Medical Greek Recipe," 21.

⁶⁹ See, for example, *Luminare maius*, f. 78 r (citing authors like Avicenna, Pietro d'Argelata, Mesue, etc.) *Thesaurus aromatariorum*, f. 114r; *Ricettario fiorentino* (ed. 1499), f. 63v-B; *Ricettario fiorentino* (ed. 1574), 258.

⁷⁰ BNCF, Mag XV 76, f. 21r. The ingredients include: "cira bianca," "raxina," "opoponago," "fore deramo," "arminiaga," "arestiologia," "incenso maschio," "mira," "gabino," "olio," "letrigerio," "delio," and "laxedo di vino."

⁷¹ Dino del Garbo, *Expositio super tertia et quarta fen IV. libri Canonis Avicennae*, f. 154v a-b. On this see Guy de Chauliac, *Inventarium sive chirugia magna*, 177.

⁷² Turpentine and its derivatives have been traditionally used to treat skin infections due to its soothing, anti-inflammatory, and antiseptic properties. See Barnes and Greive, "Topical pine tar."

⁷³ Dino del Garbo, *Expositio super tertia et quarta fen IV. libri Canonis Avicennae*, f. 154v: "et dicitur unguentum apostolorum quia un eo sunt xii medicine."

more likely, through an intermediary vernacular translation – can be found in Manuscript A's detailed description of the remedy's properties, which closely paraphrases his wording:

Unguento apostolorum elq(u)ale edito inguento vene(r)is ed inguento p(er)fetissimo
 aguarire ligiermente le fistole greve / Eguarisse le scrofoli cative / e mondifica le feriti Togli
 lacarne morta / e le salda e dixe ch(e) le son(no) xii medixine come son(no) li xii apostoli.⁷⁴

Nardi's book, produced over a century after manuscript A, provides instead a tailored version of the *unguentum apostolorum* recorded in the updated civic pharmacopeia. In this case, variation does not derive from a divergent manuscript tradition, as in Manuscript A, but reflects a customized adaptation of a well-established ointment within surgical practice.⁷⁵ The official recipe is condensed: not all components are mentioned, and quantities are omitted.⁷⁶ Herbal ingredients are summarily referred to as "altre cose." By contrast, the preparation process is described in detail, with attention to stages, instruments, and techniques, not as a permanent record but as a shorthand annotation. Nardi's formulation thus emphasizes procedure – particularly his own method of compounding the unguent – over strict adherence to a fixed list of ingredients. Notably, details included by Nardi, such as the addition of verdigris (*verderame*) at the final stage, as the mixture cools, are absent from the civic formularies.⁷⁷

3. Beyond mainstream pharmacology: magic, astrology, and alchemy

Whereas these manuscripts largely feature remedies associated with surgical treatments, they also record a much wider range of therapies. Although most remedies can be situated within the Hippocratic–Galenic tradition, some texts offer a glimpse into alternative forms of medical practice, including alchemical, astrological, and magical knowledge – a trait that distinguishes them from official pharmaceutical literature. This should not surprise us. The recourse to magic or religious cures, including incantations and invocations, were part of the therapeutic repertoire, often complementing more orthodox naturalistic

⁷⁴ BNCF, Mag XV 76, f. 20v–21r. Cf. *Expositio*, f. 154va: "Unguentum apostolorum et est unguentum veneris rectificans cum facilitate fistu(las) difficiles et scrophulas ulceratas et eradicat eas et mundat vulnera ex carne put(refacta) sine dolore."

⁷⁵ Cf. Bénézet, *Pharmacie et médicament en Méditerranée occidentale*, 633. The Apostle's unguent ("onguent des apôtres") is rated among the most frequent ones in Benezet's magisterial medieval and early modern survey of apothecary inventories and pharmaceutical literature.

⁷⁶ BNCF, Mag XV 142, f. 61r. Only a few ingredients are mentioned: "gomme," "terbentina/tremintina," "ragia liquida," "cera," "litargino," "verderame," and "altre cose."

⁷⁷ Ibid.: "eccetto il verderame il quale si mette da ultimo dase et si continua dimenare finche sia freddo." I find a similar recommendation in Francesco Sirena's *L'arte dello Speciale* (Pavia, 1679, 788) a monumental work containing over 1,200 recipes: "Il verderame si debe porre nell'unguento subito colato, e piu non se gli deve far sentir fuoco, perche perderebbe parte di quel suo bel color verde."

medicines.⁷⁸ Charms, associated with other empirical cures (*experimenta, empirica, miraculum*) which could not be fully explained rationally, and were increasingly resisted by academic medicine, still found a place in late medieval medicine.⁷⁹ Examples are especially abundant in the earlier recipe-books or in collections associated with rural practitioners or those of semi- or non-professional status. The author of the Giovanni di Benedetto's collection, for example, lists various such recipes. For instance, an incantation to cure "scrofula" (an infection of the lymph nodes causing an abscess in the neck),⁸⁰ or to make a person sleep as though he were dead,⁸¹ a spell to see if an ill person would live or die,⁸² an incantation to free someone from a serpent's bite,⁸³ and a miraculous unguent.⁸⁴ To cure someone from a serpent's bite, for example, requires drawing a circle with a stick in the middle of which the sick person is supposed to sit, using woman's milk or dragon's blood, writing the word "agios" three times, reciting a number of prayers to Jesus Christ, and sucking up the poison from the wound.⁸⁵ (Fig. 7)

The presence of incantations in Manuscript C is considerably less pervasive, yet still discernible. For example, a blood-staunching charm reproduces the widely attested *stans sanguis* tradition, whose stability across Latin and vernacular witnesses underscores its integration into practical medicine.⁸⁶ Here, the incantation consists of a prayer (three *Pater Noster* and *Ave Maria*), physical manipulation (binding the fingers), and imperative for-

⁷⁸ On magic and medicine, see Copenhaver, "Natural Magic, Hermeticism and Occultism in Early Modern Science," 261–301; Park, "Medicine and Magic: The Healing Arts," 129–149. On the overlap and complementarity of medical, ecclesiastical, and folk systems of healing in early modern Italy, see Gentilcore, *Healers and Healing in Early Modern Italy*. Charm translates *car-men*, which is the usual heading found in Latin medical recipe books, house-hold miscellanies, commonplace books, and medical compendia for treatments employing words. They may be spoken as in a performative speech act, written on the body, on foods or over drinks, or on amuletic objects, or parchment carried by the patient. Often, they are accompanied by ritual gestures and prayers. For a general discussion of charms and magic in the late medieval period, see Kieckhefer, *Magic in the Middle Ages*, 56–90.

⁷⁹ See the excellent discussion of charms as "experimenta" and "empirica" in Olsan, "Charms and Prayers," 349–350.

⁸⁰ BNCF, Mag XV 76, f. 16r: "Encanto dalescrofole elq(u)ale se vol dire adi di dome(n)ga," followed by an incantation in Latin.

⁸¹ Ibid. f. 21r: "A fare dormire una p(er)sona ch(e) parera morta."

⁸² Ibid. f. 22r: "bello exp(er)imento se li i(n)fermo di vivere omorire."

⁸³ Ibid. ff. 23v–24r: "Aliberare chi tu voi dalmorso del serpente."

⁸⁴ Ibid. ff. 37r–38r.

⁸⁵ Ibid. ff. 20v–21r.

⁸⁶ Wellcome MS 174, f.4r: "A stagnare el sangue: dirai tri pater nostri e tre ave marie alaude de la trinitade e ligali quatro dedi de la mano. ligalo con uno spageto ben stretto e dirai: sangue sta fiso come fa el corcefiso: sangue sta forte come fe cripto ala morte sangue sta in la vena toa come fa cristo a la fede soa."

e manuel alfa 7 o. Enota ch quello breue di essere
facto d'arta ligene e uenerentemte edesse dire noue
messe morture sopra lo ihermo sotto ipani delalano
e atore le noue messe el priore di dire speciale orone
p lui ep quistana messa di dire lo iherme tre hostie
e opidi le messe tali lo breue g grandissima regu
tia topore soprat. Enota ch tute uoi guardare
de messe d i festore tiopo ine suna cosa especialme
te cose ch uano iorno sicomo molino d'apartore
roda o altre cose ch i uadano iorno Ancora gna
da da la carne del lo edalacore salda capo
alato agumj cauli e fume cuigore tiopo sedal
fiedo di pie e fra liberto senza fallo

Alberare di tu uoi dal morso del spente

Quando tu uoi liberare alcuna psona dal morso
del spente e malarasse era uno archio i tra cruz
uno legno fortissimo edacapo de questa legno scure
di latte de dona ouere sangue de drago E se tu no
poi auore de questa cose scure o laqua benedetta
g una punta de corallo queste parole i fra scire
re + agros + agros + agros + e poe di qtra
giurazone se guone + sup asputin i basalsai
ambulabis 7 oculabis leone i dracone + Inno
mine patris 7 filij 7 spu sca Amen

Quamalia uenenga que epis i stancia tui
militatoz quilibz uenitit usq ad huc archulum
itaz possim uidere de certe q est uous huc mortus
7 ipuz libret sine mora sp peno oia xpi + eli
7 foras i noie + xpi + nazareni cuiusfisi

filij dñi nostri + dei uiui 7 ueri dipoenens + 7
beate marie uirginis q g parie filio sps sca
+ uiuit 7 regnat p oia secula seculor Amen
denacis ato absq timore e nulla leione cor
poris 7 aie E si uedrac uenire quello ch a facto
lonale torandose tuto gozam pena e como tu
louide comomadaohe di lui d'bia subito suzare
lapantura de bi fermo auenenado senza alcuna
leione e di ello d'bia tirare asi loueneno e poi
de cusi + xps uiuat + xps regnat + xps
impit + xps libret hanc creatura i firma
7 famula sui. A. ab homibus languoribus 7 ab ini
mial suis uisibilibus 7 i uisibilibus 7 ab homibus
pualis uenengas 7 mororibus amen

Dimas 7 gistas i medio diuino + magister
+ sanctus deus + scf foras + sanctus i mortalis
+ saluator mundi misre nobis amen
E di tre uolet questi scongiurazone E fa che
lo i fermo seda i mezo del sotto scito x archio

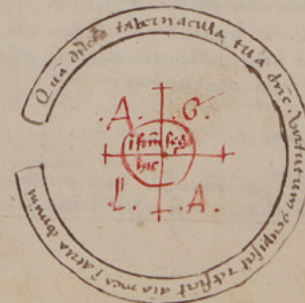


Fig. 7 – BNCF, Magliabechiano XV 76, ff. 23v–24r. Incantation to free someone from a serpent's bite. Courtesy of the Biblioteca Nazionale Centrale di Firenze, Ministero della Cultura.

mula (“*sangue sta fiso come fa el corcefiso*”).⁸⁷ The charm’s logic rests on an analogy with the body of Jesus Christ: just as Christ’s body remained fixed on the cross and in death, so the patient’s blood is commanded to remain within the veins. The performative effect of the incantation combines liturgical elements, spoken command, and manual intervention.⁸⁸

Another charm is recorded to aid the extraction of a decayed tooth.⁸⁹ This charm blends Marian devotion, learned magical elements, and practical technique. Its central analogy – likening painless extraction to the effortless flow of milk from the breasts of the Virgin Mary – parallels other vernacular charms that use sacred physiology as a healing model. The inclusion of liturgical phrases (*agios, adonai, athanatos*) situates the text within the multilingual tradition of Latin *experimenta*, where the power of divine names signals ritual efficacy.⁹⁰

Alongside incantations, some manuscripts also preserve astrological lore. Since antiquity, astrology had functioned as “handmaiden to medicine”⁹¹ providing supplementary guidance for determining diagnoses, prognoses, and treatments. Although not all learned physicians were confident in using astrology in medical practice,⁹² often engaging in heated debates⁹³ – and recent scholarship has noted a significant decline in the status of astrol-

⁸⁷ This formula closely mirrors versions preserved in manuscripts such as London, BL cod. Harley 2389, f. 29r: “To staunch blode. ‘sanguis mane in te sicut fecit Christus in se. sanguis mane in tua uena sicut Christus in sua poena. sanguis mane fixus sicut Christus quando fuit crucifixus.’”; also Wellcome MS 417 (f. 97v) and NLW Peniarth MS 369 (f. 108v), where the phrase “*sanguis... sta in te fixus sicut Christus stetit crucifixus*” finds a near-verbatim counterpart in the vernacular. For a broader discussion, see Bauer, “Biblical Magic,” 271–272; Murray Jones and Olsan, “Performative Rituals,” 406–433.

⁸⁸ Murray Jones and Olsan, “Performative Rituals,” 409.

⁸⁹ Wellcome MS 174, f. 44r: “Achavar uno dente senza dolore cum dui dedi che sia gusuo fioloasto. Di con devotione queste parole + si come fo dolia lo late de la verzine maria lo quale de con le soi mamelle al suo cussi possa tirare questo dente senza dolia + agios + adonai *athanatos* di le sopra scrite parole tre volte poi pilia lo dente che dole cum li dedi che sono apreso a lo dedo grosso e tirai fora facendo cum reverentia et e approvato.”

⁹⁰ Manuscript evidence (e.g., Bodleian Library, Rawlinson c. 299; Wellcome MS 5262) shows that such invocations commonly accompany explicit procedural steps, as here, where the charm culminates in the physical extraction of the tooth. On these “powerful words,” see Olsan, “Charms and Prayers,” 357–358; more generally see Skemer, *Binding Words*, 96–107.

⁹¹ Cf. Pfeffer, “Reassessing the Marginalization of Astrology,” 1162. On medical astrology, see among many others: Darrel, “Astrology,” 542–561; Grafton and Siraisi, “Between the Election and My Hopes: Girolamo Cardano and Medical Astrology,” 69–131; Azzolini, *The Duke*, 135–166, and Siraisi, *Medieval and Early Renaissance Medicine*, 135–136.

⁹² Cooper, “Approaches to the Critical Days,” 536; Vermij and Hirai, “The Marginalization of Astrology,” 405.

⁹³ On the partial or disputed relevance of astrology in Renaissance medicine, see Wear, “Galen in the Renaissance,” 229–262 (esp. 245). Astrology was a hotly disputed subject throughout the sixteenth century, see Cooper, “Approaches to the Critical Days,” 542.

ogy as early modernity progressed –⁹⁴ iatromathematics remained a widespread ancillary discipline across many forms of medical practice well into the seventeenth century. Medical practitioners regularly used horoscopes and astrological charts to identify the “critical days” for illness,⁹⁵ determine when to bleed a patient, or mix medicines according to the zodiac sign governing that body part. It is therefore not unexpected to find traces of such knowledge in surgeons’ handbooks, as lunar almanacs were especially necessary to determine the most favorable moments to intervene with patients, especially when letting blood, bathing, or cupping.⁹⁶

Oddly enough, the presence of astrology is most conspicuous in Manuscript B, which otherwise largely transmits Latin surgical literature. The manuscript’s final section devotes several folios to astrological material, including notes on the twelve signs, the beneficent and pernicious properties of each planet, the classification of signs according to their qualities, the properties of the moon, auspicious and inauspicious hours of the day, and a section on phlebotomy.⁹⁷ Two sketchy astrological tables accompany the hand notes (Fig. 8). This is a clear example of juxtaposition of learned sources and supplementary practical information (based on simple astrological principles) in a single book, reflecting the broad spectrum of expertise required from surgical practitioners. It also demonstrates the adaptability of such handbooks to accommodate knowledge deriving from different epistemic domains, combining both academic and vernacular sources.

A second type of material with a discernible astrological declination attested in the manuscripts pertains to botany. At the intersection of learned and folk lore, botanical treatises and manuscript herbaria sometimes address plants in terms of planetary dominance. The practicalities of herbalism instructed healers to gather herbs “during specific phases of the moon depending on how they would use the plants,”⁹⁸ but there was also a corpus of medieval literature that connected herbs to different signs of the zodiac.⁹⁹ This knowl-

⁹⁴ On the marginalization of astrology in the transition to the modern world, see the extensive debate in Pfeffer, “Reassessing the Marginalization of Astrology.”

⁹⁵ See Pennuto, “The Debate on Critical Days in Renaissance Italy,” 75–98, and Cooper, “Approaches to the Critical Days.”

⁹⁶ Lunar phases draw an analogy between the moon’s causing the tides and the moon’s action on the fluid humours of the body. See Cooper, “Approaches to the Critical Days,” 541; Carey, “Judicial Astrology in Theory and Practice,” 90–98 (esp. 93); Vermin and Hirai, “The Marginalization of Astrology,” 405.

⁹⁷ BNCF, Pal. 1068, “De duodecim signis,” “De bonitate et malitia omnium planetarum” (f. 120r), “de signis solis,” “Signa mobilia, comunia, stabilia” (f. 122r), “de proprietate lune” (f. 124r), “de horis bonis et malis” (f. 124v), etc.

⁹⁸ See Eamon, “Astrology and Society,” 145.

⁹⁹ According to Voigts “Plants and Planets,” 29–46 (esp. 29 and 45), there were two kinds of such treatises disseminated in the late Middle Ages: one – made up of three textual traditions – addressing the relationships of all seven planets to plant (the Alexander/Pseudo-Albertus tra-

edge enabled medical practitioners to treat specific ailments by determining what sign and planet ruled over the part of the body that needed care, and then prescribing an herb of the same astrological sign. Manuscript C provides evidence of astrological botany in two brief sections entitled: “Queste sono le herbe de li segni celesti” and “Queste sono le herbe de li sete pianeti,”¹⁰⁰ followed by a name concordance and a succinct description of the main therapeutic use of each plant.¹⁰¹

Alchemical experimentation is perhaps the heterodox practice that is best represented across all manuscripts. Commonly regarded as a subordinate and artisanal branch of applied physics in the Middle Ages, alchemy enjoyed an uninterrupted standing in industrial, metallurgic, and pharmaceutical pursuits, but acquired a far more prominent status in the sixteenth century.¹⁰² It is worth noting that alchemy was not an institutionalized discipline, and therefore remained in the margins of the medical orthodoxy well into the seventeenth century.¹⁰³ However, it proliferated in a sort of middle ground – often discredited in theory but embraced in practice. In Florence in particular, alchemy was a *de facto* phenomenon, which was greatly stimulated by the Medici family’s interest and personal involvement in alchemical experimentation.¹⁰⁴

The manuscripts offer extensive evidence of the diverse applications of alchemical experimentation in pharmacology, especially in the production of oils, waters, pigments,

dition; the Kiranides tradition); and a second cluster of texts, each one about a single plant deriving its powers from a specific planet. On the plants especially associated with the sun (sunflower) and the moon (peony-lunaria), see also Segre, “Botanica astrologica e alchimia vegetale,” 533–560, and Arber, *Herbals*, 260–261.

¹⁰⁰ Wellcome 174, ff. 56v–57r.

¹⁰¹ Ibid. ff. 57v–58r.

¹⁰² On the rise of alchemical interest in the Renaissance despite its criticism and lack of institutional protection, see Long, *Openness, Secrecy, Authorship*, 143–174. On the general reluctance of university-educated physicians to accept distillation, which was viewed predominantly as “an artisan activity,” see Moran, *Distilling Knowledge*, 37–66 (esp. 55). However, in practice many physicians “showed a readiness to study with, and learn from, contemporary alchemists.” cf. Palmer, “Pharmacy in the Republic of Venice,” 115. On alchemy as a “vernacular science of matter” see Smith, *The Body of the Artisan*, 129–151.

¹⁰³ The increasing legitimation of alchemy can be put down to the new cosmological and religious overtones fostered by the Neoplatonic focus on natural magic and the occult, an empirical turn that favoured experimentation with materials and saw the publication of treatises and handbooks for the manual arts (*artes mechanicae*), and later, the rise of Paracelsian medicine and iatrochemistry as a competing model to the orthodox Galenic paradigm. See Newman, “From Alchemy to ‘Chymistry,’” 497–499.

¹⁰⁴ See, among others, Bellorini, *The World of Plants*, 168–176; Perifano, *L'alchimie a la cour de Côme Ier*, 46–47; Clericuzio, *Chemical Medicine*, 375–376; Barker, “Cosimo I de’ Medici and the Renaissance Sciences,” 520–580; Conticelli, “*Guardaroba di cose rare et preziose*”; Piccardi, *La farmacia granducale*.

dyes, cosmetics, and various medicinal and industrial household products. Among the various alchemical procedures, distillation stands out with remarkable prominence.¹⁰⁵ Hydro-distillation, a method utilizing water (steam) as an extraction solvent to capture volatile or polar components of plant materials, had been employed in pharmacy as early as the thirteenth century but acquired increased legitimacy and visibility with the publication of distillation manuals.¹⁰⁶ By the late sixteenth century, distillation had evolved into a standard and widely adopted procedure in the preparation of medicines.¹⁰⁷

Nardi's casebook is heavily interpolated with alchemical recipes, deriving from later hands – evidence of the burgeoning interest in chemical experimentation in the Medici grand duchy.¹⁰⁸ The other manuscripts, nonetheless, feature some form or other of distillation or alchemical procedures. Manuscript C, for instance, provides the description and therapeutic uses of simple waters obtained by distillation and decoction in several folios, classing them according to the four properties in the Galenic pharmacological theory (cold, hot, wet, and dry). Its owner, Gasparo di Cagali, indicates that much of the information in this section is drawn from a certain Maximo da Milan. Inside the lower cover the volume includes two fine drawings of distilling apparatus (Fig. 9). Similarly, the Magliabechiano XV 76, written in 1468, contains a miscellany of alchemical, medicinal, and cosmetic recipes, some of which include distillation processes. For example, the author indexes a certain “water to break any metal” (“acqua da rodere ogni metallo”) which has also multiple other marvelous uses as hair dye and as writing ink, when combined with tin and copper filings.¹⁰⁹ According to the author, this water is obtained through distillation in a still and requires that the person in charge carefully observe changes in color as the process unfolds. Manuscript D, in turn, bears considerably fewer traces of recipes requiring sophisticated distillation processes, except for a few preparations (e.g., “per rompere un ferro in 2 ore”) containing mineral substances that involve distillation.¹¹⁰ Taken as a whole, however, there is clear indication that simple distillation procedures were likely undertaken by surgeons in home laboratories, and that compilers drew from the *segreti*

¹⁰⁵ For the medieval tradition of distillation, see Forbes, *A Short History of the Art of Distillation*, 55–98. For the use of distillation in pharmacy, see Debus, *The Chemical Philosophy*, I: 19–25.

¹⁰⁶ Among the most influential was Hieronymus Brunschwig's *Liber de arte distillandi de simplicibus* (known as the *Small book of distillation*, 1500), which systematized and disseminated through the printing-press the traditional knowledge of extracting medicinal waters from plants and other curative materials. See Taape, “Distilling reliable remedies”; Debus, *The Chemical Philosophy*, I, 21–23; and Hirsch, “The Invention of Printing.” On the sixteenth century as the “new age of distillation,” see Taape, *Crafting Medicine*, 69–112.

¹⁰⁷ See Bellorini, *The World of Plants*, 168–176.

¹⁰⁸ See Strocchia, “Notes from the Front,” 19.

¹⁰⁹ BNCF, Mag XV 76, f. 18v.

¹¹⁰ BNCF, Mag XV 19, f. 10v.



Fig. 9 – Wellcome Library, MS 174, lower margin. Two distillation apparatuses. Courtesy of the Wellcome Library.

literature,¹¹¹ including not only medical but also chemical and technical recipes, in wide circulation both in print or manuscript form.

Surgeons across the social spectrum: Latin, Vernacular, and hybridity

The diversity of content, medical approaches, and text types featured in the surgeons' books is mirrored by the range of linguistic varieties, registers, and styles displayed across Latin and the vernaculars. Together, these features attest to the heterogeneity and broad sociodemographic reach of surgery as an early modern category. While it lies beyond the scope of this essay to reconstruct a social profile of the authors or users of these handbooks¹¹² – however tentatively – one feature nonetheless warrants brief consideration, as it opens promising avenues for investigating the social and educational backgrounds of early modern surgeons. Specifically, the corpus reveals patterns of alternation, juxtaposition, and code-switching between Latin and the vernacular. This broad phenomenon takes various forms in the corpus.

The first case is relatively commonplace and concerns the co-occurrence of vernacular and Latin sections presented as discrete text blocks, typically identifiable as one or more recipes in one language followed by others in another. A good example is Manuscript A that, among the incantations discussed above, alternates between languages, and even preserves a similar prayer recorded in Latin and Italian in proximity.¹¹³ While Italian is prevalent in the recipe collection, the presence of Latin liturgical charms alongside vernacular ones points to a blurring of linguistic barriers within the religious sphere, to the extent that the scribe alternates between the two without clear distinction. Manuscript C, transmitting primarily recipes in Italian, also contains individual sections with a handful of Latin ones.¹¹⁴

Manuscript B, by contrast, presents a situation that is perhaps the inverse of the two cases above. Although it primarily transmits Latin surgical literature, the compiler nevertheless inserts recipes in Italian. For instance, folio 111v records a “Balsamus artificialis ut oleum preciosissimum etc.,” while folio 113r contains “Balsamo artificiale da mettere nelle ferite,” followed by a series of vernacular recipes before the text returns to Latin material.¹¹⁵

¹¹¹ On secrets and books of secrets, see Leong and Rankin, *Secrets and Knowledge*, 7–20; Eamon, “How to Read a Book of Secrets,” 23–46. On recipe collections and secrets as part of the surgical practitioner training in England, see Jones, “Learning surgery from medieval manuscripts,” 126.

¹¹² See, as an example, Strocchia's well-documented reconstruction of Nardi's profile and career.

¹¹³ Mag XV 76, e.g., “Longinus miles fuit hebreus virus non vidit latus domini nostri jesu Christi cum lancea perforavit...” (ff. 14r–v) and “Signor mio, Jesu Christo, como lonzino fo hebreo e fo cavaliero zudio e denote per lo fiancho dritto de lalancia sangue...” (ff. 22r–v).

¹¹⁴ Wellcome 174, ff. 11r, 13v–14r, 19v–20r, 20v–21r, 48v–49r, 33r, 65v–66r, 67r.

¹¹⁵ BNCF, Pal. 1068, ff. 111v, 113r and subsequent folios.

Another instance of co-occurrent bilingualism is found in Manuscript E. As shown in the sample page from his casebook, Nardi uses Italian for recording the patient, condition, cure, and treatment. (Fig. 10) As marginal annotation, the surgeon adds paratextual *tituli*, such as “de ulceribus in vulva” “de ulceribus gallicis in mammellis,”¹¹⁶ which may be interpreted as reference markers for later consultation or as points of correlation with diseases described in medical literature.¹¹⁷ In this instance, vernacular and Latin are juxtaposed in a clear case of functional bilingualism, reflecting a professional surgeon proficient in both a higher linguistic register used for technical medical discourse and the everyday vernacular employed in hospital practice.

In other cases, slippage or variation between the two codes occur in evidently perfunctory and unconscious ways. These are evidence of what linguists have termed code-switching or code mixing, namely “the alternate use of two languages (or dialects) within the same stretch of speech, often within the same sentence.”¹¹⁸ This includes insertion of isolated items from the second language within the syntactic structure of the first language; the interchange between the first and second language, each with their own separate syntax, or congruent lexicalization, notably shared syntactic structure where both languages can fulfil lexical items. Nardi’s book provides interesting cases. Recipes are recorded largely in Italian but, incidentally, Latin may slip in inadvertently. This happens when, for example, after an Italian recipe against “tigna” – a scaly, crusting disease of the scalp and skin –, Nardi inserts a Latin *titulus* “Ad idem sepius probatum” and then continues in Italian (Fig. 11).¹¹⁹ This case begs the question of whether the surgeon was actually translating impromptu from a Latin recipe collection and a lapsus occurred with the title, or whether the expression “Ad idem ...” had become a fossilized phrase to introduce similar recipes in succession.

A similar question arises with Nardi’s transcription of the cerate reportedly formulated by his master (“dal mio maestro”) discussed earlier.¹²⁰ In this case, the surgeon may have been translating there and then a Latin recipe into Italian, except for the final section which was copied in Latin (cf. Fig. 6 above):

di poi lo sfasciai et vi metti su il cerotto di ordinatione dal mio m(aestro) quale e in questo modo:
R/ terebentina venetiana d 4

¹¹⁶ BNCF Mag. XV 142, f. 2v.

¹¹⁷ Ibid., ff. 1r–3v, 31r–32v. The procedure is repeated on several folios.

¹¹⁸ Winford, *An Introduction to Contact Linguistics*, 14. The terminology to describe this or similar phenomena, however, is debated among specialists, see, Gardner-Chloros, *Code-Switching*, 10–13 and Schendl and Wright, *Code-Switching in Early English*, 23–24.

¹¹⁹ BNCF Mag. XV 142, f. 20v.

¹²⁰ Ibid., f. 10r.

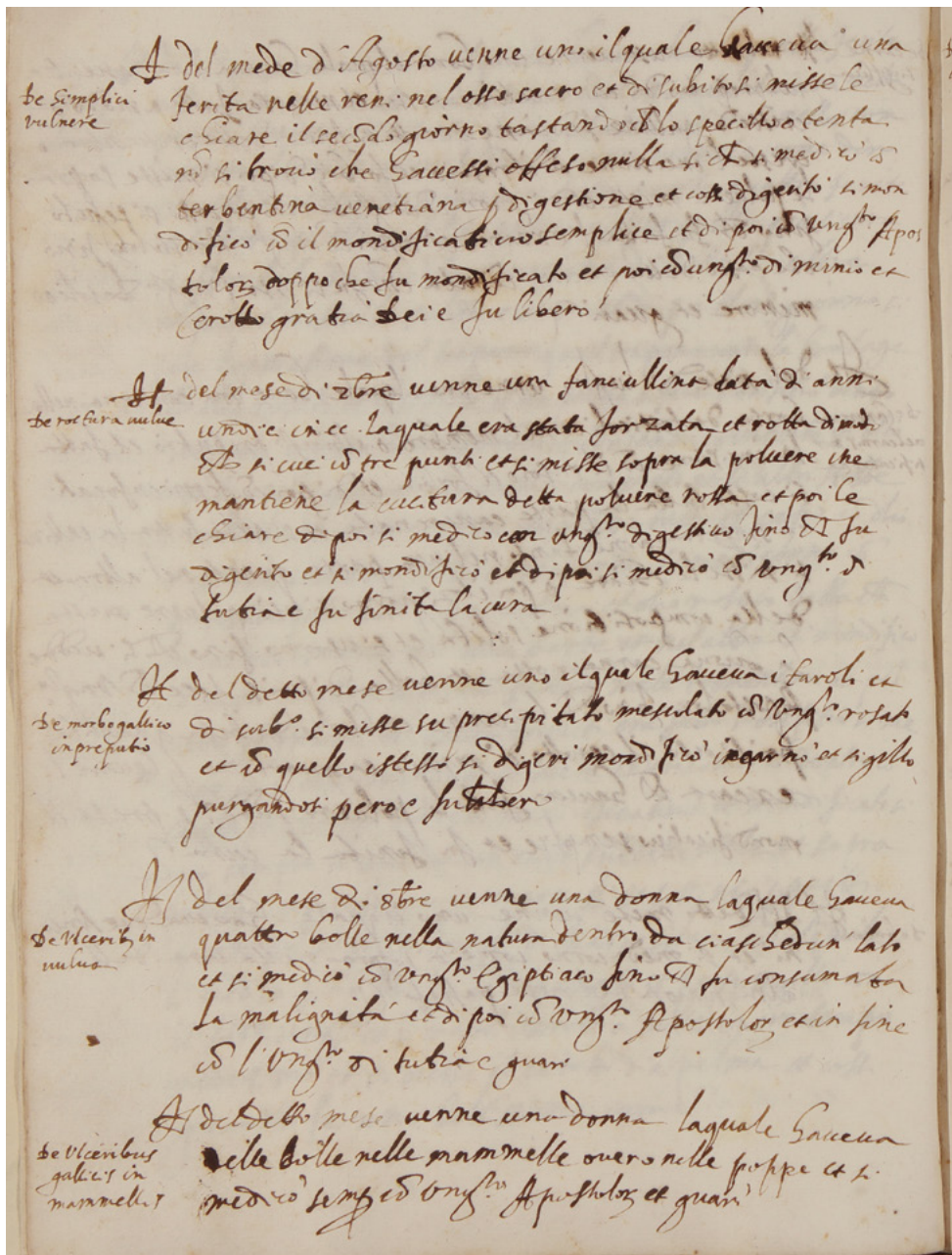


Fig. 10. BNCF, Magliabechiano XV 142, f. 2v. Coexistence of vernacular and Latin marginalia. Courtesy of the Biblioteca Nazionale Centrale di Firenze, Ministero della Cultura.

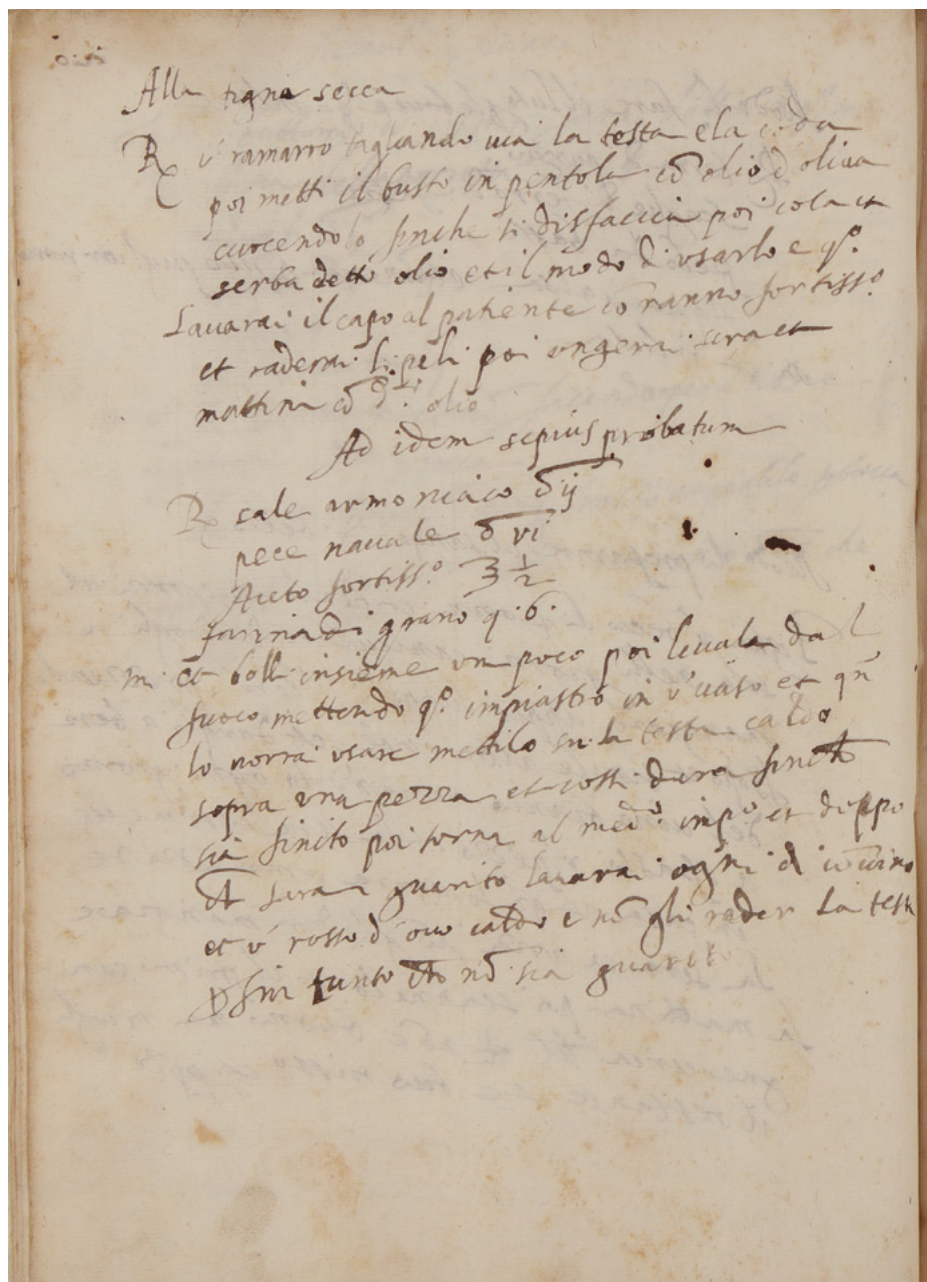


Fig. 11. BNCF, Magliabechiano XV 142, f. 20v. Italian recipe followed by a *titulus* in Latin. Courtesy of the Biblioteca Nazionale Centrale di Firenze, Ministero della Cultura.

Terra sigillata

Sangue di drago (an p. eg.)

Bolarmenio

m. et subtilissime fiant pulveres et fiat cerotum S.A. et impongasi (atur) super locum affectum.

Evidence of the code-mixing is the word “impongasi” in Italian, crossed out, and corrected as “imponatur” (Latin). This type of instance indicates an advanced convergence between the two codes, an actual overlap in functionality as regards both the status and register. From the user’s perspective, shifting from one linguistic code or variety to another implies a degree of competence in the languages involved and, therefore, requires a previous stage of bilingualism.¹²¹ Nardi’s capacity to self-correct and adjust are indicative of an advanced Latin literacy, as expected from a professional surgeon.

A final case of code-mixing reveals, by contrast, what seems to be a lower-literacy practitioner who sometimes merges both registers. Unlike Nardi, the Veronese surgeon compiling manuscript C, who in most cases keeps Latin and the vernacular separate, occasionally produces a macaronic Latin-vernacular.¹²² A case in point is the list of astrological correspondences of certain plants discussed above.¹²³ (Fig. 12) Likely an impromptu and partial translation of a Latin source, the scribe fails to fully adapt the original to the Italian (both morphologically and syntactically) and produces a hybrid discourse combining elements of both languages. This hybrid language appears, for example, in the entries below:

Lune est herba peonia et quando la luna cresse questa cresse e anchora quando la luna descresse questa descresse et vale contra epileisia et demonum et terzianam

Jovis est herba eupatorium vel agrimonia vel petalasilus: valet contra litragia et desenteria colicam.¹²⁴

These examples offer a snapshot of the social and educational range of practicing surgeons, many of whom operated across different levels of society and within a variety of guild structures and public institutions, in both urban and rural settings. This diversity points to a profession situated within a diglossic, if not multilingual, world and challenges the rigid professional and artisanal divide traditionally ascribed to surgery. As the language of these manuscripts demonstrates, the distinction was not between discrete hierarchical niches

¹²¹ See Crespo and Moskowich, “Latin Forms in Vernacular Scientific Writing,” 52.

¹²² Wellcome MS 174, ff. 24r, 56v–58r.

¹²³ Wellcome MS 174, f. 57r.

¹²⁴ See traces of Latin cases (genitive: “Lune”; accusative: “tertianam” / “colicam”); verbs (“est” / “valet”); conjunctions (“et” / “vel”) alongside vernacular forms (“quando la luna cresse” / “vale contra epileisia,” etc.)

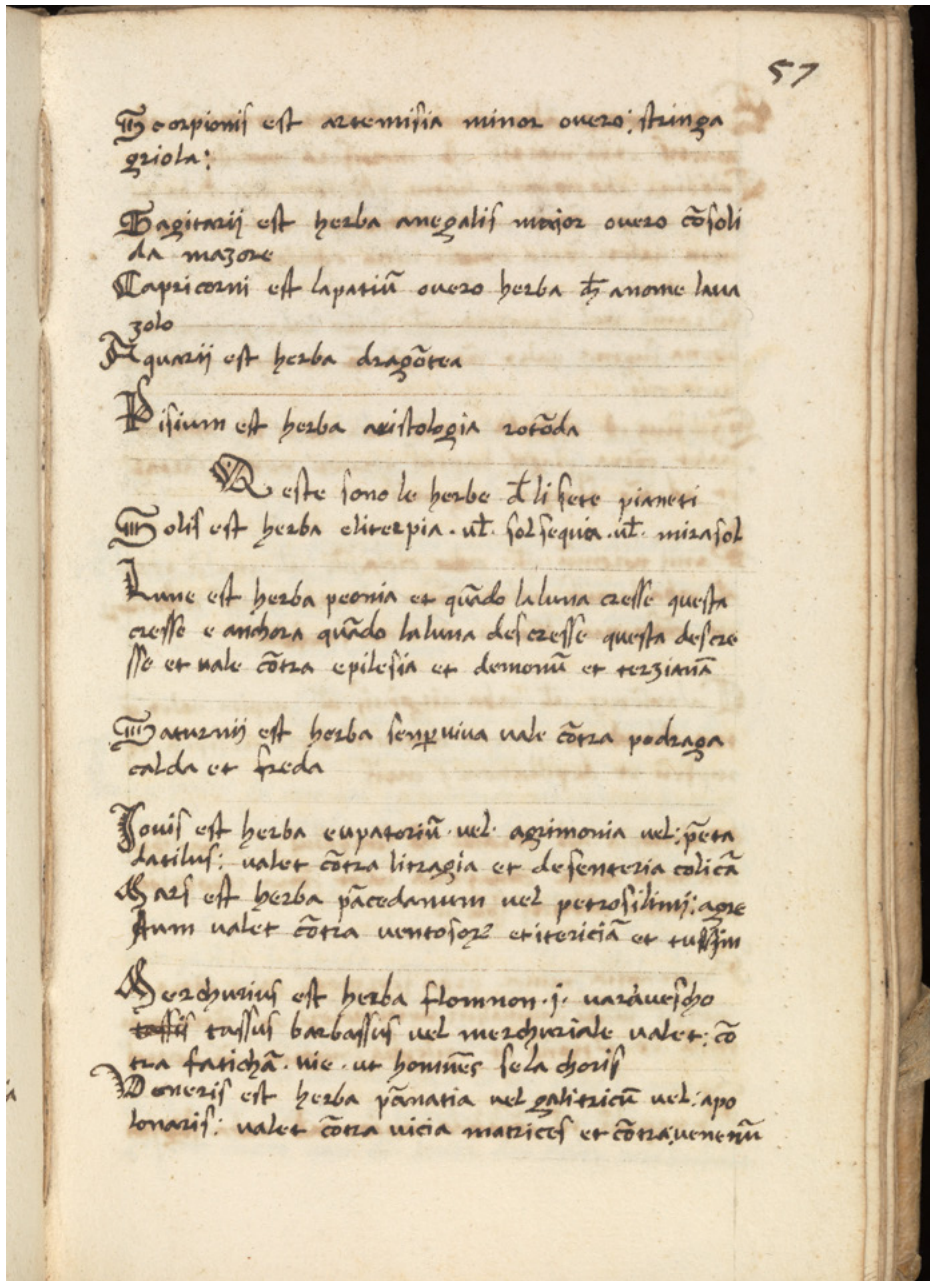


Fig. 12. Wellcome Library, MS 174, f. 56v. Astro-botanical section connecting the properties of herbs to zodiacal signs and planets. Courtesy of the Wellcome Library.

but rather involved fluctuating degrees of literacy, practical training, formal instruction, and experience, combined in highly idiosyncratic ways.

Conclusion

This study focuses on three areas that scholarship on early modern surgery has only recently brought to the fore.¹²⁵ First, it places medication and pharmaceutical knowledge at the heart of the surgeons' practice – an aspect that has often been obscured by the conventional distinction between interventions on the external and internal parts of the body imposed by the structures of medical colleges and guilds.¹²⁶ Second, it examines the porosity between different modes of surgical knowledge: on the one hand, "learning by doing," associated with craft and artisanal education, oral transmission, and the vernacular; on the other, institutional forms of teaching in universities, associated with writing, learned literature and, above all, Latin.¹²⁷ Third, it considers the status and circulation of surgeons' manuscript books and recipe collections, which were produced, used, and transmitted across generations but have barely survived. These books brought together practical experience, medical and pharmaceutical knowledge, and personal information about their authors' lives and professional activities, thereby challenging clear-cut distinctions between practical manuals, learned medical texts, and personal records.

The surveyed manuscripts provide a variegated picture of early modern surgical practice in northern Italy, shedding light on actual knowledge-in-use across a diverse category of practitioners. Medication emerges as a particularly crucial area of surgical activity, and the recording of recipes is perhaps the best-represented feature of the corpus. Yet their number, distribution, and organizational criteria vary considerably, depending on the pragmatic function of each book. Manuscripts A and C, for example, are fundamentally recipe collections, whereas the others, besides recording remedies, perform additional functions, such as documenting patients and treatments, transmitting surgical literature, and recording personal observations and miscellaneous information. As a whole, these texts perform overlapping functions to varying degrees: (1) as encyclopaedic repositories of learned or empirical knowledge (memory); (2) as platforms for experimentation, in which different strands of medical knowledge are combined; and (3) as documentation of

¹²⁵ On some of these new directions, see Donato, Leong, and Taape, "Introduction," 3–7.

¹²⁶ As this essay was under review, similar conclusions have been drawn independently by Stolberg, "Surgical Training and Practice," 84–86 (for Germany) and Cavallo, "Learning to Dress Wounds," 58, 67–68 (for Turin) in a recent publication. This essay provides yet further evidence for fifteenth and sixteenth-century Tuscany. On the notion of "surfaces" of the body and the dichotomy between external and internal, see Savoia, *Corpi, pratiche e modelli cognitive*.

¹²⁷ On this divide between "learned" and "artisanal" approaches in history of surgery, see Donato, Leong, and Taape, "Introduction: Learning to Cut and Cutting to Learn," 3.

actual praxis, closely tied to the practical application of medication and healing.

The remedies recorded are, as expected, primarily oriented toward the external treatment of the body, reflecting the surgeon's practice, but also extend to more general medicine of the whole body in some cases. Significant differences emerge. Nardi's casebook, for example, attests to his role as a surgeon in the *medicheria* of Bonifazio's hospital, with therapies focused on the treatment of wounds, lacerations, and other external ailments, and characterized by a predominance of waxes, unguents, plasters, and oils. By contrast, other cases examined here display a wider therapeutic repertoire, including incantations (Manuscript A) and iatromathematics or medical astrology (Manuscripts C and D), suggesting that the barber-surgeon's role often encompassed first-aid cures, treatment of common diseases, and general medicine also grounded in popular medical practices.

In institutional settings – most notably Nardi's casebook – remedies closely follow the remedy-type approach typical of official formularies and printed pharmaceutical literature, thus aligning more closely with medical orthodoxy. However, unlike printed pharmacopeias, the emphasis in recording remedies is placed on practical “how-to” instructions, often implying customization, simplification, or variation from standard formulas. Other manuscripts, by contrast, organize remedies according to disease, symptom, body part, or therapeutic action, in keeping with more traditional forms of healing that place the patient, rather than the production of standardized pharmaceutical forms, at the center of medical practice. Whatever the particularities of individual manuscripts, pharmaceutical knowledge and practice emerge as a core component of the surgical profession. Although the evidence remains incomplete, it is likely that the preparation of remedies was considered a core surgical competence and formed part of surgical training, as evidence from outside Italy suggests.

The sociodemographic contours of surgery are also well mapped in the corpus. The evidence reveals the broad social spectrum and range of practitioners encompassed by the category of “surgery” in the early modern Tuscany. This spectrum ranges from licensed, university-trained physicians – most notably the authors of manuscripts B and E, who display a strong command of Latin and of the surgical medical literature – to barber-surgeons (the owner of A and D) or practitioners with modest or limited institutionalized training (the author of C). This variety confirms the porosity of the discipline and cross-pollination mechanisms underscored by recent studies.

In a similar vein, the linguistic features of these texts further reveal the surgeons' varying levels of education and social positioning. The manuscripts thus range from purely vernacular texts – often kept as *ricordanze* by rural barber-surgeons – to largely vernacular works that incorporate occasional Latin sections or glosses, and, at the other end, to texts produced by university-trained physicians who demonstrate a strong command of both linguistic registers and the ability to combine or alternate between them. However, overlaps and contamination blur the traditional distinctions between learned and artisanal do-

mains, featuring individuals often operating in a diglossic context with varying degrees of education and access to Latin and/or vernacular medical literature.

The more complex question of what genre of literature texts like the ones in our sample belong to, and whether a single label can encompass such variety, remains unresolved. Nevertheless, an *instrumental* dimension emerges consistently. Like tonsils, razors, and plasters, these texts were part of the surgeons' professional toolkit – a *vade mecum* for use. Shorn of the pretense of public authorship and ostentatious erudition of surgical casebooks and printed works, these modest books served the crucial function of recording the private secrets of a practice, often within close-knit family or apprenticeship networks. Whether in the form of closed, definitive collections treasured for immediate and future reference, or as open, miscellaneous records by multiple hands over time, these manuscripts stand as a rich – and quite exceptional – testament to early modern surgical practice.

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Crafting practical mathematics: The making of an abacus manual

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Abstract

This paper examines an unpublished manual of practical mathematics, the *Libro di ragione* (MS Baldovinetti 229), written in 1461 by the Florentine Matteo Cerretani (1444–1519). Based on a comparative analysis with earlier and later abacus manuscripts, this paper argues that such texts were not passive repositories of techniques, but active sites of knowledge production. Cerretani's manual emerges as the result of processes of selection and reorganization of clusters of mathematical problems – the so-called *ragioni* – drawn from other Tuscan sources and closely tied to commercial practice. Far from being an isolated case, this mode of compilation reflects a broader pattern of knowledge-making within the abacus tradition, one of the main channels through which practical mathematics circulated in late medieval and early modern Europe. Finally, archival evidence further allows us to reconstruct Cerretani's social and cultural networks, shedding light on the *milieu* in which such knowledge was shaped, transmitted, and used.

Keywords

abacus manuals, practical mathematics, Renaissance Florence, knowledge-making

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Introduction: abacus mathematics and its sources

Abacus mathematics was one of the most widespread traditions of practical arithmetic in late medieval Europe, circulating through networks of practitioners.¹ Recent scholarship has emphasized the long-term importance of this culture in shaping economic practices as well as technical and scientific knowledge.² Its surviving sources span the late thirteenth to the sixteenth century, with fourteenth and fifteenth-century Italy as its main center of production.³ In this context, Tuscany – and Florence in particular – played a crucial role in fostering a “culture of precise quantification” closely tied to accounting, measurement, and calculation.⁴

The rise of mathematical education took place outside traditional channels of learning. Specialized schools appeared in major cities as well as in smaller towns and villages, expanding opportunities to acquire practical numerical skills through teaching and hands-on practice.⁵ As the government of Prato declared in January 1498, “knowledge and practice of mathematics are useful and necessary for the everyday activities of men in commerce; without them, society itself can scarcely be preserved.”⁶ Abacus masters were mostly laymen who taught privately or were appointed by public authorities, while also offering their mathematical expertise as consultants in accounting, building practices, and occasionally astrology.⁷ They described their knowledge as an ‘art’, that is, a craft, revealing the epistemological status of abacus mathematics in the period.⁸ Thanks to the survival of numerous archival sources, Florentine abacus schools are relatively well documented. They functioned much like artisanal workshops and were accordingly known as *botteghe d’abaco*: learning there resembled workshop training, where apprentices acquired skills through observation and repeated practice. As abacus manuals show, students learned

¹ Cf. Danna, *The Craft of Indo-Arabic Numerals*, and Høyrup, *The World of the Abbaco*.

² Cf. Kelly and Ó Gráda, “Connecting the Scientific and Industrial Revolutions”; Cormack, Walton, and Schuster, eds., *Mathematical Practitioners*.

³ About 485 practical arithmetic manuals were produced in Italy before 1600. Of these, about half were written in the fourteenth and fifteenth centuries. Cf. Danna, “Elaboration and Diffusion of Useful Knowledge,” 60–70.

⁴ Goldthwaite, “The Practice and Culture of Accounting,” 641–642. Cf. Tognetti, “Una civiltà di ragionieri.”

⁵ Cf. Ulivi, “Scuole d’abaco”; Black, *Education and Society*.

⁶ Papi, “Francescani e matematica,” 197.

⁷ Cf. Biagioli, “The Social Status of Italian Mathematicians.” For a broader discussion of mathematical practitioners and mathematical practice, see Bennett, “Practice and Profession.”

⁸ The introduction to the first printed abacus book, issued in Treviso in 1478, is particularly telling. See Flores D’Arcais, ed., *L’aritmetica di Treviso*, f. 1: “Incommencia una practica molto bona et utile a ciaschaduno chi vuole usare l’arte dela merchadantia, chiamata vulgarmente l’arte de l’abbacho” (Here begins a very good and useful treatise for anyone who wishes to practice the art of commerce, commonly called the art of the abacus).

mathematical craft through the solution of problems – the so-called *ragioni* – drawn from mercantile and artisanal contexts.

To understand this culture and its dynamics, we must consider its main sources: abacus manuals, which offer exceptional insight into the medieval and early modern tradition of practical mathematics. By developing mathematical procedures around problems drawn from everyday commercial and artisanal activities, these manuals transformed mathematical knowledge into an operational tool for acquiring and applying numerical skills. Abacus manuals were social and cultural artefacts in which algorithmic techniques were elaborated in response to concrete practices and, in turn, helped to improve those practices. They were instructional texts whose production formed part of the expansion of technical literatures in the late Middle Ages. Like other vernacular sources – such as mercantile notebooks, recipe collections, and craft books – they raise important questions about the codification and transmission of know-how.⁹ Written by schoolmasters and practitioners, they largely eschewed modern notions of authorship and instead embodied a form of “collective knowledge.”¹⁰ In this sense, abacus manuals sustained practical knowledge across generations while being continually reworked in use.

This paper addresses a simple but often overlooked question: how were abacus manuals made? Focusing on Matteo Cerretani’s *Libro di ragione*, it reconstructs the practices of selection and adaptation through which practical mathematical knowledge was transmitted and reconfigured.¹¹ Cerretani’s manual forms part of a wider network of textual circulation and cultural exchange. After outlining its main characteristics, the paper compares MS Baldovinetti 229 (National Library of Florence) with other Renaissance abacus manuals and integrates archival evidence to reconstruct Cerretani’s socioeconomic and cultural environment. In doing so, it explores the mechanisms through which practical mathematics was produced in vernacular manuals crafted by liminal practitioners such as Cerretani.

Matteo Cerretani and his Libro di ragione: a Renaissance manual of practical mathematics

The ownership note identifies MS Baldovinetti 229 as having been written by the Florentine Matteo Cerretani in Pisa in 1461.¹² The note clearly tells us that “This book belongs to

⁹ On instructional and reference texts see Creager, Grote, and Leong, “Learning by the book.” Cf. Danna’s paper in this volume.

¹⁰ Smith, *From Lived Experience*, 37–39. For a reflection on authorship in practical mathematics texts, albeit in a later context, see Morel, “Five Lives of a *Geometria subterranea*,” 225–228.

¹¹ For a recent discussion of the composite and stratified nature of abacus manuals, see Ceccherini, “Come nasce un libro d’abaco.”

¹² The manuscript is on paper, in quarto, 220x148 mm, and consists of 105 folios. Cf. Van Egmond, *Practical Mathematics*, 132–133.

Matteo di Niccolò Cerretani, written in his own hand in 1461 in Pisa. Whoever finds it is asked to return it, for the sake of God and Saint Nicholas, for it is no small labor to produce such a book.”¹³ The manuscript is a typical Renaissance abacus manual, which Cerretani himself calls *Libro dirittamente di ragione* in the initial religious invocation.¹⁴ The analysis below shows that it was not an entirely original composition, but the result of the compilation and reorganization of previous textual materials. It gathers a wide range of problems (*ragioni*), which can be classified according to Van Egmond’s categories of practical mathematical problems. This typology situates the manuscript within the abacus tradition and clarifies its purpose.¹⁵ Table 1 outlines the structure of Cerretani’s manual, indicating the contents and their corresponding folios.

Before tackling the *ragioni*, the manual introduces Indo-Arabic numerals and explains the four operations with fractions, providing the fundamental tools.¹⁶ As later evidence suggests, Cerretani was both the writer and the primary user of the manual, as was often the case with contemporary vernacular practical texts.¹⁷ After this preliminary section, the manual proceeds to the *ragioni*, presenting them progressively from the simplest to the most complex. It gathers problems involving prices, measurements, and currencies;¹⁸ these are followed by problems on companies, bartering, discounts, and metal alloys, solved using the rule of three and the rules of false position,¹⁹ before moving to algebraic and geometrical problems (Fig. 1v–r).²⁰ The final section is devoted to volumes and quantities, silver and gold coins, and additional geometrical problems.²¹ The organization of the contents points to the manual’s didactic purpose, following a fairly coherent structure with problems presented, as noted above, in increasing order of difficulty. Although this structure may have emerged from the recombination of materials accumulated over time, the resulting text displays a degree of coherence that goes beyond a simple collection of

¹³ BNCF, MS Bald. 229, f. 1r: “Questo lib(r)o è di Mateo di Niccholò Cieretani schrito di xua mano l’anno 1461 a Pisa. Chi llo truova lo renda da parte di Dio e di San Niccholò, ch’è faticha a falgli.”

¹⁴ Ibid. The following invocation is similar to those found in other contemporary texts: “In the name of God and of his glorious mother, the humble Virgin Mary [...] and of all the heavenly court of paradise [...] may he grant that I may be able to write or copy this *Libro dirittamente di ragione*.” (Al nome sia [di Dio e della] sua mad[re] gloriosa e umile vergine M[ari]a [...] e di tutta la santa chorte del pa[radiso] [...] choncedimi ch’io possa schrive(re) overo chopiare q(u)esto lib(ro) dirittamente di ragione).

¹⁵ Van Egmond, “Types and Traditions,” 391–428.

¹⁶ BNCF, MS Bald. 229, ff. 1–22v.

¹⁷ Cf. Creager, Grote, and Leong, “Learning by the book,” 6–10.

¹⁸ BNCF, MS Bald. 229, ff. 22v–43.

¹⁹ Ibid., ff. 43–68v.

²⁰ Ibid., ff. 68v–86v.

²¹ Ibid., ff. 87–105.

heterogeneous materials.²² These remarks will gain further significance shortly, as another abacus book comes into play.

Table 1. The structure of Cerretani's manual

CONTENTS	FOLIOS
Preliminary material: introduction; numeration; <i>librettine</i> ; the four arithmetical operations	1r–21v
Business problems: prices and products via the rule of three	21v–22r
Operations with fractions	22v–27r
Business problems: exchange	27r–28r
Business problems: mensuration, prices and products	28r–33v
Recreational problems: money and number problems	34r–v
Recreational problems: series and progressions, and problems of pursuit	35r–37r
Business problems: exchange	37r–40r
Recreational problems: find a number	41r–v
Business problems: interest	42r–43v
Recreational problems: money problems	44v–47r
Business problems: partnership	47r–49r
Business problems: barter	49r–50v
Business problems: discount	50v–52r
Business problems: alligation	52v–63r
Business problems: equation of payments	63r–65r
Business problems: interest	65r–66r
Business problems: equation of payments	66r–68v
Recreational problems solved by algebra	68v–78v
Geometrical problems: measurement of figures and real objects	79r–85v
Recreational problems	86r–105r

Based on the surviving manuscripts, the text appears to have enjoyed some success within the tradition of practical arithmetic, being preserved in three manuscripts that convey a closely similar text. All three are later versions, dating from around 1465 to 1495.²³ Except for the last, written in Pisa by the merchant Andrea Lanfreducci, all are anonymous

²² About abacus manuscript technology, see Ceccherini, “Come nasce un libro d’abaco.”

²³ In chronological order, these are: BMLF, MS Ash. 353; CU, MSS Plimpton 205, 206. Cf. Van Egmond, *Practical Mathematics*, 78, 266–267.

and compiled by different hands.²⁴ Among them, MS Ashburnham 353 stands closest to Cerretani's manual, matching its structure and its wording, whereas MS Plimpton 206 lacks the geometrical section. The close similarity among these witnesses points to the diffusion of a relatively stable textual core within a network of practitioners – a pattern of standardisation common in fifteenth-century abacus production, as the treatise of the Florentine master Benedetto and an anonymous manual from the first half of the century discussed below attest.²⁵

The existence of multiple versions of the same text, together with the long-term circulation of the autograph across different contexts, raises the question concerning the usefulness of these manuals. Since they often contained commercial information – such as prices, currencies, and weights – that was liable to change over time and from one place to another, one may ask why older copies continued to circulate. Yet this variability did not undermine their usefulness. Although current commercial information was undoubtedly valuable, abacus manuals were intended to teach algorithmic techniques, not to provide up-to-date data. What mattered above all was the acquisition of mathematical skills and the ability to apply them across a wide range of practical situations. The persistence of older versions contributed to the stabilization of a shared body of mathematical knowledge, reinforcing the internal coherence of the tradition.

These later versions suggest that abacus manuals could move beyond their original context of production, reaching individuals engaged in diverse activities and facing comparable computational demands. What might seem a single compilation thus reflects a wider environment of exchange, in which texts functioned as flexible tools within networks of practitioners rather than as fixed and bounded works. Abacus manuals were not primarily aimed at a single social group, but belonged to a broader social *milieu* of practitioners – apprentices, merchants, artisans, and teachers –, the so-called *strato culturale intermedio*, that is, an amphibious sphere of cultural activity situated between artisanal practices and learned culture, and operating across vernacular and Latin.²⁶

Matteo Cerretani belonged to this social and cultural context. Like many *marchands écrivains*, he also worked on manuscripts containing literary and philosophical texts.²⁷ Matteo was born in 1444 into a family with a long-standing tradition originating from the Flo-

²⁴ On Lanfreducci family, see Petralia, *Banchieri e famiglie mercantili*, 191–192.

²⁵ On the basis of the surviving manuscripts – at least eighteen – Benedetto's abacus treatise appears to have been the most widely circulated in the fifteenth century. Cf. Danna, *The Craft of Indo-Arabic Numerals*, 131–132.

²⁶ Maccagni, "Leggere, scrivere e disegnare," 636–638. Cf. Biagioli, "The Social Status of Italian Mathematicians."

²⁷ The following manuscripts can be attributed to Cerretani's workshop: BMLF, Pluteo 90 sup. 135¹; *ibid.*, Laurenziano Gaddi 106; BNCF, MS Fond. Naz. II V 98. I borrow the expression *marchands écrivains* from Bec, *Les marchands écrivains*.

rentine countryside.²⁸ His father, Niccolò, was a prominent politician who held key offices for the Florentine republic, such as *Gonfaloniere di giustizia*, *Priore*, *Gonfaloniere di compagnia*.²⁹ Like his father, Matteo joined the *Arte dei Mercatanti* or *Calimala* in 1471, and around the same time married Ginevra Cambi, daughter of the merchant banker Bernardo. The couple had several children and lived in a house at Canto alla Paglia, near the Baptistry of St. John, together with Matteo's brothers, Paolo and Giovanni, and their respective families.³⁰ Matteo held several public offices: he served as one of the *Buonuumini*, as *Gonfaloniere di compagnia*, and as *capitano* or *podestà* in various towns of the Florentine dominion.³¹ He also held the offices of *Camerlengo del Monte comune* and *Signore della Zecca*, both of which required numeracy.³² This invites the question of whether writing a mathematical manual may itself have enhanced an individual's suitability for such appointments. This hypothesis becomes even more plausible if we consider that abacus manuals are rich in problems involving currencies, exchange rates, and alloy calculations, which were relevant to the circulation of coins and the minting practices. For instance, a typical problem concerning alloying metals (*allegare*) sounds like the following one: "A man has a quantity of metal with an alloy of 10 ounces 16 denari per pound, and he wishes to make a coin alloy of 8 ounces 20 denari per pound; I ask how much copper must be added per pound."³³

Like many young Florentines of his social background, Matteo probably received training in practical mathematics.³⁴ It is nevertheless useful to formulate some hypotheses about it, given the availability of multiple channels of cultural transmission and learning in the Renaissance. When he wrote the manual, Matteo was seventeen. On the basis of the surviving evidence on manuscript ownership, he appears to have been the youngest known writ-

²⁸ Originally from the village of Cerreto, at the foot of Monte Morello, the family settled in Florence at the end of the twelfth century.

²⁹ Niccolò married Averarda Alberti. Niccolò features as a protagonist in Leon Battista Alberti's dialogue *De iciarchia*. Cf. Boschetto, "Note sul *De iciarchia*," 203–215.

³⁰ In 1480, the family numbered fourteen members: see ASFi, Monte Comune, Copie del Catasto, 91, ff. 827r–828r; *ibid.*, 93, ff. 147r–148r.

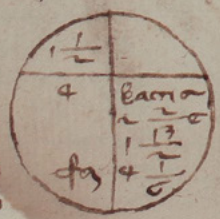
³¹ Among the offices held by Matteo were the *podesterie* of Buggiano (from 20 May 1482) and Montepulciano (from 1 March 1492), the *vicariati* of Certaldo (from 1 July 1495) and Casentino, the *capitanati* of Livorno (from 8 April 1500 and again in 1515), and the *castellania* of the Fortezza Nuova in Volterra (from January 1512). Cf. Papi, "Fra ragioni ed esperienze," chapter 4.

³² On 1 July 1493, Matteo Cerretani began his term as *Camerlengo*, which he held until January of the following year. He also served as *Signore della Zecca* on two occasions, in 1499 and 1518, when he was responsible for the minting of gold coinage. Cf. *ibid.*

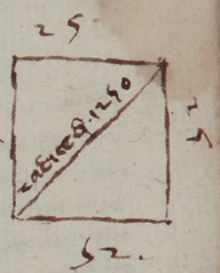
³³ BNCF, MS Bald. 229, f. 58r: "Uno à moneta a llegha di 10 once 16 d(enari) p(er) lib(r)a, vuole fare moneta a llegha di 8 once 20 d(enari) p(er) lib(r)a. Adomando q(u)anto rame bisongnerà giugnere p(er) lib(r)a."

³⁴ On the prominent role of mathematical training in Florence, see Tognetti, "Una civiltà di ragionieri," 237–242, and Black, *Education and Society*, 1–42.

Et si tuone arde. acc. uno. v. r. rondo. g. m. r. v. d. g.
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Et si tuone arde. acc. uno. v. r. rondo. g. m. r. v. d. g.
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Et si tuone arde. acc. uno. v. r. rondo. g. m. r. v. d. g.
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m. e. d. e. p. m. o. f. a. e. d. a. m. a. p. l. a. f. a. c. t. a. a. c. c. p. i. t. v. i. e. n. n.
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Fig. 1r – BNCF, MS Baldovinetti 229, ff. 82r: section on practical geometry. Courtesy of Ministero della Cultura – Biblioteca Nazionale Centrale di Firenze. Any further reproduction by any means is forbidden. È vietata ogni ulteriore riproduzione con qualsiasi mezzo.

er and owner of this type of book, which circulated primarily among abacus masters and practitioners. By that age a young Florentine would normally have completed his schooling and entered an apprenticeship.³⁵ In this sense, the writing of an abacus book may be understood as an exercise in consolidating and reworking the mathematical knowledge acquired as a pupil. It was widely understood that mathematical skills, painstakingly acquired during schooling, could easily be lost without regular practice.³⁶ Copying and rewriting mathematical problems formed part of the learning process itself. Writing was therefore not simply a means of recording mathematical knowledge but one of the most effective ways of acquiring fluency in practice, internalizing procedures, and assessing one's own competence. As Lorraine Daston has argued, "understanding an algorithm means working through it, step by step, with the hand as well as the head."³⁷ By crafting his manual, Matteo Cerretani produced a valuable *aide-mémoire* for the everyday activities in the market and in public offices, while also creating a tool that embodied his expertise. Unlike other abacus manuals, however, Cerretani's book soon passed out of the family's possession, passing into several hands between Florence and Rome.³⁸ Notes added to the first folio attest to its history until the early seventeenth century. In 1502, one of Matteo's sons, Andrea, donated the book to Bernardo Rustici. By 1586, it had come into the possession of Giovanni Scala, and by 1595 it is recorded in Rome as belonging to Giulio Fagni. In the early seventeenth century, the manuscript was owned by the Florentine master Giovanni Silli.³⁹

Cerretani's manuscript was by no means exceptional. Its production and subsequent circulation exemplify key features of the abacus tradition, particularly its distinctive forms of authorship and transmission. Abacus books exhibit little or no authorship, instead constituting a "voice of collectivity" that reflects the cumulative and collective making of practical knowledge.⁴⁰ Individual manuals therefore differed less in the procedures they

³⁵ Cf. Cherubini, "Frammenti di quaderni," 236–242, and Ulivi, "Scuole d'abaco."

³⁶ Contemporaries recognised the demanding nature of abacus training. Referring to his son, an apprentice in Francesco Datini's company, ser Lapo Mazzei urged Datini to allow the boy to continue his mathematical studies, warning that "if he is removed from the abacus now, it will not take a month for him to forget everything, because in that subject, unless one becomes firmly grounded, everything is lost" (Camesasca, ed., *Epistole*, 261). The experience of Guerrieri di Tribaldo Rossi confirms this concern: after seven months of study, an interruption of just one month was enough for him to lose much of what he had learned, and on returning to school he was reassigned to the *librettine* class (see Klapisch-Zuber, "Le chiavi fiorentine di Barbablù," 766–769).

³⁷ Daston, *Rules*, 89. Cf. Danna, Locatelli, "Dalla teoria alla prassi della matematica."

³⁸ Ownership notes are particularly valuable for understanding the purposes and circulation of these sources; they can also shed light on the personalities of their owners and compilers. While some compilers and owners seem eager to guard these texts jealously, others clearly sought their wide diffusion.

³⁹ BNCF, Bald. 229, f. 1r.

⁴⁰ Smith, *From Lived Experience*, 37.

contained than in the ways those procedures were configured. Their aim was not to build a deductive science but to provide useful tools: collections of *ragioni* accompanied by the rules and algorithms required to solve them. The authority of these rules and algorithms rests not on formal demonstration but on their effectiveness in practice. Like recipes, the *ragioni* were presented as sequences of operations to be followed: it was only by repeatedly working through them that pupils gradually assimilated the underlying rules, learned to recognize analogies between different problems, and thereby acquired the ability to transfer the same procedures to new cases.⁴¹ The practical knowledge embodied in these manuals likewise occupied an intermediate epistemic position between handicraft and science, much like the mechanical arts. Abacus manuals thus codified practical mathematics by organising and applying procedures, not through systematic exposition or theoretical demonstration. Yet this mode of learning fostered a distinctive form of generalization: problem solving followed an inductive logic that moved not from particular cases to general principles, but from one particular case to another.⁴²

Let us consider, by way of example, a typical *ragione* drawn from Cerretani's manual. It concerns the so-called rule of three and its application to a business problem involving the price of a given quantity of goods.

When you have to do some *ragione* in which there belong three things, I say that you must take the thing that you ask or wish to know, and then take that which is not similar to the thing you wish to know. And having done this, you must set the one against the other, and the sum that it makes you must divide by the other part, that is, the thing that remains, and what comes out will be the result of what you ask. And below I will give you an example so that you will understand it.

Eight braccia of cloth are worth 11 florins; how much will 97 braccia be worth? You must do thus: the thing that we ask, that is, what 97 braccia will be worth; the thing not similar to the braccia is 11 florins; and therefore you must multiply 11 by 97, which makes 1067 florins; and this 1067 you must divide by 8, and it comes to 133 $\frac{3}{8}$; and so much will 97 braccia of cloth be worth, when 8 braccia are worth 11 florins.⁴³

⁴¹ Cf. Maccagni, "Leggere, scrivere e disegnare," 642–644, and de Beaune, Hilaire-Pérez, and Vermeir, "L'analogie, les techniques et le savoirs."

⁴² Cf. Daston, *Rules*, 57–58, 76–81, 96–97.

⁴³ BNCF, MS Bald. 229, f. 21v: "Quando ài a fare alchuna ragione nella quale s'apartengha 3 chose, dicho che debi p(r)endere la chosa che domandi, overo vuoi sapere, e poi p(r)endere quella che non è similgliante a quella chosa volgi sapere. E fatto questa debi metter l'una chon tro all'altra, e quella soma che fa debi partire nell'altra parte, overo chosa che t'è rimasto, e quello che ne verà sarà l'efetto di quello domandi e qui apresso te ne darò essenpro p(e)r modo lo 'ntenderai. Otto b(r)accia di panno valgliono 11 fl, che verano 97 b(racci)a[?] Devi chosi fare: la chosa che nnoi dimandiamo sie che varanno 97 b(racci)a; la chosa non similgliante a le

According to Michael Baxandall, fifteenth-century practitioners faced a “formidable confusion” of problems arising from everyday commercial life. The rule of three provided a common computational procedure that reduced this diversity to a common proportional structure, allowing the fourth quantity to be calculated from three known ones. Indeed, “in late medieval and early modern commercial arithmetic, the most frequently used of all reckoning rules was the Rule of Three.”⁴⁴ In the present example, the problem can be expressed as a simple proportion: if 8 *braccia* of cloth are worth 11 florins, what is the value of 97 *braccia*? In modern notation:

$$\frac{8}{11} = \frac{97}{x}$$

The unknown is therefore obtained from the following operation:

$$x = \frac{97 \times 11}{8}$$

Cerretani's Manual in Context

The comparative analysis that follows suggests that the *Libro di ragione* should not be understood simply as a repository of algorithmic procedures. Rather, its organisation reveals how inherited mathematical materials could be selected and recombined into a coherent manual for teaching and practical use. Historical and comparative evidence indicates that Cerretani's manuscript drew on previous texts, one of which can be identified as a school manual written by an abacus master.

When he wrote his manual, Matteo was in Pisa and probably working as an apprentice to his uncle Rosso Cerretani, who was active in the leather trade.⁴⁵ The Cerretani family had enduring ties with Pisa that spanned several generations, including Matteo's grandfather, father, uncles, and brother.⁴⁶ Among them, Niccolò Cerretani, Matteo's father, maintained particularly close connections with the city. He served as captain of Pisa in 1466 and was repeatedly involved in organising the voyages of the galleys: first as *conductor* of the ships sent to Flanders and England (October–November 1441), then as patron of the

b(racci)a sie 11 fl e però debi multiprichare 11 vie 97, fa 1067 fl, e questo 1067 à a partire in 8, vienne 133 3/8 e ttanto varanno 97 braccia di panno valendo 8 braccia 11 fl.”

⁴⁴ Baxandall, *Painting and Experience*, 96; Daston, *Rules*, 57.

⁴⁵ See ASFi, Catasto 825, f. 51r. Rosso was most likely already in Pisa before 1451: see ASFi, Catasto 715, I, f. 231v. By 1469, Rosso was still living in Pisa in a “house with a garden and a small attached dwelling,” which he held from the friars of Nicosia, paying an annual rent of 12 pounds of candles: see ASFi, Monte Comune, Copie del Catasto 91, f. 127r; ASPi, Gabelle dei contratti, reg. 16, f. 40v.

⁴⁶ In 1427, Matteo's grandfather was appointed *Provveditore della gabella*, a post he held for two years (see Boschetto, “Note sul De iciarchia”). Matteo's brother Giovanni taught civil law from 1483 to 1488 (see Verde, *Lo Studio fiorentino*, 451–453).

galleys that sailed from the port of Livorno in April 1443 for Catalonia and Sicily, afterwards as *Console del Mare* (1458); and finally, as captain of the galleys sailed for Flanders and England (October–April 1459–1460) and for Catalonia and Sicily (March 1470).⁴⁷ Against this background, Matteo – born in 1444 – was probably educated in Pisa, where several abacus masters were active.⁴⁸ It is therefore to the manual of one of these masters that we must turn our attention.

The most likely candidate is the manual written by the Pisan master Cristofano di Gherardo Cevoli, a source well known to scholars of abacus mathematics. It conveys a didactic programme probably adopted in his school and a vernacular translation of Fibonacci's *Practica geometriae*.⁴⁹ Its first section, the *Libbro d'abaco*, gathers a collection of *ragioni* with a stronger didactic emphasis.⁵⁰ An ownership note allows the manuscript to be dated to 1441.⁵¹ Cristofano began his career as master later, after serving in the Pisan army; he probably taught mathematics until his death, which occurred between 1454 and 1455.⁵² Matteo Cerretani may have attended his school or studied under one of his pupils, since abacus manuals “had several generations of users as their audience.”⁵³ The available evidence, however, points more strongly to a connection through Matteo's father, Niccolò, within the Pisan maritime *milieu*.⁵⁴ Three annotations in Cristofano's manuscript indicate that the master's son, Dino, took part in two maritime expeditions in 1442 and 1443, making it plausible that he came into contact with Niccolò Cerretani.⁵⁵ This provides a plausible explanation for how Niccolò – and, through him, Matteo – may have gained access to Cristofano's manual.

Comparison with Cristofano's manual demonstrates that Cerretani's *Libro di ragione* drew extensively on the master's collection of *ragioni*. The sequence of problems is in fact almost identical in the two manuscripts, as shown in Table 3. Table 2 illustrates both the

⁴⁷ Cf. Boschetto, “Note sul De iciarchia,” 205–206.

⁴⁸ Cf. Ulivi, “Su Leonardo Fibonacci,” 271–282.

⁴⁹ Fibonacci, *La pratica di geometria*.

⁵⁰ BRF, MS Riccardiano 2186, ff. 9r–80v. For a description see Van Egmond, *Practical Mathematics*, 147–148. Cf. Danna, *The Craft of Indo-Arabic Numerals*, 101.

⁵¹ BRF, MS Ricc. 2186, f. 9r. Cf. Fibonacci, *La pratica di geometria*, 8. The date in the manuscript follows the Pisan style; thus, 1 May 1442 corresponds to 1 May 1441 in modern reckoning.

⁵² Ulivi, “Su Leonardo Fibonacci,” 278. But I found a certain “Cristofoni Ceuli, civis et mercator pisanus,” involved in an act dated 1467: see ASPi, Gabelle dei contratti, reg. 16, f. 17r.

⁵³ Danna, *The Craft of Indo-Arabic Numerals*, 103.

⁵⁴ About this *milieu* see Mallett, *The Florentine Galleys*.

⁵⁵ BRF, MS Ricc. 2186, f. 131v. For a transcription of the annotations, see Fibonacci, *La pratica di geometria*, 9. Although the year is only partially legible and was read by Arrighi as 1448, the chronology adopted here is based on the identification of the officials named in the annotations – Giovanni Bandini and Giovenco (rather than Francesco, as transcribed by Arrighi) della Stufa – with the Florentine galley voyages reconstructed by Mallett, *The Florentine Galleys*, 159.

close textual affinity between the two manuscripts and their principal differences, which are chiefly linguistic, reflecting the Pisan vernacular of the former and the Florentine vernacular of the latter. It reproduces two corresponding *compagnia* problems concerning partnership contracts.

Table 2. Partnership problem

Cristofano, f. 20r
Two men do a partnership together and find that they have made a profit of £100. The first invested 17, the second 41. I ask how much each should receive. You must proceed as follows: add together the capital of the partnership, namely 17 and 41, which makes 58, and this is the divisor. Now, to determine the share of profit due to each. To find what is due to the first, you must multiply his capital by the profit, that is, 17 by 100, which makes 1700; divide this by 58, and it yields £29 s. 6 d. 2 14/29, and this is what is due to the first, namely to him who invested 17. Now see what is due to the second: multiply 41 by £100, which makes 4100; divide this by 58, and it yields £70 s. 13 d. 9 15/29, and this is what is due to the second. Thus we have that the first receives £29 s. 6 d. 2 14/29 and the second £70 s. 13 d. 9 15/29. If you wish to check it, add together £29 s. 6 d. 2 14/29 and £70 s. 13 d. 9 15/29, and you will find that they make exactly £100, which is correct. ⁵⁶
Cerretani, f. 47r
Two partners do a partnership and find that they have made a profit of £100. The first invested 17, the second 41. I ask how much each should receive. You must proceed as follows: add together the capital of the partnership, namely 17 and 41, which makes 58, and this is the divisor. Now, to determine what is due to the first, you must multiply what he invested by what has been gained, that is, 17 by £100, which makes £1700; divide this by 58, and it yields £29 s. 6 d. 2 14/29, and this is what is due to the first, that is, to him who invested £17. Now see what is due to the second: you must multiply what he invested by what they have gained; thus multiply 41 by £100, which

⁵⁶ BRF, MS Ricc. 2186, f. 20r: “Due homini fan(n)o compagnia i(n)sieme e trovansi avere ghuadagnato £ 100. Il p(r)imo misse 17, il secondo 41. Adima(n)do quanto toccherà per uno. Dei fare cosi: agiungie i(n)sieme il co(r)po della compagnia, cioè 17 e 41, fa 58, e questo è il pa(r)titore. Ora, p(er) vedere quello toccha di ghuadagnio a ciaschuno. Ora, p(er) vedere q(ue)llo che ne toccha al p(r)imo, dei mult(iprichare) lo suo capitale contra lo ghuadagnio, cioè 17 via 100, che fa 1700, e q(ue)sto pa(r)te i(n) 58, viene £ 29 s. 6 d. 2 14/29, e cotanto toccha al p(r)imo, cioè a colui che misse 17. Ora vedi quello che toccha al s(econd)o: mult(ipricha) 41 via £ 100 fa 4100, pa(r)te i(n) 58 ne viene £ 70 s. 13 d. 9 15/29, e tanto toccha al s(econd)o. Et abbiamo che al primo toccha £ 29 s. 6 d. 2 14/29 e al s(econd)o toccha £ 70 s. 13 d. 9 15/29. Se la vuoi p(ru)ova(re) giu(n)gie i(n)sieme £ 29 s. 6 d. 2 14/29 co(n) £ 70 s. 13 d. 9 15/29 e troverai di punto faran(n)o £ 100 e sta bene.”

makes £4100; divide this by 58, and it yields £70 s. 13 d. 9 15/29, and this is the profit due to the second. Thus we have that the first receives £29 s. 6 d. 2 14/29 and the second £70 s. 13 d. 9 15/29. If you wish to test it, add together what falls to each and see whether it amounts to £100.⁵⁷

The problem concerns the division of profits between two partners according to shares (*Adomando quanto tocherà per uno*). Here too, proportion plays a central role. One notes the profit (100 £) and the investment of each partner (17 £ and 41 £), then calculates the capital of the partnership by summing the investments (58 £), and finally determines the profit due to each partner by means of a simple proportion, that is, in modern notation:

$$\frac{17}{58} = \frac{x}{100} ; \frac{41}{58} = \frac{x}{100}$$

The first forty-one folios of Cerretani's manual correspond very closely to Cristofano's *Libbro d'anbaco*, both in the sequence of *ragioni* and in their textual formulation. At the same time, the selective reuse and adjustments point to a process of appropriation and reorganisation rather than mechanical copying. Alternative algorithms are occasionally introduced: for instance, two methods are provided to calculate the florin value of £3250, whereas Cristofano uses a different one.⁵⁸ Elsewhere proofs (*prove*) are added – not formal demonstrations but practical procedures for checking the correctness of a result – as in a problem involving the loan of a sum of money: «The £ is lent at 3¼ d. per month; I ask, in how much time do £128 yield £12 16 s. 8 d.[?]».⁵⁹ In problems involving alloying and the Florentine *popolino*, additional explanations absent from Cristofano's text are introduced.⁶⁰ Cerretani also makes occasional copying errors, as in a problem on the equation of payments, where he writes £100 instead of 1000, while keeping the other figures unchanged.⁶¹ Moreover, some *ragioni* are omitted, such as the problem concerning the “man who lends to another a chest full of grain.”⁶²

⁵⁷ BNCF, MS Bald. 229, f. 47r: “2 chompag(n)i fanno chompangnia e truovansi ghuadagnato 100 £. El primo misse 17, el sichondo misse 41. Adomando quanto tocherà per uno. Desi chosi fare: raggiunni insieme el chorpo della chompangnia, cioè 17 e 41, fa 58, e questo è 'l partitore. Ora, p(er) vedere quanto tocha al p(rim)o debbi multip(r)ichare quello misse chontro a quello à ghuadagnato, cioè 17 vie 100 £, fa 1700 £ e questo parti in 58, viene 29 £ 6 s. 2 d. 14/29 e chotanto tocha al primo, cioè a chi misse 17 £. Ora, vedi quanto toccha al sechondo: debi multip(r)ichare quello misse chontra a quello à ghuadagnato, p(er)ò multip(r)icha 41 vie 100 £, fa 4100 £, e questo parte in 58, viene 70 £ 13 s. 9 d. 15/29 di denari, e chotanto tocha di ghuadang(n)o al sichondo. Abbiamo che al p(rim)o tocha di ghuadang(n)o 29 £ 6 s. 2 d. 14/29, e al sichondo tocha di ghuadang(n)o 70 £ 13 s. 9 d. 15/29. E se lla vuoi p(r)ovare raggiungi insieme quello tocha a ciaschuno e vedi se ffa 100 £.”

⁵⁸ BNCF, MS Bald. 229, f. 39v–40r; BRF, MS Ricc. 2186, f. 17v.

⁵⁹ BNCF, MS Bald. 229, f. 42r.

⁶⁰ Ibid., ff. 58v, 62r–v.

⁶¹ Ibid., f. 66r.

⁶² BRF, MS Ricc. 2186, f. 35r.

Yet there is more. It is possible to trace the connection between these manuscripts further back in time, to an anonymous manuscript compiled in Lucca in the mid-fourteenth century.⁶³ References to this city in several problems of Cerretani's manual and Cristofano's first prompted comparison with this text, already edited by Gino Arrighi.⁶⁴ However, as shown in Table 3, the body of the Lucca manuscript was reorganized. For instance, some bartering problems in the final part of the Lucca text (ff. 73–75) appear in the core sections of Cristofano's and Cerretani's manuals (ff. 20v–22; ff. 48v–52). Conversely, the latter include sections absent from the Lucchese manual, such as problems on the equation of payments (ff. 89r–92r), discounts (92v–93v), and valuation of silver and gold in different places (ff. 94v–95r). A further divergence concerns the figures themselves, which do not always match: for example, a problem may give 12 denari instead of 14, or assign a different value to the florin. Proofs found in Cerretani and Cristofano are sometimes absent from the Lucchese manuscript, and vice versa, as in the section on the application of the rule of double false position (ff. 31r–32v).⁶⁵

Another similar text can be placed in Pisa between the Lucchese manuscript and Cristofano's, suggesting an intermediate stage in the transmission. This is MS 41.38, preserved in the Archiepiscopal Library of Pisa and written in the early fifteenth century.⁶⁶ The manuscript contains a text closely related to those examined here, especially to Cristofano's manual, and thus to Cerretani's. Set against these sources, MS 41.38 is more extensive in some sections, most notably in the section on the equation of payments (ff. 63r–77v), while omitting others, such as the *Ragione di marchi d'ariento* and the *Ragione d'oro*.⁶⁷ Since this manuscript belonged to the Rossellini, a Pisan family with connections to Lucca, it may have provided one channel by which problems of the Lucchese tradition entered the Pisan milieu.

As the evidence discussed here points primarily to a Tuscan network linking Lucca, Pisa, and Florence, it also reveals a broader pattern within the abacus culture. Practical mathematics developed cumulatively by successive acts of selection and recombination, not through linear textual descent.⁶⁸ Abacus manuals were therefore not transmitted as fixed texts, but continuously reworked by reconfiguring clusters of problems already circulating within the tradition. Viewed through the lens of artisanal epistemology – that is, a

⁶³ BSL, MS 1754. For a description see Van Egmond, *Practical Mathematics*, 163–164.

⁶⁴ Arrighi, ed., *Scuola lucchese. Libro d'abaco*.

⁶⁵ BNCF, MS Bald. 229, ff. 46v–47v; BRF, MS Ricc. 2186, f. 21r–v.

⁶⁶ BAP, MS 41.38. Cf. Galoppini, “Ti mosterò simiglianti ragioni.” The manuscript also includes a *pratica di mercatura*, currently being edited for publication by Laura Galoppini and Andrea Bocchi.

⁶⁷ BRF, MS Ricc. 2186, f. 41r–v; BNCF, MS Bald. 229, ff. 94v–95r.

⁶⁸ A comparable case of circulation can be observed in the transmission of a Florentine abacus manual between Florence and Faenza, suggesting that similar processes of transmission and adaptation extended beyond the Tuscan context. Cf. Papi, “Note su un libro d'abaco.”

form of knowledge grounded in practice and in the effectiveness of procedures rather than theoretical demonstration – these findings shift attention from questions of originality, innovation, and authorship to the social practices that shaped and transmitted mathematics.⁶⁹ The comparison thus serves as a heuristic tool. Its value lies not in reconstructing a straightforward line of textual descent, but in identifying shared textual units whose different configurations reveal processes of selection, recombination, and adaptation. Table 3 presents these parallel sections across the manuscripts of Cerretani, Cristofano, Rosselmini, and Lucca; folio references are provided for each section.

Table 3. Parallel sections

Lucchese 1350 ca.	Rosselmini 1410 ca.	Cristofano 1441	Cerretani 1461
			1r–21r
1r–7r		9r–14r	21v–31v
	≈ 6v–13v	14r–16r	32r–37r
≈ 11v–33v	≈ 25r–44v	16r–21r	37v–48r
≈ 73r–75r	≈ 57v–63r	21r–22r	48v–52r
37r–44v	45v–57v	22r–25v	52v–62v
	≈ 63r–77v	25v–28r	63r–68r
≈ 81r–v	77v–95r	28r–32v	68v–78v
	95r–105r	32v–38r	79r–88v
		38r–41v	89r–95r
			95v–105r

Arranged chronologically, the table makes the cumulative development of the tradition more readily visible. Earlier textual blocks are generally retained, while later manuscripts tend to introduce additional sections and recombine inherited material. Cerretani's manual illustrates this cumulative dynamic particularly well. While the other manuscripts lack an introductory section, Cerretani's manual includes one (ff. 1r–21r). It opens with a presentation of the Indo-Arabic numerals, followed by the multiplication tables – the so-called *librettine maggiori e minori* – and the operations of multiplication and division. This section resembles that of other manuscripts from the first half of the fifteenth century. It is particularly close to the introductory section of the *Ragioni appartenente all'arismetricha*, a Florentine text that circulated widely from around the 1430s.⁷⁰ This text represents a paradigmatic

⁶⁹ Cf. Smith, "Epistemology, Artisanal."

⁷⁰ The earliest surviving manuscript, anonymous, is preserved in BNCF, MS Magl. XI 119. Other manuscripts transmit more or less the same text, including BMLF, MSS Ashb. 343, Ashb. 608; BL, MSS Add. 8784, Add. 10363; and BNF, Ital. 463. Cf. Van Egmond, *Practical Mathematics*, 375.

Florentine abacus manual, whose standardised structure influenced later texts which were organized as follows: a presentation of the positional numeral system, followed by operations and fractions, sections dealing with practical applications of rules, and additional sections involving algebra and geometry.⁷¹ The explanation of the Indo-Arabic numerals found in this text was especially influential and appears in numerous fifteenth-century manuals: “Since there are nine figures in the abacus, by which whoever knows them will easily come to know the others, and since they must be learned, I shall first set out these nine and write above them what they are.”⁷² The presence of this introductory section makes the manual more self-contained, as it includes elementary notions and techniques that masters could otherwise leave implicit. Unlike Cristofano’s manual, Cerretani’s makes these basic notions explicit, thereby providing a more comprehensive point of entry into the text. This addition reflects the ways in which inherited materials could be reorganized and extended to create a more comprehensive pedagogical handbook.

In some sections, the manuscript departs from earlier models by adding new material. In particular, it contains a series of recreational problems found neither in Cristofano’s text nor in the other manuscripts considered here. These problems deal with a variety of situations, such as finding an unknown number or quantity, dividing numbers or sums of money, and similar tasks. A typical *ragione* from this final miscellaneous section (ff. 95v-105r) concerns the division of an inheritance, a problem with a long history that already appears in the collection of Alcuin of York and subsequently became widespread in European mathematical literature.⁷³ Although miscellaneous sections are also found in the other manuscripts, the problems collected here do not correspond to those preserved in the surviving witnesses examined above. This divergence suggests that the final section

⁷¹ Cf. Danna, *The Craft of Indo-Arabic Numerals*, 142–143.

⁷² BNCF, MS Magl. XI 119, f. 10r: “Con ciò sia cosa che sono nove figure nell’abacho p(er) le quali chi conoscie q(u)elle agievolmente conoscerà poi l’altre e anche si vogliono imparare, io inporrò p(r)ima quelle nove e di sopra iscriverò quelle che sono.”

⁷³ Cf. Alcuino, *Problemi per rendere acuta la mente dei giovani*, 20–21; Van Egmond, “Types and Traditions.” BNCF, MS Bald. 229, ff. 104v-105: “A man, at the point of death, [leaves money to his sons.] To the youngest he says: ‘Go to the chest and take 1 florin, and also one ninth of what remains.’ To the next he says: ‘Go and take 2 florins, and one ninth of what remains.’ To another he says: ‘Go and take 3 florins, and one ninth of what remains.’ And so on, for as many sons as he has, increasing each time by 1 florin and one ninth of what remains, as with the others. In the end, each is found to have received the same amount. I wish to know how many sons there were and how much money he had.” (E’ gli è uno che viene a morte, e à figliuoli. Al minore dicie: va’ in sul chasone piglia 1 fl. di q(u)egli vi sono el 1/9 di ciò che vi rimane. E all’altro dicie: va’, tone 2 el 1/9 di ciò che vi rimane. E all’altro dicie: va’, tone 3 el 1/9 di ciò che vi rimane. E cchosi a quanti figliuoli gli resta viene di ghrado in ghrado chresciendo 1 fl., el 1/9 di ciò che vi rimane chome gli altri insieme si truova tanti d. l’uno q(u)anto l’altro. Volglio sapere q(u)anti figlioli e q(u)anti d. aveva.)

was not simply drawn from the tradition examined here but reflects a further stage of selection and rearrangement. It remains unclear whether these recreational problems were introduced by Cerretani himself or reached him through intermediary sources. Their pedagogical purpose nevertheless appears quite clear, since they assemble a miscellaneous set of exercises that draw on techniques developed throughout the manual.

Against this comparative background, Cerretani's manual appears less as an isolated work than as one instance of a wider textual tradition. As one instance of this corpus, it reveals how mathematics circulated through the transmission of earlier materials. From this perspective, the historical significance of these manuscripts lies less in their originality or innovation than in what they disclose about the cumulative processes through which mathematical practices were transmitted and reconfigured.⁷⁴ The comparison further suggests that practical mathematics emerged less from the invention of new procedures than from the compilation and adaptation of inherited ones. In this sense, writing an abacus manual was itself a mode of knowledge-making: a practical activity of organising, refining, and making mathematical know-how ready for use.

Concluding remarks

The case study highlights how abacus manuals were produced and transmitted across generations of practitioners, pointing to their broad and enduring diffusion. These manuscripts were not passive records but emerged from successive acts of compilation that recombined problems into new textual configurations. What emerges is a tradition sustained by interconnected communities of practitioners, where problems, techniques, and solutions were exchanged across trading zones. As has recently been observed for practical mathematics manuals more generally, writing a manual often meant bringing together, selecting, and improving existing solutions to a common set of problems.⁷⁵ Cerretani's manuscript exemplifies this process. Its significance lies in the particular textual form through which it organized a body of mathematical knowledge into a coherent manual for learning and calculation. Much as an artisan arranges the tools of his craft, the compiler reshaped earlier materials, producing a text that functioned simultaneously as a tool for calculation, a support for learning, and a marker of expertise.

Seen in this light, abacus manuals appear less as derivative compilations than as crafted artefacts. Their construction cannot be separated from their use: writing problems were themselves ways of doing mathematics. The persistence of shared structures and recurring problems does not point to inertia, but to a pedagogical setting oriented towards the acquisition of transferable techniques and the recognition of patterns across heterogeneous

⁷⁴ Cf. Danna, *The Craft of Indo-Arabic Numerals*, 14.

⁷⁵ Ibid., 290–291, and Morel, “Five Lives of a *Geometria subterranea*,” 250–251.

situations. Abacus mathematics thus emerges not as a simplified form of knowledge, but as a distinct form of mathematical practice, grounded in use, shaped by concerns for effectiveness, and embedded in specific social and cultural contexts. Its procedures relied not on formal demonstration, but on analogy, iteration, and the flexible application of rules. Cerretani's *Libro di ragione* therefore offers more than a local case study. It provides a window onto a wider tradition of practical mathematics, in which knowledge was crafted by assembling, adapting, and transmitting common procedures. Reconsidering these sources in such terms means recognising abacus manuals not as marginal by-products, but as central sites of practical knowledge, where doing mathematics meant, above all, making it through writing.

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 Monte Comune, Copie del Catasto, regg. 91, 93
- ASPi = Pisa, Archivio di Stato
 Gabelle dei contratti, reg. 16
- BAP = Pisa, Biblioteca Arcivescovile
 MS 41.38
- BL = London, British Library, MSS Additional 8784, 10363
- BMLF = Firenze, Biblioteca Medicea Laurenziana
 MS Ashburnhamiano 353
- BNCF = Firenze, Biblioteca Nazionale Centrale
 MS Baldovinetti 229
 MS Magliabechiano XI 119
- BNF = Paris, Bibliothèque nationale de France, Italien 463, <https://archivesetmanuscrs.bnf.fr/ark:/12148/cc9536h?collect>
- BRF = Firenze, Biblioteca Riccardiana
 MS Riccardiano 2186, <http://teca.riccardiana.firenze.sbn.it/index.php/it/?view=-show&myId=945afe40-f4a5-4357-b6c9-acec54d4c693>
- BSL = Lucca, Biblioteca Statale
 MS 1754
- CU = New York, Columbia University
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Practical mathematical knowledge in early modern Verona: Feliciano, Tartaglia and interdisciplinary exchange

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Abstract

This article examines how practical mathematical knowledge was shaped through interactions between abbaco mathematicians and other expert practitioners in early sixteenth-century Verona. During the 1520s and 1530s, the Veronese abbaco masters, Francesco Feliciano and Niccolò Tartaglia both taught practical mathematics, undertook consultancy, and developed successful printed works while working in the city. Through comparing their practices, publications, and professional networks, I argue that the differing communities they engaged with shaped not only the problems they addressed, but also the values they promoted. Feliciano's surveying activities fostered process-based forms of knowledge directed toward reliability, fairness, and practical competency, while Tartaglia's engagement with military practitioners encouraged ambitious approaches to motion and theory, with a focus on ingenuity and innovation. Their frontispieces similarly show both a shared image of mathematical expertise and a divergent reach in epistemic ambition. In this way, I show that exchange across professional worlds was not incidental, but integral to the production of abbaco knowledge.

Keywords

practical mathematics, Niccolò Tartaglia, Francesco Feliciano

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Introduction

Recent scholarship on Renaissance and early modern science has increasingly emphasised the role of practice, material engagement, and social interaction in the formation of knowledge. Rather than treating knowledge as separate from practice, historians have shown how it evolved through use, in turn shaped by the routines of work, the demands of specific tasks, and exchanges between practitioners working across different social and professional settings. This approach has been particularly productive for the study of early modern mathematics, where attention to practical calculation and geometric visualisation has revealed the central epistemic role of artisans and non-elite experts.¹ More recently, scholars have emphasised the importance of reconstructing practical knowledge as it moved from lived experience into written form, as embodied techniques were stabilised and reformulated in procedures, diagrams, and printed texts.²

This article examines these processes through a focused study of practical mathematical knowledge in early sixteenth-century Verona, integrating social history, intellectual history, and material culture. During the 1500s, Verona was a key city in the *terraferma*, or mainland territories, of the Venetian Republic. As an important centre of trade, grain production, and military defence, it depended on increasingly sophisticated forms of commercial and practical mathematics. In the cities of central and northern Italy, such skills were cultivated through the *abbaco* tradition, whose history extended to the early 13th century works of Leonardo Fibonacci. In popularising Hindu-Arabic arithmetic and mathematical problem solving, particularly in the merchant world, Fibonacci helped launch a long-standing program of practical mathematical education throughout the Italian peninsula.³ By the early sixteenth century, commercial mathematics was taught in a network of public and private schools, where children of merchants, landowners, and artisans learned calculation, bookkeeping, and applied problem-solving, often alongside basic literacy. These schools were led by *maestri d'abbaco*, who rarely confined their activities to teaching alone. In addition to instruction, *abbaco* teachers often competed in mathematical contests, delivered public lectures, and acted as consultants on problems of trade, valuation, measurement, surveying, and other practical affairs.⁴ As a result, these non-university educated practitioners occupied an unusual social position. Able to move between multiple professional worlds, they were well placed to translate practical and embodied forms of expertise into more stable textual and visual forms.

¹ Cormack, “The Role of Mathematical Practitioners”; Cormack et al., *Mathematical Practitioners and the Transformation of Natural Knowledge*, vol. 45; Lefèvre et al., *The Power of Images in Early Modern Science*.

² Smith, *From Lived Experience to the Written Word*; Jardine, “The Book as Instrument.”

³ For more on Fibonacci and the commercial revolution of the 13th and 14th centuries, see Danna, “Leonardo Fibonacci”; Danna, “The Spread of Hindu-Arabic Numerals,” 61–66.

⁴ Høytrup, *The World of the Abbaco*; Grendler, *Schooling in Renaissance Italy*.

In the 1520s and 1530s, Verona's two main schools of practical mathematics were led by Francesco Feliciano (c.1470–1542) and Niccolò Tartaglia (c.1499–1557). Both were recognisably formed within standard *abbaco* practice. Each taught practical mathematics, cultivated their reputations through mathematical competition, worked beyond the classroom as consultants, and drew on their practical mathematical expertise in print. Yet neither was wholly typical of the profession at large. At the more ambitious edge of *abbaco* culture, they both became well known for their consultancy work and achieved an unusual degree of success in publication. While Tartaglia's works, including *Nova scientia* (1537) and *Quesiti et inventioni diverse* (1546), have attracted sustained attention from historians of science, Feliciano's more conventionally *abbaco*-oriented texts, the *Libro de abbacho* (1517) and *Scala Grimaldelli* (1526), have received far less scrutiny, despite their considerable success over an extended period.

This article is divided into two main parts. The first situates Verona within the Venetian Republic in the early sixteenth century, outlining the city's economic and military significance and the role of *abbaco* mathematics within its educational and professional landscape. It also introduces Feliciano and Tartaglia as coexisting practitioners in Verona between approximately 1517 and 1534. The second part turns to a comparative analysis of their practices, examining their interactions with different expert communities, their printed texts, and the contrasting epistemic ambitions embedded within their work. While Feliciano and Tartaglia worked alongside one another as Veronese *abbaco* masters for well over a decade, their surviving texts articulate notably different forms of practical mathematical knowledge. I propose these differences were shaped not simply by individual ability or intellectual ambition, but by sustained interaction with different practitioner communities in the period prior to their publication.

Feliciano's consultancy work involved quantity and land surveying, during which he interacted primarily with merchants and landholders. While this work involved variable measures and the need for expert judgement, it also depended on recognised procedures, and authority largely rested on reliability, fairness, and practical competence. In contrast, Tartaglia's first publication emerged from his engagement with practitioners in the rapidly developing world of the military arts. The different communities they engaged with prove important in at least three ways. Military interaction exposed Tartaglia to problems of motion that were less easily contained within the regular procedures of *abbaco* mathematics, brought him into contact with practitioners interested in pursuing more abstract mathematical analysis, and opened up a broader horizon of advancement, including drawing the attention of military elites and powerful patrons. Perhaps most importantly, the military arts provided a context in which speculative ingenuity and mathematical novelty were more readily treated as virtues. In a field being transformed by technological innovation and the increasingly elite status of military leaders, mathematical novelty was less likely to be viewed as a departure from practical usefulness, but as a mark of superior expertise.

At the same time, Feliciano and Tartaglia did not develop their ideas in isolation from each other. Working in the same city, they encountered overlapping communities of practitioners and participated in a shared abbaco culture. While direct evidence for their close relationship remains limited, I suggest Tartaglia's recounting of multiple exchanges with Feliciano, in which he refers to him as "my maestro,"⁵ as well as notable affinities in the ways they envisioned the value of mathematics, suggests a stronger relationship than has usually been recognised. In this way, the works of Tartaglia and Feliciano register both similarity and divergence, revealing how a shared abbaco environment could be developed in markedly different directions. In this sense, mathematical knowledge in use was not simply adapted to social settings after the fact, it was constituted through them, taking different shape as it moved across mercantile, agricultural and military worlds.

Part 1. Verona and practical mathematics

In the sixteenth century, Verona occupied a significant position within the terraferma of the Venetian Republic. Nearing 50,000 inhabitants, the city's population almost matched that of Florence, and it had become critical to trade, food supply and the defence of Venice itself.⁶ Since the late fifteenth century, maintaining these functions required increasingly sophisticated techniques of calculation, measurement, and technical problem-solving, which, in turn, raised the profile of practical and commercial mathematics.⁷ One domain in which these demands were deeply embedded was commerce. Located on major overland routes linking Venice with Milan and northern Europe, Verona's importance to the Venetian Republic was closely tied to its position as a corridor for the movement of goods, money, and information.⁸ By the late fifteenth century, this position supported an active merchant community whose activities connected rural producers with urban markets and long-distance trade in agricultural goods and textiles such as woollen cloth and, increasingly, silk textiles. Commercial practice in this setting involved a wide range of mathematical tasks, including currency conversion, partnership accounting, credit management, pricing, and profit calculation. As trade expanded and transactions became more complex, demand grew for expert practitioners able to apply mathematical techniques across different commercial contexts.

Trade and commerce were closely connected to Verona's role in agricultural administration. The city of Venice lacked arable land and depended increasingly on mainland

⁵ Tartaglia, *Quesiti et inventioni diverse*, bk. 9 qn. 9, "Mo maestro."

⁶ Knapton, "The Terraferma State," 88; Farrell, "Connections and Community," 4.

⁷ For more on the spread of abbaco beyond commerce, see Danna, "The Spread of Hindu-Arabic Numerals," 66–68.

⁸ Black, *Early Modern Italy*, 37.

territories for food supplies, including Veronese grain.⁹ This dependence placed pressure on cities such as Verona to organise production, oversee estates, and manage irrigation to regulate water distribution across cultivated land.¹⁰ The planning, construction, and maintenance associated with these systems required skills in mathematically-based problem solving. At the same time, a large share of Venetian state revenue came from land-based taxes assessed on agricultural output.¹¹ Managing both food supply and state income required systematic measurement, as land needed to be surveyed and divided, harvests estimated, and storage and transport capacities calculated, making mathematical expertise increasingly central to the effective functioning of Verona's agricultural systems.

Perhaps most dramatic was the increased demand for specialist mathematical skills generated by Verona's importance to Venetian military efforts. The War of the League of Cambrai (1508–1516) exposed deficiencies in Venetian defences, particularly during the period when Verona fell out of Venetian control. After the city was recovered, Venice invested heavily in fortifications across the *terraferma*, and Verona became a central site for military planning and construction. The city's *castelvecchio* served as a base for the training and lodging of troops as the Venetian republic developed a standing army that was to become one of the strongest across Italy.¹² These local projects coincided with rapid changes in European artillery, as the development of mobile cannonry opened new possibilities for attack and increased firepower proved too strong for standard fortifications.¹³ Designing more effective defensive structures required careful measurement, geometrical planning, and proportional calculation, making mathematical skills an increasingly essential component of military practice.¹⁴ As Brioiist has put it, "military expertise had never been so precious and warfare so technical."¹⁵ Like changes in other early modern cities, Verona's growing importance to Venice in trade, agricultural administration, and military defence intensified requirement for specialised knowledge in commercial and practical mathematics and elevated mathematical expertise from a routine skill to a valued form of professional competence.¹⁶ These demands were met within an already developed educational landscape. By the late fifteenth-century, Verona supported an established culture of *abbaco* teaching directed toward transmitting the skills needed for trade and practical affairs, as well as consultants able to provide expert mathematical advice when required. It was within this local environment that Feliciano and Tartaglia worked, and in turn, produced some of their most influential texts.

⁹ Alfani and Di Tullio, "The Venetian Fiscal System," 28.

¹⁰ See, for example Knapton, "The Terraferma State," 101.

¹¹ Alfani and Di Tullio, "The Venetian Fiscal System," 22–28.

¹² Knapton, "The Terraferma State," 97.

¹³ Black, *Early Modern Italy*, 8.

¹⁴ Cf. Bennett and Johnston, *The Geometry of War 1500–1750*.

¹⁵ Brioiist, "Familiar Demonstrations in Geometry," 2.

¹⁶ Cf. Cormack, "Introduction: Practical Mathematics..."

Abbaco mathematics in Verona

In Verona, the development of practical mathematical expertise was centred primarily in the city's *scuole d'abbaco*. As recent work by Francesca Masiero has shown, abbaco teaching in Verona formed part of a long-established and publicly supported civic education system. The city had promoted abbaco instruction from at least the thirteenth century, and by the fifteenth century its importance was evident in the generous salaries paid to abbaco masters and the provision of free teaching spaces in prominent locations, including Piazza delle Erbe and the Palazzo della Ragione.¹⁷ Like abbaco schools elsewhere in Italy, these institutions trained pupils from mercantile, artisanal, and other practically oriented backgrounds in arithmetic, geometry, and applied problem-solving.¹⁸ Yet the Veronese schools also reflected the northern Italian tradition, which differed from the Florentine model which focused almost exclusively on calculation. In Verona, pupils began by learning reading and writing, before moving through arithmetic, geometry, accounting, surveying and algebra.¹⁹

Masiero's analysis of surviving Veronese abbaco manuscripts further highlights the local character and wider standing of the city's abbaco tradition. Written in the Veronese dialect, the treatises show that the city's abbaco teaching was adapted to regional needs, with problems directed toward locally important trades, such as wool and silk, and with descriptions of land surveying according to local methods, including the use of the rod known as the *perticha*. At the same time, the manuscripts circulated well beyond Verona, suggesting that the city's abbaco teaching was well regarded more broadly.²⁰ By the early sixteenth century, abbaco schools were also attracting students from higher-status mercantile families, a shift that reflected both the limitations of traditional Latin schooling and the growing practical and social prestige of mathematical expertise.²¹

The work of Veronese abbaco masters also extended beyond teaching. Like their counterparts elsewhere on the Italian peninsula, they often participated in mathematical challenges intended to show their skill and increase their reputation, as well as consulting on matters of calculation, measurement, and practical advice.²² In his later works, Tartaglia recalled a series of challenges posed to him during his years in Verona, many of them by

¹⁷ Masiero, *Literacy and Learning*, 126–131.

¹⁸ For good overviews of standard abbaco teaching, see Ulivi, "Masters, Questions and Challenges in the Abacus Schools"; Danna, "The Spread of Hindu-Arabic Numerals."

¹⁹ Grendler, *Schooling in Renaissance Italy*, pp.

²⁰ Masiero, *Literacy and Learning*, 148.

²¹ Cf. Grendler, *Schooling in Renaissance Italy*; Høyrup, *The World of the Abbaco*.

²² For more on abbaco masters commonly engaging in mathematical contests and consultancy see, for example, Ulivi, "Masters, Questions and Challenges in the Abacus Schools"; Goldthwaite, "Schools and Teachers of Commercial Arithmetic."

maestro Feliciano, as well as masters from Brescia, Venice, and Florence.²³ Evidence of a tradition of consultancy can likewise be found for other abbaco teachers in the city, with Masiero showing that Giovanni Maria Phanice di Rovigo and maestro Battista also worked as surveyors while teaching in Verona.²⁴

As Feliciano and Tartaglia worked side by side as Verona's two principal maestri d'abbaco during the 1520s and 1530s, they pursued activities typical of the tradition. Feliciano's career, in particular, closely matches the traditional profile. His school was located in the Palazzo della Ragione, in which – according to his nephew – Feliciano constructed his teaching space “out of boards and beams at his own expense.” There he taught “reading, writing, addition, subtraction, all kinds of accounting of every kind and everything related to mathematics,” activities Feliciano's nephew described as “a useful and essential resource for a city.”²⁵ As well as teaching and engaging in mathematical challenges, Feliciano also became well known as a master surveyor, being called on for the measurement of land, produce, and water levels, as well as consultation on commercial partnerships and exchange.

During his Veronese years, Tartaglia also operated in remarkably similar ways. Tartaglia taught abbaco in the nearby Palazzo Mazzanti in Piazza delle Erbe and consulted on practical mathematical concerns.²⁶ Evidence of his consultancy is found both in Tartaglia's later works, and in the archival record. For example, in his *General trattato*, Tartaglia describes how, during a period of famine in Verona, he was asked by the city bakers to make a mathematical table so they could determine “how much bread to make with respect to the price of wheat.” The prices had risen to such a degree that the old table, “anciently made” was no longer applicable and so the bakers turned to Tartaglia to extend it. However, to “do this rightly” Tartaglia did not follow a simple arithmetic rule, but rather sought out specific practical information, including the amount of taxes the bakers were required to pay, and the limits imposed by the city on the bakers wages.²⁷ Further evidence is shown in a testimonial disposition by Tartaglia, found by Favaro in the municipal archives of Verona. According to his testimony, Tartaglia was brought in to determine the value of a number of gold and silver items described in a goldsmith's bill of exchange, and to resolve a subsequent dispute.²⁸

²³ References to Feliciano can be found in Tartaglia, *Quesiti et inventioni diverse*, bk. 9 qns 1, 8, 9, 13. Further references to Verona can be found in Tartaglia, *General trattato di numeri et misure*, pt. 1, f. 254v. “as you will understand from the following problem, which was put to me toward the end of 1532 in Verona”; f. 277v. “This other problem, similar to the preceding one but somewhat more difficult, was put to me in Verona in the year 1533 by a Genoese man.”

²⁴ Masiero, *Literacy and Learning*, 143–144.

²⁵ Quoted in Gallozzi, “Francesco Feliciano,” 54.

²⁶ Masotti, “Tartaglia, Niccolò,” 259.

²⁷ Tartaglia, *General trattato di numeri et misure*, pt. 1, ff. 171–172.

²⁸ Favaro, “Per la biografia di Niccolò Tartaglia,” 352–353.

Another indication of Tartaglia's close engagement with Verona's practical mathematical culture can be found in his discussions of local customs in relation to trade, construction, and agriculture long after he had left the city. In his last major work, the *General trattato*, Tartaglia provides extensive detail of Verona's customs in matters as varied as the measurement of land, cloth, wheat, wine, and ruins.²⁹ Introducing land measurement as "a most commonly useful and necessary thing," Tartaglia remarked that "almost every city has a certain particular order or custom, not only in the buying and selling of lands, but also in the material ways they use to measure them." He explained his focus on the customs of Verona was due to its location as his "homeland." Although he had been born in Brescia, Verona was the first place in which his career had been sustained, and he was "lovingly nourished ... and honoured for about 15 years."³⁰ Together, this evidence suggests that during their time in Verona, both Feliciano and Tartaglia operated not only as schoolmasters and participants in mathematical contests, but also as regular providers of practical quantitative expertise.

Practical mathematics in print

At the same time, during their years in Verona, neither Feliciano nor Tartaglia was wholly representative of abbaco practitioners more generally. Rather, both followed the mathematician Luca Pacioli, a major figure in the abbaco tradition, in achieving an unusual degree of success through print. They are therefore best understood not as average practitioners, but as locally-rooted exponents who developed recently opened opportunities in especially ambitious ways. These new opportunities arose through broader changes in the circulation of practical mathematical knowledge. Abbaco knowledge had previously circulated mainly through oral instruction and manuscript. However, from the late fifteenth century, a new tradition of printed abbaco treatises greatly expanded their reach. As Angela Nuovo has shown, these printed manuals emerged in close connection with the urban educational cultures of northern Italy, especially in major commercial centres such as Venice and Milan, where dense school networks and expanding economic activity created a reliable market for instructional works.³¹

Abbaco books were typically structured around problems, ostensibly drawn from trade, measurement, and everyday calculation, and served students, merchants, and other practitioners seeking practical problem-solving rather than scholastic theory. They were often written by especially enterprising abbaco masters, who drew on their teaching and consultancy experience to produce books that could both supplement in-

²⁹ Tartaglia, *General trattato di numeri et misure*, pt. 3.

³⁰ Ibid., pt. 3, bk. 2, f. 7.

³¹ Nuovo, "Abacus Manuals, Schools and Urban Readers," 312–316.

come and enhance professional standing.³² Such works were part of a broader shift in which practical knowledge of all types was increasingly valued and instructional texts became highly sought after. The publishing activity of the Venetian calligrapher and woodblock cutter Giovanni Antonio Tagliente provides a striking example. His successful publications included not only his *Libro de abaco* (1515), written by his relative Girolamo Tagliente, but also guides to needlework, accounting, and the art of writing.³³

Beyond this broader development in the printing of practical manuals, the publications of the abbaco-trained friar Luca Pacioli stand out for the way they expanded the scope, aspirations and status of practical mathematics. His *Summa*, printed in Venice in 1494, brought together commercial and more scholarly mathematical traditions into a single, wide-ranging synthesis, presenting abbaco mathematics as a serious field of knowledge.³⁴ In doing so, it helped raise the standing of practical mathematics within Renaissance culture. This ambition became still clearer in the *Divina proportione* (1509), in which Pacioli presented the study of geometry as a privileged route to order, harmony, and higher knowledge of creation, incorporating illustrations by Leonardo da Vinci. In a culture in which the greatest prestige was often accorded to humanistic learning, Pacioli asserted the centrality of mathematical knowledge, not merely as useful, but as a sign of intellectual authority in its own right. His works helped open the way for later abbaco authors, including Feliciano and Tartaglia, to both perceive and present their practical expertise in more expansive and ambitious terms.³⁵

The Venetian terraferma also provided a strong base for abbaco publication. As Francesca Masiero has shown, the region was among the most active centres of abbaco publishing in Italy, responsible for five of the first six printed abbaco manuals, with presses in the terraferma continuing to produce more abbaco editions than any other region well into the sixteenth century.³⁶ Within this regional context, Verona provided a particularly fertile setting for the production of abbaco knowledge. Long before Feliciano's publications, the city already held a manuscript tradition of practical mathematical writing, including treatises focused on land measurement, currency exchange, and local commercial procedures. Feliciano's *Libro de Abbacho* and *Scala Grimaldelli* can therefore be read as particularly successful printed extensions of this local tradition. They similarly

³² Ibid., 2.

³³ Rivali, "Tagliente, Giovanni Antonio"; De Luca and Nuovo, "Libri d'abaco e strumenti didattici tra Venezia e Milano nella prima età moderna," 257–259.

³⁴ Pacioli, *Summa de arithmetica geometria proportioni*.

³⁵ Sangster et al., "The Market for Luca Pacioli's *Summa Arithmetica*," 120–121.

³⁶ Masiero, *Literacy and Learning*, 148; The first six printed abbaco books in chronological order are commonly identified as Anon, *L'arte de l'abbacho* (Treviso Arithmetic); Borghi, *Qui comenza la nobel opera de arithmetica*; Calandri, *Libro d'arithmetica*; Sfortunati, *Luminario de arimetica*; Tagliente and Tagliente, *Libro de abaco*; Feliciano, *Libro de abbacho*.

offered structured treatments of calculation, proportion, and applied problem-solving grounded in everyday economic and agricultural needs. Their repeated reprinting and long afterlife further suggest that Feliciano's works addressed enduring demands within urban and rural economies.³⁷

Although also grounded in Verona's abbaco culture, Tartaglia's published work aligned more closely with Pacioli's broader intellectual ambitions. Even as he later produced texts addressing familiar concerns of commercial measurement and calculation, Tartaglia's first publication diverged sharply from traditional abbaco terrain.³⁸ With *Nova scientia*, Tartaglia did not set out to produce an instructional manual codifying established techniques, but to articulate a genuinely new science centred on his original mathematical analysis of projectile motion. The origins of this project can be directly traced to Tartaglia's interactions with highly experienced and mathematically curious military practitioners operating in and around Verona. However, there was also local precedent for the printing of technical military literature. As early as 1472, Verona had seen the production of Roberto Valturio's *De re militari*, the earliest work to combine technical and military knowledge with print and illustration. Taken together, the publications of Feliciano and Tartaglia show how the same Veronese abbaco culture could generate markedly different textual responses to distinct professional environments. In Feliciano's case, durable manuals of practical procedure and in Tartaglia's, a mathematically ambitious science of motion. The coexistence of Feliciano and Tartaglia in Verona thus offers a distinctive opportunity to examine how practical mathematical knowledge was shaped through interaction with different practitioner communities.

Part 2. Feliciano and Tartaglia compared

Francesco Feliciano and the surveying arts

Francesco Feliciano was a professional maestro d'abbaco and mathematical consultant whose career was centred in Verona, though his reach extended across northern and central Italy. Originally from Lazise, Feliciano moved to Verona around the age of ten and by his mid-twenties was already working in the city as an abbaco master. Alongside teaching at his school in the Palazzo della Ragione, he supplemented his income through consultancy, particularly in the surveying arts. Such work brought him into sustained contact with landowners, merchants, and other technical practitioners, and

³⁷ Gallozzi, "Francesco Feliciano," 56–58.

³⁸ His much later work, Tartaglia, *General trattato di numeri et misure* shows far more affinities to the traditional structure of Feliciano's work. Thank you to the anonymous reviewer who pointed out a comparison to this later work of Tartaglia's may also prove insightful.

helped establish his reputation as an expert *misuratore*. Feliciano's writings are particularly revealing of the range of knowledge expected of an abbaco consultant, in which he combines foundational mathematical knowledge with their application to mercantile, artisanal, and agricultural problems, including accountancy, valuation, estimation, and, above all, surveying and measurement.

In his works, Feliciano repeatedly emphasised the geographical reach and the practical variety of his work. In the preface to the *Scala Grimaldelli*, he provided a sense of the scope of his professional activity, asserting his authority by recalling the three decades he had spent working as a surveyor "almost throughout the whole of Italy." Acting alone as well as in collaboration with other surveyors, Feliciano measured such diverse things as "lands, cattle, oats, wines, walls, woods, marshes, [and] drainage waters."³⁹ This kind of work often required translating irregular parcels of land into computable figures and the use of proportional reasoning where direct measurement was impractical or impossible. Therefore, the authority of such measurements rested not only on exactness, but on competence in recognised procedures grounded in a long-established practical tradition.

Feliciano consistently foregrounded instruments and embodied practice in his discussions of measurement. A key instance concerned the use of the surveyor's level, which he described as essential in situations where "the true measurer has the burden of carrying water from one place to another, to create fountains or to water meadows or fields."⁴⁰ The accompanying image depicts a simple but effective device consisting of a vertical post supporting a flat plank. From the plank hangs a plumb bob to ensure it is level and small uprights at either end with holes to provide a straight line of sight (Figure 1). Explaining its use, Feliciano offered a worked example in which a surveyor seeks to determine whether a particular location lies higher or lower than "a stream at the foot of a mountain." He goes on to describe how the measurer must progressively move the level so that, looking through the holes, "one can just make out" a mark placed on a stick at the previous location. By repeating this procedure across the terrain, the surveyor can determine the difference in height over the given expanse.⁴¹

³⁹ Feliciano, *Scala Grimaldelli*, "quasi per tutta l'Italia a misurare in compagnia, e senza compagnia de' misuratori, terre, feni, biave, vini, muri, boschi, paludi, & livelar acque, e simil cose . . .," f. n.p.

⁴⁰ Gallozzi, "Francesco Feliciano," 70.

⁴¹ Feliciano, *Scala Grimaldelli*, f. 79.

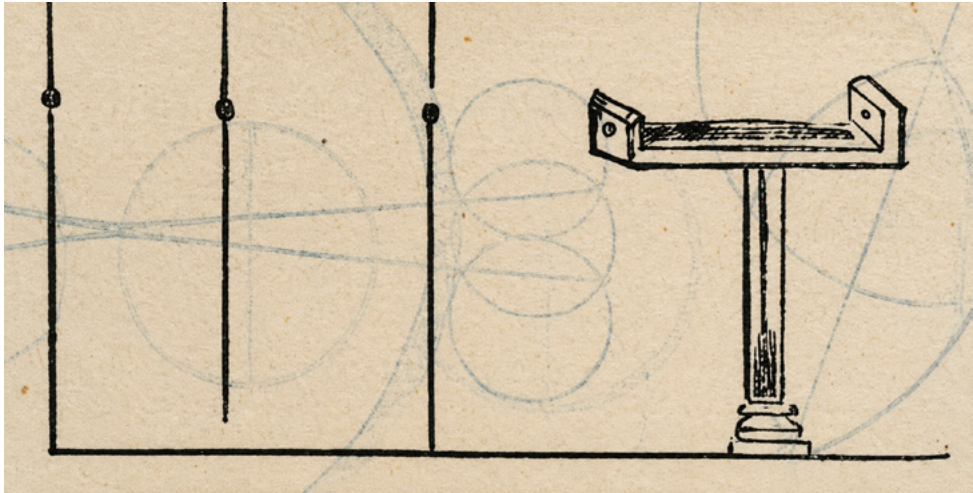


Fig. 1 – Feliciano's sketch of a surveyor's level to determine differences in height, Scala Grimaldelli (1526).

Along with this attention to instruments, Feliciano expressed concern for their proper use. Remarking on “the difficulty of the art of measuring,” Feliciano noted that growing demand for surveying services across Italy had led him to observe that “many follow this art, but few are capable.”⁴² In 1526, he became the first author to publish an account of the surveyor's cross, an instrument consisting of a horizontal disc with pairs of cross-pieces at right angles, designed to improve the accuracy of land measurement. While acknowledging its value, he warned that “there are some who work well with the surveyor's cross,” whereas “others still carry the cross knowing little or nothing about its usage.” Drawing on his own experience “measuring lands, fences, fields,” Feliciano explained that he wished to show correct procedure not only through words, but also through images (Figure 2). His aim was not only to help inexperienced practitioners, but also those who employed surveyors, so that they may also judge “who will do well and who will do badly.”⁴³ In Feliciano's account, measurement is depicted as a highly skilled form of expertise requiring experience, judgement, and disciplined practice.

⁴² Ibid., f. 65.

⁴³ Ibid., ff. 64–65.

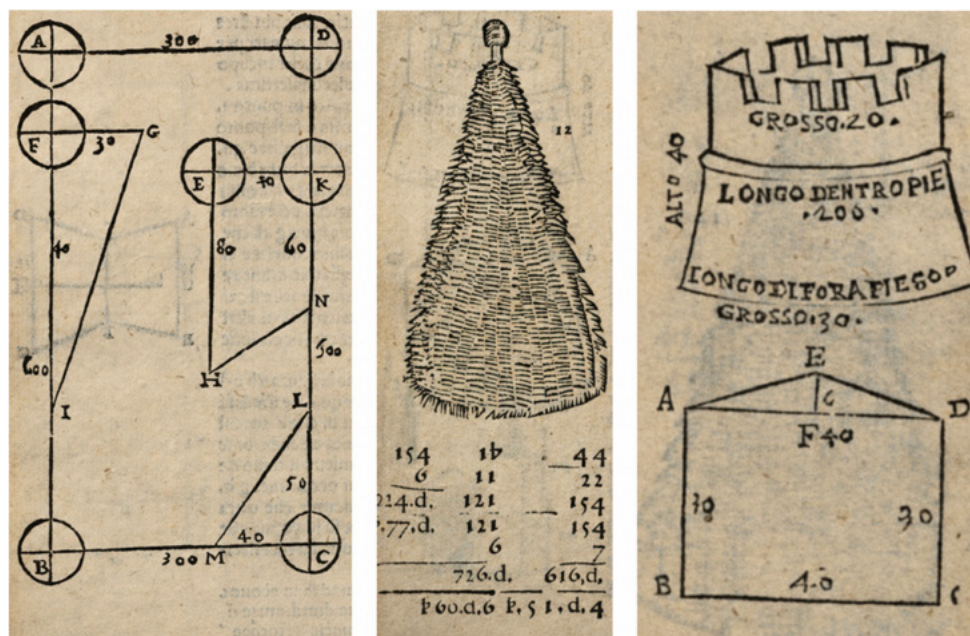


Fig. 2 – Some of Feliciano's images of measurement problems, *Scala Grimaldelli* (1526).

Feliciano extended the proper qualities of the consultant surveyor to encompass a moral and ethical dimension. While describing the difficulties involved in measuring the amount of hay in a wagon, Feliciano emphasised that the expert measurer should be “a good man” who, above all else, possessed a “good conscience.” To do the job fairly, a surveyor must avoid empty words, ground claims in facts, and maintain fairness between clients, “because he cannot serve one while displeasing another.”⁴⁴ In this way, Feliciano insisted that expertise in measuring was inseparable from ethical responsibility.

Feliciano's written works translated his expertise in teaching and consultancy into printed form within the same local context as Tartaglia. Feliciano's *Libro di abbaco*, first published in 1517, appeared around the same period Tartaglia arrived in Verona.⁴⁵ Nearly a decade later, after years of professional overlap in the city, Feliciano published the more ambitious *Scala Grimaldelli* (1526). The reception of Feliciano's books attests to their practical value and enduring influence.⁴⁶ The *Libro di abbaco* was reprinted in 1519 and

⁴⁴ Feliciano, *Scala Grimaldelli*, f. 76; Gallozzi, “Francesco Feliciano,” 69–70.

⁴⁵ Masotti, “Tartaglia, Niccolò” tell us Tartaglia most likely moved to Verona between 1516 and 1518.

⁴⁶ Grendler, *Schooling in Renaissance Italy*, 308.

1525, followed by a revised and expanded edition prepared by the author in 1532 and published posthumously in 1550. The *Scala Grimaldelli* enjoyed even greater success, first appearing in 1526 and then being reissued eight times over the following forty-four years, before being expanded in the seventeenth century by the Veronese accountant Filippo Macario, and reprinted repeatedly well into the seventeenth century.⁴⁷ The available evidence suggests that books such as Feliciano's appealed not only to those first learning abbaco mathematics, but also to readers with prior training. In his study of the readership of Florentine abbaco texts, Goldthwaite found that many owners were merchants already schooled in the tradition, drawn not only to the practical utility of such works but also to the intellectual appeal of their problems, whose working-out could provide "its own satisfaction."⁴⁸ In combining technical instruction, mathematical problem-solving and explicit ethical guidance, Feliciano's works gave durable form to a vision of practical mathematical knowledge grounded in skilled measurement, practical experience, and professional responsibility.

Niccolò Tartaglia and the military arts

Niccolò Tartaglia was nearly thirty years younger than Feliciano, and his route into abbaco mathematics was less conventional. Born into a modest family in Brescia, a terraferma city repeatedly contested during the Italian Wars, he was left in poverty after the death of his father when he was still a child.⁴⁹ The War of the League of Cambrai marked his early life in especially traumatic ways. During the sacking of Brescia in 1512, he suffered severe head and jaw wounds that left him struggling to recover his speech. For this, he earned the mocking nickname Tartaglia, "the stammerer," which he later adopted permanently "in memory of my misfortune."⁵⁰ Too poor to receive even basic abbaco schooling, he taught himself to write and pursued learning largely outside formal institutions. In later life, he recalled turning seriously to abbaco mathematics at around the age of fourteen, developing a particular aptitude for algebra.⁵¹ This background did not place him outside abbaco culture, but it seems to have encouraged an unusually self-reliant intellectual style, grounded in intensive textual study and a willingness to seek knowledge beyond customary pathways.

Around the age of seventeen, Tartaglia left Brescia, itself recently returned to Venetian control after years of French occupation and moved to Verona. There, as we have seen, he engaged in the range of professional activities typical of the abbaco master, teaching practical mathematics, offering private instruction, and serving as a consultant on problems of

⁴⁷ Gallozzi, "Francesco Feliciano," 71.

⁴⁸ Goldthwaite, "Schools and Teachers of Commercial Arithmetic," 432.

⁴⁹ For more detail on the timeline of Tartaglia's life see Pizzamiglio, "Niccolò Tartaglia," 37–40.

⁵⁰ Tartaglia, *Quesiti et inventioni diverse*, bk. 6 qn. 9.

⁵¹ Favaro, "Per la biografia di Niccolò Tartaglia," 345.

calculation, measurement, valuation, and accounting. Yet, despite this conventional profile, Tartaglia's first publication departed strikingly from both Feliciano's works and usual forms of abbaco writing. In contrast to problems of bookkeeping or surveying, Tartaglia's *Nova scientia* announced itself as a "new science" devoted to the mathematical analysis of gunnery. Described by its author as a "newly found invention" containing results "never heard or thought of by any other person, ancient or modern," the treatise centred on the geometrical treatment of cannon fire (Figure 3).⁵² It introduced abstract representations of projectile trajectories and included a full-scale template for constructing a gunner's quadrant, marking a significant expansion of the epistemic ambitions typically associated with abbaco mathematics.

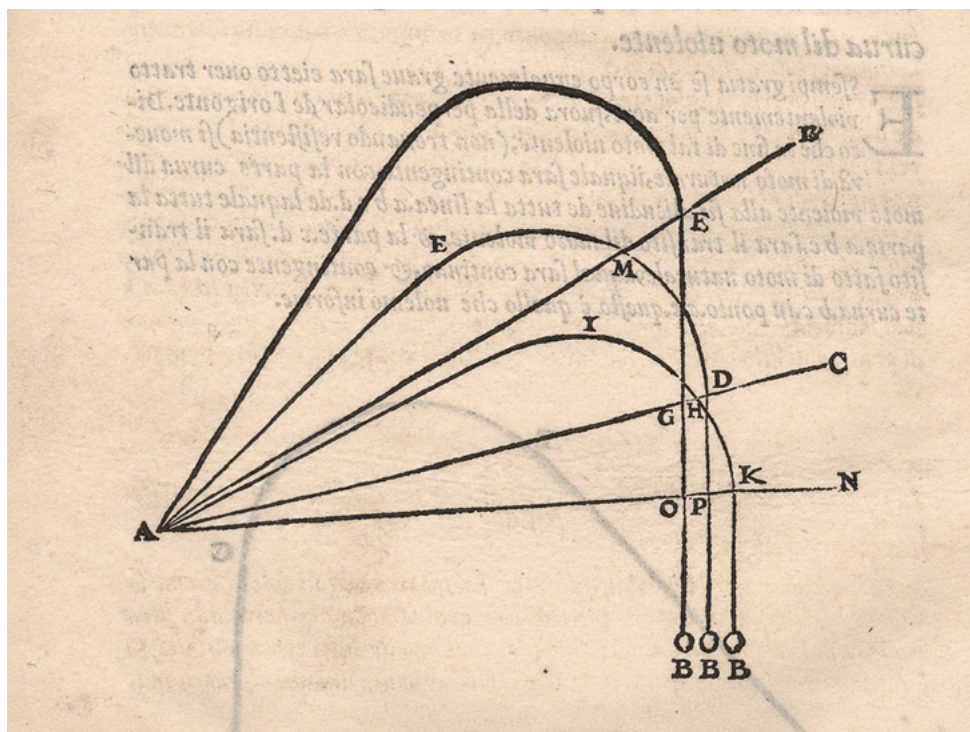


Fig. 3 – Tartaglia's geometric analysis of projectile motion, *Nova scientia* (1537).

I propose that Tartaglia's striking divergence from the subject matter and conventions of standard abbaco writing can best be understood through his interactions with expert military practitioners in Verona. These exchanges introduced him to a class of problems

⁵² Tartaglia, *Nova scientia*, ii, Epistle.

less readily managed through the usual routines of abbaco practice, brought him into contact with practitioners who appear to have been unusually receptive to mathematically ambitious and speculative inquiry, and opened access to a wider social horizon in which his expertise could be directed toward elite military leaders and potential patrons as well as technical practitioners.

In the dedicatory epistle to *Nova scientia*, Tartaglia explains that he first took up the problem of gunnery in 1531 after a skilled bombardier stationed at Verona's Castelvechio, described as a "close and kind friend," posed a speculative question, at what angle would a cannon shot travel the greatest distance?⁵³ Drawing on his abbaco expertise, Tartaglia concluded that the optimal elevation was forty-five degrees. This result satisfied his bombardier friend after it "was verified by means of certain specific experiments."⁵⁴ However, the inquiry did not end there. A year later, Tartaglia's conclusion was challenged by the chief bombardier of Padua, who argued that a lower angle would yield a greater range. To resolve the dispute, the Paduan bombardier arranged a field experiment against one of Tartaglia's defenders, Sir Leonardo Iustiniano, chief bombardier of Verona. As Tartaglia explained:

A certain quantity of money was bet on this [question] and they finally arrived at the experiment. A culverin of twenty [libra] was brought to the countryside around Santa Lucia. Each of them shot according to what they suggested and without any difference in reference to the ball and to the charge. The one who shot according to our conclusion reached 1972 perches...the other, who shot two points lower, reached only 1872 perches. For this reason, all the bombardiers and the other persons recognised the truth of our conclusion, although before the experiment they had doubted it and most of them had been of the contrary opinion as it seemed to them that the piece was elevated too much.⁵⁵

Although later commentators have emphasised the practical military inspiration of *Nova scientia*, Tartaglia's own account points instead to the largely theoretical character of the bombardiers' interest. As indicated by the illustrations within the treatise, the high angles under discussion were not typically employed in combat, since their use required substantial excavation behind the gun emplacement (Figure 4). The question was therefore not one of immediate tactical advantage, but a speculative puzzle pursued by technically sophisticated practitioners interested in understanding the behaviour of artillery beyond the constraints of everyday use. Tartaglia himself emphasised this orientation in the dedication of *Nova scientia*, presenting his new science as especially valuable for "speculative

⁵³ Tartaglia and Valleriani, *The Nova scientia of Nicolò Tartaglia. A New Edition*, 67.

⁵⁴ Ibid.

⁵⁵ Ibid., 71.

Mathematical Bombardiers.”⁵⁶ In this respect, Tartaglia’s military practitioners appear not simply as practical men of war, but as participants in a more reflective culture of quantitative inquiry.

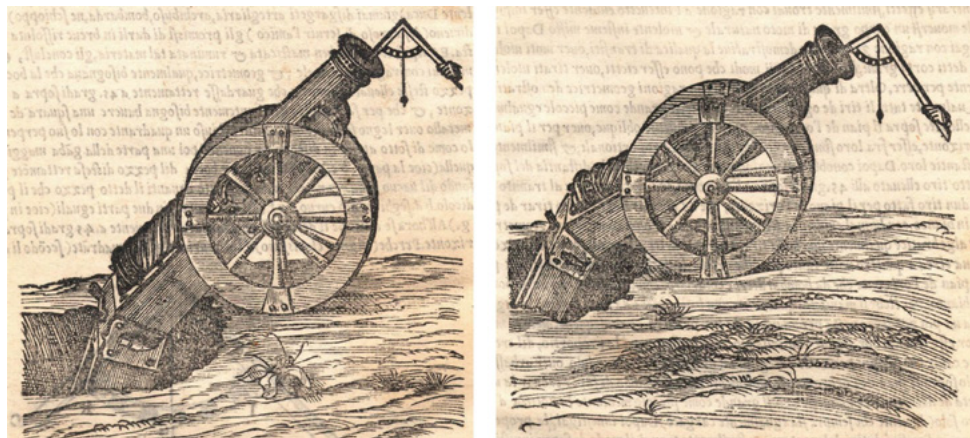


Fig. 4 – Tartaglia’s illustrations of the bombardier’s experiment, *Nova scientia* (1537).

This episode is revealing in several respects. Most obviously, it presented Tartaglia with a different problem than those more commonly posed in surveying, valuation, or book-keeping. Although those fields also involved uncertainty, judgement, and changing conditions, projectile motion confronted him with relations of movement that were harder to stabilise through the ordinary procedures of *abbaco* mathematics. Yet the episode suggests something more than the novelty of the problem itself. The bombardiers involved were not merely seeking a practical rule. They were willing to pursue a speculative question, to test competing conclusions experimentally, and to treat mathematical argument as a meaningful way of adjudicating between them. By taking on their questions as his own, Tartaglia’s engagement with these theoretically-minded gunners encouraged him to extend practical mathematics into a more explicitly analytical and demonstrative form. The military world offered not only a new class of problem, but also a community in which more ambitious mathematical treatment was recognised and valued.

Examining the problem more deeply led Tartaglia to a further methodological innovation. Projectile motion could not be adequately captured through the ordinary resources of Euclidean geometry alone. Seeking a theory capable of accounting for motion, Tartaglia turned to Aristotle, incorporating concepts from natural philosophy into his mathematical analysis. This move was highly unusual for an *abbaco* master, as Aristotelian philos-

⁵⁶ Tartaglia, *Nova scientia*, Incipit, [f. 1v], ii, “speculativo Mathematico Bombardiero.”

ophy was an elite discipline typically reserved for university-trained Latin scholars. Yet Tartaglia's move into this new terrain can still be understood, at least in part, as an extension of abbaco problem-solving practice, in which practitioners often showed a pragmatic willingness to draw on whatever bodies of knowledge proved useful, regardless of their traditional disciplinary or institutional location.⁵⁷ The expanding book trade in northern Italy also facilitated such movement by making scholarly materials more accessible beyond university settings. Through sustained interaction with theoretically inclined bombardiers, a background in abbaco problem solving and access to newly available forms of knowledge, Tartaglia forged a mode of inquiry that bridged practical experience, applied and speculative mathematics, and natural philosophy.

The military arts mattered in a third way as well. They offered Tartaglia access to a social and epistemic horizon that differed from that available through the more ordinary commercial work of the abbaco master. Surveying, valuation, and land measurement were indispensable to civic administration and economic life, but they were usually tied to practical service and private clients. By contrast, the military arts were bound up with territorial defence, state survival, noble command, and elite authority. Artillery expertise in particular could therefore be addressed upward, not only to working practitioners, but also to rulers, captains, and military leaders. This wider horizon is visible in Tartaglia's dedication of *Nova scientia* to the Duke of Urbino, Francesco Maria della Rovere, who was both a noted patron of mathematicians, including Luca Pacioli, and a major military leader, having served as captain general of the Venetian forces and later as supreme commander of the Holy League.⁵⁸ In presenting his work as a *scientia* rather than as an extension of ordinary abbaco practice, Tartaglia was responding not only to the nature of the problem, but also to the elevated audience and patronage possibilities that military mathematics made available.

Unlike Feliciano's surveying-focused works, which have remained largely outside histories of early modern science, *Nova scientia* has long been recognised as a pioneering contribution to the science of ballistics.⁵⁹ It has also been seen as a foundational effort to integrate practical mathematics with natural-philosophical reflection on projectile motion, a line of inquiry later pursued most famously by Galileo, also trained in the abbaco tradition.⁶⁰ Seen in this light, Tartaglia's later prominence marks not a major departure from abbaco culture, but one of its most ambitious and historically consequential exten-

⁵⁷ For more on this feature of the abbaco tradition see Ekholm, "Tartaglia's *Ragioni*," 181.

⁵⁸ Briost, "Familiar Demonstrations in Geometry," 2–4.

⁵⁹ Tartaglia and Valleriani, *The Nova scientia of Nicolò Tartaglia. A New Edition*; Lefèvre, "Gun-nery," sect. 4.5; Bennett, "The Mechanical Arts," 691–692.

⁶⁰ Indeed, in a letter to Cesare Marsili in 1632, Galileo wrote that his "primary intention when I started speculating about motion was to find just such a trajectory." Translation from Frova and Marenzana, *Thus Spoke Galileo*, 83.

sions. Like Pacioli before him, Tartaglia did not abandon *abbaco* culture so much as extend some of its central habits, such as practical problem-solving, quantitative reasoning, and responsiveness to expert practitioners, into a more ambitious register. The result was a work that recast practical mathematics for a higher-status audience, presenting it not as a set of procedures for particular tasks, but as a general science grounded in military experience and directed toward broader theoretical claims.

Practitioner interactions and knowledge in use

Although Francesco Feliciano and Niccolò Tartaglia shared many features of occupational life, the expertise they developed diverged in important ways. Their interactions with different practitioner communities shaped their work in three key ways. First, Feliciano's consultancy generally required the stabilisation of variable quantities through recognised procedures, whereas Tartaglia's gunnery problem demanded the analysis of motion and relations not readily captured by established *abbaco* techniques. The former therefore placed greater emphasis on the reliable application of established techniques, while the latter pressed more insistently towards abstraction and the formulation of general relations.

Second, the two figures foregrounded different epistemic and moral virtues. Feliciano emphasised honesty, fairness, and professional responsibility, insisting that the expert measurer must ground claims in fact and avoid favouring one client over another. These virtues were well suited to a consultancy world in which trust, repeatability, and social credibility were paramount. Tartaglia, while also concerned with practical effectiveness, highlighted somewhat different values, including mathematical ingenuity, invention, and the demonstration of truth through challenge and experiment. His accounts of public disputes and trials underscore a conception of expertise in which authority was established not only by reliable service, but by extending knowledge into previously uncharted territory.

Third, their printed works differed in their social and political orientation. Feliciano's books were designed for sustained use by expert practitioners operating within the economic life of the *terraferma*, such as farmers, merchants, surveyors, and technicians, for whom mathematical competence functioned primarily as a practical resource, even as it could be enjoyed for its own satisfaction. Their longevity reflects their success in codifying techniques that remained interesting and applicable across generations. In contrast, *Nova scientia* did not simply transmit established methods but proposed a new way of understanding a dynamic class of phenomena. Tartaglia addressed the work both to expert practitioners, the "speculative Mathematical Bombardiers" whose questions had prompted it, and to the Duke of Urbino, a prominent military patron. While Feliciano's works circulated chiefly within professional networks concerned with land, trade, and measurement, Tartaglia's treatise positioned mathematical analysis within a domain that offered more

direct access to military command, noble patronage, and the political stakes of war. The contrast is therefore not simply between a ‘practical’ Feliciano and a more ‘theoretical’ Tartaglia. Their mathematics differed in the problems they sought to stabilise, the virtues through which expertise was claimed, and the social worlds toward which mathematical authority was directed.

Parallel visions of knowledge

Beyond their differing professional trajectories, Feliciano and Tartaglia appear to have articulated overlapping yet distinct visions of mathematical knowledge. These visions emerged within a shared world of *abbaco* and were shaped by prolonged professional co-existence in Verona. The surviving evidence also suggests a closer relationship between the two men than has generally been recognised. In his later work, Tartaglia recalls a series of questions put to him by Feliciano, describing him as “mo maestro Feliciano.”⁶¹ A comparison of their frontispieces provides further suggestive evidence of their closeness (Figure 5). Read together, the frontispieces of the two authors reveal a significant degree of shared conceptual ground, even as they also bring into focus the more expansive epistemic claims advanced by Tartaglia.

Although the content of Feliciano’s works remained more conventionally *abbaco* than that of Tartaglia’s *Nova scientia*, comparison of their frontispieces reveals overlap in imagery, ethos and an insistence on the centrality of mathematics to knowledge. In the frontispiece to Feliciano’s *Scala Grimaldelli*, the title’s meaning is explicitly figured through the image of a ladder and key. In the opening sonnet, Feliciano declares that “whoever wishes to open a strong iron lock / at the top of a tower or castle / must have the ladder and the [correct mathematical] tools.” His text promises to show “in a gentle way” how each tool is to be understood and applied, while warning that without such preparation the seeker’s efforts “will end short.”⁶² In this way, Feliciano presents knowledge as a fortified structure, accessible only through disciplined mastery of mathematical techniques. The imagery of towers, gates, and ladders indicates that the pursuit of knowledge requires effort and order and proceeds by stages toward ascent. Yet while insisting that there are no shortcuts, Feliciano also invites the reader in, presenting mathematical understanding as, in principle, open to all who are willing to learn. In his preface, he reiterates this point, explaining that his “little book” teaches forms of measurement that are “necessary for all human beings to understand,” using clear examples to demonstrate the relevant methods and practices.⁶³

⁶¹ Tartaglia, *Quesiti et inventioni diverse*, bk. 9 qn. 9.

⁶² Feliciano, *Scala Grimaldelli*, frontispiece.

⁶³ *Ibid.*, preface.

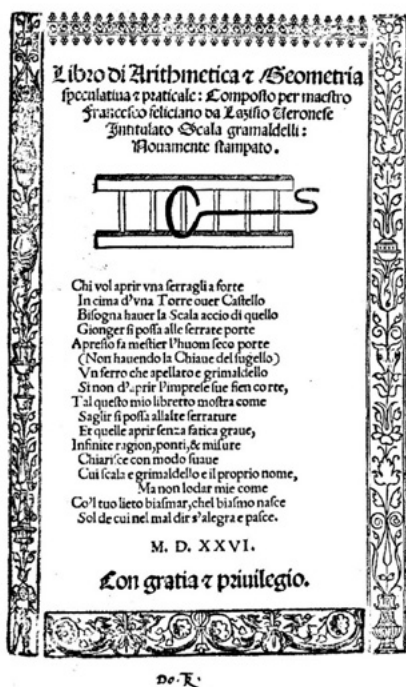


Fig. 5 – Frontispieces to Feliciano's *Scala Grimaldelli* (1526) and Tartaglia's *Nova scientia* (1537).

Tartaglia's well-known frontispiece to *Nova scientia* displays remarkable similarities in both imagery and meaning. Like Feliciano, he represents the path to knowledge through towers, gates, and ladders. He likewise presents mathematical training as the necessary first step, with the figure of Euclid indicating that entry to knowledge begins with geometry and the mathematical disciplines. He also insists that there are no shortcuts, showing a figure attempting to bypass Euclid as failing because his ladder is too short to reach the gate (Figure 5). The inscription at the base of the image similarly aligns with Feliciano's earlier frontispiece, telling the reader that "if you wish to know the causes of things" you must first learn the mathematical disciplines. Echoing Feliciano's insistence that such knowledge is learnable, Tartaglia likewise declares that "this one path is open to all."⁶⁴

Alongside these multiple affinities, however, Tartaglia's frontispiece diverges from Feliciano's in articulating a more ambitious epistemic vision. Beyond the acquisition of mathematical principles and their application to material and practical domains, Tartaglia

⁶⁴ Tartaglia, *Nova scientia*. "Disciplinæ Mathematicæ loquuntur. Qui cupitis Rerum varias cognoscere causas / Discite nos, cunctis hac patet una uia." Translatable as: The mathematical disciplines speak. If you wish to know the causes of things / Learn from us: This one path is open to all.

extends the path of knowledge all the way to the elite realm of causal and philosophical understanding. In his image, once the seeker has learned from Euclid, those principles are applied to worldly phenomena, including traditional abbaco domains such as perspective and architecture, but also scholarly fields such as astronomy and music, as well as Tartaglia's own "new science" of gunnery. From there, the seeker may be guided by Aristotle and Plato into the highest realm of philosophy. Tartaglia thus expands the scope of the abbaco master's vision beyond practical and artisanal mathematics, incorporating the elite world of natural philosophy within a single epistemic framework. These higher ambitions are reinforced in the upper section of the image. Addressing a more elevated audience than Feliciano, Tartaglia includes the shield of his dedicatee, the Duke of Urbino, Francesco Maria I della Rovere, alongside that of his wife Eleonora Gonzaga. He further surrounds the shields with a Latin inscription, directly taken from the introduction to Pacioli's *Divina Proportione*, which confidently asserts that "as gold is revealed by fire, ingenuity shows itself through mathematics."⁶⁵

In this way, comparison with his fellow Veronese abbaco master highlights both a shared commitment to mathematics as an organising principle of knowledge, and a difference in the scope and ambition of that commitment. Where Feliciano emphasised the reliable ordering of the world through measurement, instruction, and ethical practice, Tartaglia advanced a vision in which mathematics unified practical expertise and speculative reasoning into a pathway toward ultimate metaphysical explanation. The frontispieces therefore complicate any simple account of divergence. Even as Tartaglia's frontispiece showed greater ambition, his epistemic vision remained visibly articulated through imagery and assumptions shared with his older Veronese colleague.

Conclusions

In sixteenth-century Verona, practical mathematics did not develop only in the school-room or on the page. Rather, it also took shape through continued exchanges between abbaco masters and the wider communities who sought out their expertise. By looking more closely at these interactions, the contrast between Feliciano's work with landholders and Tartaglia's with bombardiers reveals something important. These relationships signify not merely different locations in which abbaco mathematics was performed, but an intrinsic part of the process through which it took form. In particular, they shaped not only the kinds of problems these abbaco masters encountered, but also the values they went on to promote in their published works. In Feliciano's case, his texts codified process-based, cumulative forms of mercantile and surveying knowledge, highlighting values of expert

⁶⁵ Tartaglia, *Nova scientia*. "AVE PROBATVR IGNI, ET INGENIUM MATHEMATICIS"; Pacioli, *De divina proportione*, 14.

practice, fairness and practical adequacy. In Tartaglia's case, engagement with theoretically inclined military practitioners exposed him to less readily stabilised questions of motion and drew him into a social world more receptive to abstract and innovative treatment, as well as broader possibilities for patronage and advancement. Engagement with an unsolved problem of dynamics, along with the opportunities present in the elevated military world, in turn encouraged Tartaglia to make ambitious claims, culminating in his 'new science' of gunnery. In this way, the comparison suggests that interdisciplinary exchange did not merely shape the application of practical mathematics, it helped determine what kinds of mathematical claims could be made, how far they could be extended, and the extent to which theory and innovation appeared as liabilities or virtues within different worlds of practice.

The comparison further shows that these interactions shaped not only professional trajectories but also distinctive visions of knowledge. As explored in the analysis of their frontispieces, Feliciano and Tartaglia articulated overlapping, yet different epistemic ideals. Feliciano presented mathematical problem-solving techniques as a set of keys to be learnt in order to provide access to higher level of knowledge, while Tartaglia advanced a more expansive vision in which mathematics unified practical expertise and speculative reasoning into a pathway toward metaphysical philosophical understanding. These parallel visions did not emerge in abstraction. They were forged through ongoing engagement with each other, as well as with practitioners, tools, and texts that allowed them to explore what mathematics could be applied to and what it could plausibly explain.

The comparison also highlights the flexible social and epistemic position of *abbaco* masters in Renaissance Italy. *Abbaco* practitioners were able to move between the worlds of the educator, artisan, technician, merchant, printer and, on occasion, scholar and nobleman. This mobility provided them with the tools and opportunities to translate embodied forms of expertise into more stable mathematical procedures, texts, and visual representations. *Abbaco* mathematics was therefore not merely a medium for transmitting knowledge between social worlds. It was itself an important site of knowledge production, in which solving problems of trade, measurement, surveying, and war could be reworked into communicable rules, printed books, and broader claims about the scope and authority of mathematics. Together, Feliciano and Tartaglia reveal *abacus* mathematics as an adaptable epistemic domain, capable of supporting both practical problem-solving and speculative inquiry.

More broadly, this study underscores the importance of attending to personal and professional relationships in the history of science. While historians have increasingly recognised the role of practice, material culture, and institutions in the production of early modern knowledge, face-to-face interactions between practitioners, especially those operating across different traditions and social hierarchies, remain underexplored as sites of knowledge production. The cases of Feliciano and Tartaglia show the value of treating

these relationships as objects of historical investigation in their own right. As Kapil Raj has argued, science is produced, in large part, “through the encounter and interaction between heterogeneous specialist communities of diverse origins.”⁶⁶ By foregrounding such encounters, this article contributes to a growing body of work that treats knowledge not as a static collection of techniques or theories, but as something continually produced through interpersonal exchange. Attending to these interactions allows us to see more clearly how relations between practitioners from different social and occupational worlds opened new possibilities, generated new motivations, and contributed to the production of innovative knowledge in early modern science.

⁶⁶ Raj, “Beyond Postcolonialism ... and Postpositivism,” 343.

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Writing, transmission, and the politics of knowledge in early modern handbooks of water management and hydraulics

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Abstract

This article analyses six handbooks of water management written by publicly employed hydraulic officials in Augsburg, Barcelona, Bologna, Florence, Naples, and Rouen in the sixteenth and seventeenth centuries. So far studied primarily from a local perspective, each of these handbooks has often been described as an exceptional source. By comparing them here for the first time, we argue instead that they formed an emerging genre in early modern Europe. This genre aimed at achieving status for author and discipline alike: by claiming a degree of specialisation and expertise, the hydraulic officials who wrote these six handbooks also claimed a degree of specialisation for their field, water management. We argue that the genre of early modern handbooks of water management has been overlooked in the historiography, and that a focus on it is useful to understand the emergence of increasingly specialised hydraulic experts and their body of knowledge about waters in early modern Europe.

Keywords

Practical knowledge, water management officials, environmental history

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¹ The article has been co-authored by all four scholars; names are accordingly listed alphabetically.

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1. Introduction

The early modern period witnessed a proliferation of technical writings in which artisans and practitioners systematically documented their crafts. These texts manifested a deliberate intent to render specialised knowledge accessible for the common good.² In 2015, Pamela Long pointed out that the content, reception, and use of these practical books, along with the literacy practices of the craftsmen themselves, remained significantly underexplored.³ Interest in early modern technical literature has since grown, with writings on agronomy, horticulture, botany, medicine, practical mechanics, mining, metallurgy, and navigation garnering particular focus.⁴ Writings on water management and hydraulics have also received some scholarly attention; Long herself has for instance studied a group of proposals for improving potable water supply and mitigating flooding in Rome. The authors of these texts, who were of diverse occupational backgrounds and primarily outsiders to the day-to-day management of the city's water systems, based their analyses upon an understanding of natural philosophical principles and ancient hydraulic engineering techniques.⁵ Less well-known, however, are the great many handbooks of practical water knowledge penned in this period by authors involved in the professional administration of hydraulic systems. We contend that this corpus is deserving of deeper analysis.

Bringing together several cases of water management handbooks produced in Europe between 1525 and 1650, this article represents a first attempt to define these sources as a genre and to examine them in a comparative perspective. We pay special attention to the motivations behind their production, the specificities of their various urban and hydrographic contexts, and the content and results of the writings themselves. Although some of the handbooks have long attracted historical attention, this has almost invariably been local and largely antiquarian in nature, focusing on their documentary value for reconstructing historical hydraulic systems, or treating them as archaeological and aesthetic artefacts. In recent years, scholars have begun to examine these texts from the perspective of the history of science and practical knowledge, and a few critical editions have been produced. This academic renewal, we argue, leads to an important revision: although these water manuals were often described as exceptional in local historiographies, our research

² Authoritative introductions to this phenomenon in early modern Europe remain Eamon, *Science and the Secrets of Nature*; Long, *Openness, Secrecy, Authorship*; Smith, *From Lived Experience to the Written Word*; and Zilsel, "The Sociological Roots of Science."

³ Long, "Trading Zones," 846.

⁴ Harwood, "The Green Revolution," 7–31; Savoia, "Skills, Knowledge, and Status," 27–54; Raphael, "Producing Knowledge about Mercury Mining," 95–118; Sánchez Martínez, "Artesanos, cartografía e imperio," 21–41. For an earlier study, see Ciriaco, "Trattati di agricoltura, di idraulica e di bonifica," 45–60.

⁵ Long, "Hydraulic Engineering and the Study of Antiquity," 1098–1138; Long, "Multi-tasking 'Pre-professional' Architect/Engineers," 223; Long, *Engineering the Eternal City*, 19–42.

suggests that they were probably standard administrative tools, and much more common than previously thought.

This does not mean that they were interchangeable: each of the handbooks under consideration refers to a unique, discrete system. Broadly speaking, our sources function as technical-administrative compendia. They detail the infrastructure, supply, and maintenance of specific hydraulic networks, transcending mere technical description to become applied treatises on, for example, pressure maintenance, flow optimization, and even the day-to-day social and political management of complex systems. But unlike contemporary treatises, which aim at a certain degree of generalization, our sources are very particular to the geographical, urban, and political contexts to which they refer. Indeed, they often integrate detailed cartography, scale drawings, and cleaning protocols. It is this how-to, hands-on approach which has led us to conclude that these sources are best described as “handbooks,” or “manuals.”⁶ Between these etymologically cognate terms, we prefer “handbooks” for its inclusion of the word “-book”: though of varying lengths, our sources all display some aspiration to participate in early modern literary culture.

In short, these handbooks sought to codify specialist, localised knowledge in writing. In some cases, they were commissioned by institutions; in others, the initiative came from the authors themselves. Although often addressed to colleagues or successors, they consistently constitute a form of social writing, a concept advanced by scholars such as Brodie Waddell and Jasmine Kilburn-Toppin.⁷ In her study of the texts of London goldsmiths in the sixteenth and seventeenth centuries, Kilburn-Toppin defines social writing as a modality in which individual and institutional voices are intertwined, as authors often combine the style of personal diary with that of institutional chronicle.⁸ In this sense, these works deepen our understanding of identity formation in the early modern period, particularly the articulation of an expert identity.⁹

Crucially, this articulation went hand in hand with the emancipation of expertise about

⁶ Long, “Manuals,” 589–593, discusses “handbooks” and “manuals,” which she treats as synonymous, as a genre that originated in the ancient world and proliferated during the early modern and modern eras. She assimilates under these umbrella terms the very kinds of early modern texts centred in scholarship on the formation of early modern practical knowledge: texts that were at the time called “books of secrets,” “books of art,” and “theatres of machines,” as well as ones that Long and other scholars have variously referred to as “craft,” “artisanal,” “technical,” “practical,” or “how-to” “manuals,” “handbooks,” “books,” or “writings.”

⁷ Waddell, “Writing History from Below,” 239–264; Kilburn-Toppin, “Writing Knowledge, Forging Histories,” 297–314.

⁸ Kilburn-Toppin, “Writing Knowledge, Forging Histories,” 297–314.

⁹ On the articulation by artisan-practitioners of an expert identity through writing, see Kilburn-Toppin, “Writing Knowledge, Forging Histories,” 297–314; Long, *Artisan/Practitioners*; Smith, *From Lived Experience to the Written Word*. On early modern expertise more broadly, see also Ash, “By Any Other Name,” 3–30.

water from other technical and administrative pursuits. Prior to the period examined here, hydraulic matters were typically treated in dedicated chapters in handbooks and treatises of architecture, engineering, mining, medicine, or domestic economy.¹⁰ During the sixteenth century, however, handbooks devoted exclusively to water management began to proliferate, reflecting a growing conception among their authors of the status of hydraulics as a separate discipline – notably prior to the emergence of a theory of hydrodynamics with the work of Benedetto Castelli – and of the specialist nature of their knowledge in this domain.¹¹ The specialisation of experts and of expertise was mutually reinforcing, and the handbooks we study are a testament to this process. By bringing to light a fervent culture of hydraulic authorship in the long sixteenth century, our article helps to show how the seventeenth-century shift toward a mathematical science of hydraulics did not emerge *ex novo* from a purely oral culture of practice, but rather on the heels of a longer set of efforts to empirically describe and codify the hydrodynamic principles of specific water networks.

The main objectives of this article are: to give visibility to this hitherto underexplored genre of sources, by bringing a set of them into dialogue with one another for the first time; and to begin the work of analysing this genre, by defining its nature of “handbooks” and some of its salient technical and political characteristics. We have selected six sources produced in different European cities between the sixteenth and seventeenth centuries. In chronological order, the first source is Jacques Le Lieur’s *Livre des Fontaines* (1525), written in Rouen. The second, produced in Augsburg, is Pilgram Marpeck’s *Bericht der Brunwerk* (1556). The third is Girolamo di Pace da Prato’s *Memoriale*, written in Florence (1558). The fourth, Tommaso Laureti’s *Instruttione*, was produced in Bologna (c. 1580). The fifth, a manuscript by Giovanni Antonio Nigrone, concerns the city of Naples (1585–1609). The sixth, Francesc Socies’s *Llibre de les fonts* (1650), was written in Barcelona.

In the next section we turn to each of these six sources, presenting their hydrographic and urban context, the identity of their authors and their motivation for writing, the contents and aims of the texts, and their reception by contemporaries and scholars alike. In the discussion, we argue that the authors’ decision to codify their hydraulic knowledge in writing is most significant. We account for this transition away from oral transmission towards the written word by considering handbooks of water management as technical *and* political texts, before concluding with some reflections on potential avenues for further research.

¹⁰ See for example Fouquet, “Wissen für die ‚schöne Stadt.’”

¹¹ This disciplinary consolidation was mirrored by a process of administrative specialisation: see for example Geltner, *Roads to Health*.

2. Handbooks of water management in early modern Europe

2.1 Jacques Le Lieur's *Livre des Fontaines*, Rouen (1525)

At the beginning of the sixteenth century, Rouen was among the main urban and commercial centres of the Kingdom of France. Situated near the mouth of the Seine, it served as both a sea and river port and an outport for Paris. Since the thirteenth century, the city's drinking water supply had relied on the Gaalor conduit, which carried water from a spring located in Mont-aux-Malades to Rouen's streets and squares.¹² In the first two decades of the sixteenth century, faced with population growth, the city council built two new water supply systems: the Carville conduit (c. 1500) and the Yonville conduit (c. 1510). Costs were shared equally with the Archbishopric of Rouen, and the new infrastructure served not only the city but also several ecclesiastical institutions, as well as the Archbishop's own residence.¹³

In this context of expansion of the city's hydraulic infrastructure, in 1519 Rouen's city council commissioned Jacques Le Lieur to carry out a study of all three conduits.¹⁴ Le Lieur (active until at least 1541, therefore likely born in the late fifteenth century) was from a noble family belonging to Rouen's judicial aristocracy, and served as notary-secretary to the King of France between 1518 and 1525. He was then appointed to Rouen city council, which he served until 1541. His study of Rouen's hydraulic network, produced with the assistance of the city's master fountaineers and building officials, came to be known as the *Livre des Fontaines* (Book of Fountains). Numbering over 160 pages, it was presented to the city council of Rouen in a black wooden case emblazoned with Le Lieur's coat of arms on 30 January 1525.¹⁵

The *Livre des Fontaines* opens with an introduction in which Le Lieur emphasizes the importance of having sufficient water for urban hygiene and argues that city governors must ensure an adequate supply. The author cites Roman aqueducts as examples, referring to the work of Pliny. As Ursula Sowina has pointed out, Le Lieur's text also reveals a familiarity with the writings of Frontinus and Vitruvius.¹⁶ Following the introduction is a eulogy for Cardinal Georges d'Amboise (1460–1510), the late Archbishop of Rouen and a leading minister under Louis XII, who had been a key supporter of the construction of the city's new water supply conduits. Le Lieur praised him as “an emulator of Roman vir-

¹² Le Lieur, *Le Livre enchaîné ou Livre des fontaines*, 7. For the original manuscript, see BMR, Manuscrits, Ms G3–1 (“*Livre des Fontaines de Rouen* (1526), par Jacques Le Lieur, échevin de Rouen”), <https://gallica.bnf.fr/ark:/12148/btv1b101021843>. Accessed 17 August 2026.

¹³ Sowina, “De l'eau pour la ville,” 23–36; Levollant, “Le Livre des Fontaines,” 243–253.

¹⁴ Ibid., 243–253.

¹⁵ Sowina, “De l'eau pour la ville,” 23–36; Levollant, “Le Livre des Fontaines,” 243–253.

¹⁶ Sowina, “De l'eau pour la ville,” 23–36.

tues, a true supporter ... of the common good.”¹⁷

The body of the text is divided into three chapters, each devoted to one of the city’s principal supply lines (the older Gaalor and newer Carville and Yonville conduits). In these chapters, Le Lieur traces the route of these conduits from their sources to their outlets in urban fountains, describing the investments made for their construction and maintenance as well as the municipal officials responsible for inspecting them. He also addresses legal and regulatory issues concerning rights over the conduits, their passage through private land, and the procedures for establishing branches for private use, often invoking past conflicts over water rights and their resolution.¹⁸ A series of blank pages following each chapter seems to have been intended for future additions to the text.¹⁹

Colossal, panoramic fold-out diagrams of the supply networks were also included in each chapter. Constructed from multiple leaves of parchment fastened together, these images, executed in ink pen and watercolour, display plans of the conduits’ course, with the surrounding rural and urban topography and its built fabric depicted in stunning detail through a mix of bird’s-eye-view, elevation, and perspectival views.²⁰ According to Anne-Bénédicte Levollant, these diagrams measure 4.67 m (Gaalor), 9.30 m (Carville), and 3.30 m (Yonville) in length. They thus monumentalized the city’s hydraulic infrastructure and conferred prestige upon the project of building and maintaining it. The *Livre des Fontaines* also contained a painted panorama of the city pictured from the left bank of the Seine, known today as *La Grande Vue de Rouen*. To commemorate his service to the city, Le Lieur had depicted an inset, framed portrait, towering over the urban fabric, of himself presenting the book to city officials.²¹ He also included his family’s coat of arms, suspended from a tree in the left foreground.

In the text, Le Lieur reflected explicitly on his decision to compose a handbook. He wrote for “our successors,” he explained, “so that with the passage of time the provenance and location of the springs and beginnings of this fountain do not fall into oblivion.”²² He also announced his “care to faithfully write the truth in familiar language” over “[pursuing] great and profound elegance in my description.”²³ From the outset, the *Livre des*

¹⁷ Le Lieur, *Le Livre enchaîné ou Livre des fontaines*, 2.

¹⁸ Sowina, “De l’eau pour la ville,” 23–36.

¹⁹ Levollant, “Le Livre des Fontaines,” 243–253.

²⁰ For the original diagrams, see “Le cours de la Fontaine de Carville,” <https://gallica.bnf.fr/ark:/12148/btv1b10052444v>; “Le cours de la Fontaine de Yonville,” <https://gallica.bnf.fr/ark:/12148/btv1b10050017r>; “Le cours de la Fontaine Gaalor,” <https://gallica.bnf.fr/ark:/12148/btv1b10052443d>. Accessed 17 August 2026.

²¹ Sowina, “De l’eau pour la ville,” 23–36; Levollant, “Le Livre des Fontaines,” 243–253.

²² “[À] noz successeurs, qui sont à venir, et aussy affin que par longueur de temps ne soit mys en oubly d’où vient et où sont les sources et commenchemens de ladicte fontaine...” Le Lieur, *Le Livre enchaîné ou Livre des fontaines*, 7.

²³ “[E]n ayant plus esgard de fidelement escrire la verité en langue familière que curieusement

Fontaines was thus conceived as a reference for all who engaged in the management of the city's hydraulic infrastructure. As such, it was stipulated that it be kept in the Common Hall of the city council and that it could not be removed from the building. Its other name, *Le Livre Enchaîné* (The Chained Book), derives from the chain that secured it to a lectern in the hall.

Ultimately, these regulations did not prevent the knowledge contained in the book from circulating beyond the Common Hall. In the early seventeenth century, Rouen's master of buildings and fortifications illegally produced a copy of the manuscript, which was eventually confiscated by the city authorities.²⁴ The *Livre des Fontaines* would not be published until 1911, when a facsimile edition was produced in Rouen. Since then, the manuscript has been well known to French scholars, who have tended to emphasize its exceptional character. A later facsimile was published in the early 2000s.

2.2 Pilgram Marpeck's *Bericht*, Augsburg (1556)

The Free Imperial City of Augsburg, in what is now southern Germany, is situated on a plateau overlooking the confluence of two rivers, the Lech and the Wertach. Throughout the Middle Ages, their fast-flowing waters were harnessed to feed canals providing hydro-power for the city's numerous artisanal and industrial activities.²⁵ In the early fifteenth century, the Augsburg city council complemented this grey water network with a municipal drinking water supply system. Tapping freshwater springs south of the city, a new canal was dug to carry the water to the city walls, where water-raising machines filled a series of tanks located on top of dedicated water towers. Thence, drinking water was distributed via a network of underground timber pipes to public fountains dotted around the city's streets and squares.²⁶

A century and a half after its establishment, this system received its first major overhaul at the hands of Pilgram Marpeck. A leader of the early Anabaptist church, Marpeck (c. 1495–1556) was also a skilled hydraulic expert: after learning his trade in the mines of his native Tyrol, he worked in Strasbourg and St Gallen, before settling in Augsburg around 1544. Two years later, the Augsburg city council appointed him *Stadtwerkmeister* (Surveyor of the City's Works) and tasked him to overhaul the main water-raising machine feeding the municipal drinking water supply system. Between 1546 and 1552, Marpeck

observer grande et profonde élégance en ma description." Le Lieur, *Le Livre enchaîné ou Livre des fontaines*, 67.

²⁴ Levollant, "Le Livre des Fontaines," 243–253, here 244.

²⁵ For a recent introduction to the history of Augsburg, with earlier bibliography, see Tlusty and Häberlein, eds., *Companion to Late Medieval and Early Modern Augsburg*.

²⁶ The most complete introduction to the history of Augsburg's water management system, inscribed since 2019 on the UNESCO World Heritage List, is Emmendorffer and Trebesch, eds., *Wasser Kunst Augsburg*.

worked to replace the fifteenth-century machine, likely a chain of buckets set in motion by a waterwheel, with a *Stangenkunst* (rod engine). Equally set in motion by a waterwheel, this machine was at the cutting edge of technological innovation in the mid-sixteenth century: the waterwheel was connected by cranks to several moving rods, which set a series of superposed piston pumps in motion.²⁷

On 24 June 1556, four years after completing this overhaul, and only a few months before his death, Marpeck wrote a *Bericht der brunwerch, wie sy gericht, geornet vnd gehalten sollen werden* (Report on how the waterworks should be set up, arranged, and maintained). This manuscript, which has never been published, consists of a letter to the Augsburg city council, signed by Marpeck.²⁸ Over sixteen pages, the ageing *Stadtwerkmeister* consigns his recommendations for the future management of the municipal drinking water supply system, organised in nine articles,²⁹ along with a description of the system itself, focusing on its operating principles and maintenance.³⁰ This *Bericht* is thus at once a summary of the knowledge and expertise accumulated by Marpeck over more than a decade of hydraulic work in Augsburg, and an indispensable handbook for his successor in managing the municipal drinking water supply system.

In the preamble to his *Bericht*, Marpeck suggests that he is writing of his own initiative. Full of pride in “such [a] newly built waterwork, which is wholly different, nay a completely new invention, work, and machine,” Marpeck is determined that his technological legacy should outlive him.³¹ He points out that he is already busy training his successor, Anthoni Hilleprand, and urges the city councillors in the first article to always appoint “a competent and loyal administrator of the waterworks,”³² for “where many cooks are in one kitchen, good fare is seldom cooked.”³³ The following eight articles about the municipal drinking water system’s management lay out the responsibilities of this administrator, the organization of his subordinates into teams with distinct tasks, and the jurisdiction of the city council over the administrator’s work.³⁴

A shorter technical description follows, concerned especially with the fairness of dis-

²⁷ On Marpeck, his training in Tyrolean mines, and his hydraulic activities in Augsburg, see Martino, “Mining for water?” 26–58.

²⁸ The signature appears to be in the same hand as the text itself, suggesting that the whole document (with the exception of the annotations discussed below) might have been written by Marpeck. See StadtAAu, KA-A, Baumeisteramt, VII: 28d, [1] (P. Marpeck, *Bericht der brunwerck* (1556)).

²⁹ Marpeck, *Bericht der brunwerck*, 1–12.

³⁰ Ibid., 12–16.

³¹ “[S]ollich new gemacht prunwerck gantz auf anderm sin: Ja gar ain new erfindung, werch, vnd kunst ist,” *ibid.*, 2.

³² “[A]in verständigen trewen prunwerchs verwalter,” *ibid.*, 3.

³³ “[W]o vil käch Jn ainer kuchen sein, da werden selten guete speis kocht,” *ibid.*, 11.

³⁴ Ibid., 3–12.

tribution to all recipients of drinking water. If the fifteenth-century system had supplied only public fountains, indeed, by the mid-sixteenth century “the water is also supplied to several people and lords in their own houses.”³⁵ These people paid a fee commensurate with the supply of their tap; it was therefore important that this amount was as stable and comparable as possible across all taps. Marpeck recommended achieving this by ensuring that the diameter of the main wooden pipes was uniform, and that these were laid at the same depth underground.³⁶ The side connections departing from these pipes to supply people’s taps were smaller, and Marpeck recommended that their diameter be proportional to the height at which a tap was placed.³⁷ This allowed him to compensate for pressure differences: taps at a lower height, flowing with greater pressure, were to have a smaller diameter than taps higher up in the city, where pressure was lower. Marpeck explained how to calibrate this: the administrator was to measure outflow over one hour, and ensure it was the same across all taps.³⁸

The one known copy of Marpeck’s *Bericht*, preserved in the collections of the Augsburg Stadtarchiv, is annotated by a different hand. This suggests that the *Bericht* was read carefully by at least one of Marpeck’s successors, though it has not yet been possible to identify who this was. There is also evidence that several of Marpeck’s recommendations were heeded. In 1558, two years after receiving Marpeck’s *Bericht*, the Augsburg city council commissioned a detailed description of the network of underground timber pipes – as had been recommended in the second part of the *Bericht*.³⁹ The job description of the municipal *Brunnenmeister* (Master of Fountains/Waterworks), as recorded in acts of appointment from the seventeenth century, corresponds quite closely to the responsibilities of Marpeck’s proposed administrator.⁴⁰ Water concessions (*Wasserbriefen*) issued by the municipal administration also follow the format prescribed in the *Bericht*.⁴¹

Marpeck’s influence over the municipal drinking water supply system of Augsburg, in other words, was not limited to his technical overhaul of the main water-raising machine:

³⁵ “Auch sunder personen vnd herren Jn der selben herren heiser das wasser aus zue thaylen,” *ibid.*, 1.

³⁶ *Ibid.*, 12–13.

³⁷ *Ibid.*, 13–14.

³⁸ *Ibid.*, 14.

³⁹ *Ibid.*, 4–5. For the records of private water connections, see for example StadtAAu, KA-A, Baumeisteramt, VIII: 212; and StadtAAu, KA-A, Baumeisteramt, VIII: 213, [2.1]–[2.4].

⁴⁰ Whilst it is possible that the office of *Brunnenmeister* was only established after Marpeck recommended the appointment of a *verwalter* in his 1556 *Bericht*, earlier mentions of *Brunnenmeister* employed by the Augsburg city council suggest that the post may have originally been created in the early fifteenth century, when the drinking water supply system was first established, and later reformed in line with Marpeck’s recommendations in his *Bericht*.

⁴¹ Marpeck, *Bericht der brunwerck*, 14–15. For a *Wasserbrief*, see for example StadtAAu, KA-A, Ordner 104 (*Wasserbriefe*).

through his 1556 *Bericht*, he also contributed to an administrative overhaul of the system's management. As well as a record of Marpeck's knowledge and expertise, and a handbook for his successors, the *Bericht* was thus also a blueprint for reform. Its significance, however, has only recently been recognised by scholars of early modern Augsburg, largely thanks to the work of Barbara Rajkay.⁴²

2.3 Girolamo di Pace da Prato's *Memoriale*, Duchy of Florence (1558)

The city of Florence straddles the Arno river at its confluence with the Mugnone. During the Middle Ages, as industrial milling and commerce spread along these fast-flowing waterways, the city grew to be among the largest and most prosperous in Europe. From the thirteenth to the sixteenth century, its territory expanded considerably through conquest and acquisitions, becoming the capital of a regional state encompassing much of Tuscany and the greater part of the Arno river basin. While rivers brought wealth to Florence and its subject towns, they also posed a threat to people's lands and livelihoods when they flooded.⁴³

The central decades of the sixteenth century were a period of exceptional flooding, with more frequent and severe inundations recorded in Florence and its subject towns along the Arno.⁴⁴ In response, the newly-elevated ducal government regulated and restricted access to rivers to stabilize their embankments. They also founded within the Capitani di Parte Guelfa, the state's public works and property magistracy, a dedicated hydraulic office called the Ufficiali dei Fiumi, charged with enforcing river regulations and advising on flood mitigation.⁴⁵

From at least 1550 until the end of his life, Girolamo di Pace (1478?–1562), who hailed from Prato, served these magistracies as an engineer.⁴⁶ While little is known of his early life or formation, his talents were recognized early on at the ducal court, which retained him as a hydraulic engineer from 1534. He was involved in the construction of the water systems at the Medici villa gardens at Castello and Poggio a Caiano, and conducted inspections of rivers across Florence's dominions.⁴⁷

In October 1558, just over one year after an exceptionally devastating flood impacted towns across the Arno river valley, di Pace reflected on all he had learned during his ca-

⁴² Rajkay, "Die Kunst des Machbaren," 68–87.

⁴³ For an accounting of Arno floods in Florence and its countryside, see Morozzi, *Dello stato antico e moderno del Fiume Arno*, 7–66.

⁴⁴ Morozzi, *Dello stato antico e moderno del Fiume Arno*, 26–30 records moderate to severe floods in 1532, 1538, 1542, 1543, 1544, and 1547, for example.

⁴⁵ Murphy, "Flood Mitigation, Territory, and Time," 82–84.

⁴⁶ Di Pace's name seems to appear for the first time in a list of the Capitani di Parte Guelfa's salary allocations dated 6 May 1550. ASF, Capitani di Parte Guelfa, Numeri Neri, 8, f. 147v.

⁴⁷ Lamberini, "Il Tribolo ingegnere," 189, n. 34; Vestri, "Girolamo di Pace da Prato, ingegnere."

reer to compose a lengthy report to Florence's duke, Cosimo I de' Medici, on the state of the duchy's rivers and how to mitigate their floods. Though untitled, the librarian Cesare Guasti (1822–1889) later named the nearly-100-page manuscript *Memoriale sopra la natura, il corso, ed i ripari di quasi tutti i fiumi e fossi dello Stato Vecchio, e sopra i regolamenti, che vi erano stato fatti fino dell'anno 1558, e che si sarebbero dovuti fare nell'avvenire* (Memorial on the nature, course, and repairs of almost all the rivers of the Old State, and on methods for regulating them, imposed until the year 1558, and that ought to be done in the future).⁴⁸ Throughout the text, Di Pace foregrounded his practical knowledge, routinely discussing his “experiments” in the Florentine territory, which involved wading in rivers and measuring embankments firsthand.⁴⁹ While this “experience of things” authorized him to expound on urgent matters of river management, he acknowledged his unease in doing so, explaining that he would much prefer to “put ... [his proposals] into effect today, than to write or talk about them.”⁵⁰ It was his advanced age, which he pegged at nearly 80, and his fear that “any day may be my end,” that motivated him to encode his knowledge for later implementation.⁵¹

Without chapters or other sectional divisions, di Pace's *Memoriale* reads as a chorographical survey of Tuscany's waterways. Starting in Florence, he discusses the Arno and its major and minor tributaries, narrating in vivid detail the behaviour of their waters, identifying current or potential flood hazards, and advising on apposite remedies. Erosion, bed aggradation, weakened and ruptured embankments, and channel obstacles were among the most common problems he observed, especially in the plain of Florence, causing rivers to widen, erupt, and even change their courses. Di Pace noted the recency of several of these issues, offering illuminating testimony of rapid environmental changes underway during these years.

He recommended several by-then routine procedures to remedy these problems, such as dredging beds and reinforcing and raising embankments, as well as straightening meanders and symmetrically aligning opposing tributaries to counterbalance the force of their flows. These interventions were to be carried out according to a set of general principles that can be summarized thus: 1) reparative measures should be taken not only where water breached or overtopped embankments, but also at the original, upstream cause of the flood; 2) modifications to channels should proceed by slowly redirecting the flow of wa-

⁴⁸ The Biblioteca Roncioniana di Prato (BRP)'s autograph draft is catalogued under Carteggi di Cesare Guasti 194.

⁴⁹ BNCF, Palat. 788, f. 47v. Here and below, I cite from a presentation copy in the Biblioteca Nazionale Centrale di Firenze, shelfmark Palat. 788, on which more below.

⁵⁰ “[D]i tutta l'opera predette io le saprei hoggi meglio metterle a effetto che scriverle o dirlo,” *ibid.*, f. 83v.

⁵¹ “[M]a el tempo non melo comporta: perche io sono tanto innanzi con gli anni che io mi avvicino à gli 80, in modo che ... ogni di puo essere el mio,” *ibid.*

ter, rather than by abruptly counteracting or changing its current; and 3) uniform, widespread application of repairs was preferable to sporadic, ad-hoc intervention.⁵² Touted as “other modes, that were not followed in the past,” these principles derived from di Pace’s novel apprehension of Tuscany’s rivers as an integrated territorial network, or what we would today call a drainage basin.⁵³ He showed how all modifications of this system had to be undertaken with a mind to their effect on the whole.

Di Pace’s propositions also had implications for the government of riverside communities.⁵⁴ He issued recommendations intended to broaden compliance with river legislation, which he deemed insufficient, and correct earlier transgressions. In a not-so-veiled criticism of incumbent magistrates, he also called for the appointment of expert ministers devoted specifically to the task of river administration, specifying that they be “men of authority, affable people” capable of coordinating state technicians and earning the trust of subject communities.⁵⁵

Di Pace’s autograph manuscript, marked throughout with his own corrections and additions, is preserved in the Biblioteca Roncioniana di Prato.⁵⁶ At least two other sixteenth-century manuscript copies of the text are in the Biblioteca Nazionale Centrale di Firenze. One, a small octavo volume in an elegant script, appears intended as a presentation copy;⁵⁷ the other, in an unknown hand, attests to wider interest in di Pace’s prescriptions at the time.⁵⁸ Although it is unclear whether Cosimo I ever received di Pace’s *Memoriale*, the Ufficiali dei Fiumi’s legislation and more proactive approaches to flood mitigation in the years to follow suggest that the engineer’s recommendations were known and heeded in the 1560s and 1570s.⁵⁹

Historical study of di Pace’s *Memoriale* can be traced back to the eighteenth century, when Giovanni Targioni Tozzetti used it to understand the historical hydrography of the Florentine plain and derive solutions to flood problems in his own day. He published ex-

⁵² Di Pace first mentions these approaches on f. 3v.

⁵³ “[P]er bene che si seguire altri modi che non si faceva per il passato,” *ibid.*, f. 3v.

⁵⁴ Murphy, “Flood Mitigation, Territory, and Time,” 94–95.

⁵⁵ “[D]elli huomini che havessino a mettere à effetto tal cose, bisognerebbe anchor che fusse qualche persona, et huomini d’authorita, persone amorevole, et havessino poche altre faccende: et che pigliassino questa per loro faccenda, per che è cosa di grande importanza,” BNCF, Palat. 788, f. 25v.

⁵⁶ BRP, Carteggi Cesare Guasti, 194.

⁵⁷ BNCF, Palat. 788, ff. 2r–94r. Antonio Lupicini’s *Discorso sopra i Ripari delle inondazioni di Firenze* (1591) follows from ff. 96r–103r. The presentation manuscript is catalogued under the alternate title of “Discorso dei fiumi, fossi, laghi, e foci marine del Dominio Fiorentino, e de’ loro disordini e rimedi: al Duca di Firenze”; see Ministero della Pubblica Istruzione, *I Codici Palatini*, II:1, 318.

⁵⁸ BNCF, Landau Finaly 97, which is not explicitly catalogued as a copy of the text.

⁵⁹ Murphy, “Flood Mitigation, Territory, and Time,” 100–101.

cerpts of the text in his *Relazioni d'alcuni viaggi fatti in diverse parti della Toscana*.⁶⁰ Cesare Guasti also studied the *Memoriale*, and produced a complete manuscript copy in 1844, perhaps in preparation for a critical edition.⁶¹ Whereas twentieth-century scholars of Tuscan hydraulics and water management have largely continued to use di Pace's text as a record of historical hydrography, Di Pace's understanding of flow dynamics and his vision for institutional reform have been emphasized only more recently.⁶²

2.4 Tommaso Laureti's *Istruzione*, Bologna (1580)

The northern Italian city of Bologna is located at the southern edge of the Po Plain, at the foot of the Apennines, down whose slopes flow the rivers Reno and Savena, flanking the city to the west and east respectively. Since the twelfth and thirteenth centuries, part of their waters was deviated into the city by means of canals to provide hydropower for the city's trades – most notably its silk industry, which flourished from the fifteenth century onwards. Ruled as a largely independent Commune, then a Signoria through much of the late medieval period, Bologna was annexed to the Papal States in 1506, and remained under Papal rule throughout the early modern period.⁶³

From 1560 to 1565 the city was governed by the Bishop of Narni, Pier Donato Cesi. During his five years as Papal Vice-Legate in Bologna, Cesi undertook a grand campaign of public works, aimed at remodelling the city after the example of Rome.⁶⁴ In 1563, Pope Pius IV issued a brief mandating Cesi to renovate an underground conduit bringing drinking water to a fountain on the city's main square, originally built in the 1520s. Cesi seized the opportunity to undertake a much more ambitious project, and hired Tommaso Laureti to design two whole new fountains.⁶⁵ Laureti (c. 1530–1602) was known as “il Siciliano” after his native city, Palermo. His father was probably the Neapolitan painter Mario de Laureto, and the young Tommaso also trained as a painter, with Sebastiano del Piombo in Rome. From the early 1560s he was in Bologna, initially working as a painter

⁶⁰ Targioni Tozzetti first references di Pace in print in his *Disamina d'alcuni progetti*, 16–23, 74, and includes excerpts from the *Memoriale* in his *Relazioni d'alcuni viaggi*, vol. 5, 19–35, 89–96, 234–236, 255–256; and idem, vol. 8, 338–343.

⁶¹ Guasti's copy is in the BRP, Carteggi di Cesare Guasti 45. See on this text Petri, “Il Memoriale sui fiumi,” 64–65.

⁶² Petri, “Il Memoriale sui fiumi”; Rombai, “La ‘politica delle acque’ in Toscana”; Ferretti, “‘Imminutus crevit’: Il problema della regimazione idraulica dai documenti degli ufficiali dei fiumi di Firenze (1549–1574)”; Murphy, “Flood Mitigation, Territory, and Time”; Martino, “Hydraulic Philosophy in Early Modern European Cities.”

⁶³ For a recent introduction to the history of Bologna, with earlier bibliography, see Blanshei, ed., *A Companion to Medieval and Renaissance Bologna*.

⁶⁴ For Cesi's campaign of public works in Bologna, see Bocchi, “Shaping the City,” 91–97.

⁶⁵ Tuttle, *The Neptune Fountain in Bologna*, 21–53; a transcription of the papal brief is in the book's Appendix: Doc. 1, 186–187.

with Pellegrino Tibaldi. He would remain in the city until his definitive return to Rome twenty years later.⁶⁶

The smaller of the two fountains commissioned by Cesi, now known as Fontana Vecchia, was completed by 1565, just as the Vice-Legate's mandate came to an end and he was recalled to Rome.⁶⁷ The larger fountain, however, was only completed in 1567: known as Fontana del Nettuno, it stands to this day as one of the most famous monuments of Bologna. As Richard Tuttle has demonstrated, its final design was the outcome of a collaboration between Laureti and the young Flemish sculptor he had hired in Florence, Giambologna.⁶⁸ The latter modelled and cast the bronzes adorning the fountain, including the monumental Neptune after which it is named, while Laureti designed the fountain's pedestal and basin, as well as the hydraulic infrastructure needed to bring water to the fountain.⁶⁹

It is this infrastructure, which also fed the Fontana Vecchia, which Laureti described in detail in a handbook entitled *Istruttione del Laureti intorno alla Fonte agl'Illustrissimi Signori Quaranta del Reggimento* (Laureti's Instruction about the Fountain to the most Illustrious Senators of Bologna).⁷⁰ It was only written around 1580, for two reasons. First, the late 1570s saw the first campaign of repairs on the Bolognese fountains' water supply system, overseen by Laureti himself.⁷¹ Second, in 1580 Laureti was preparing to leave Bologna for Rome. This second reason for writing was made explicit in the preamble to the text, as well as in the preface to one of the presentation copies of the *Istruttione*.⁷² Laureti therefore intended to leave a trace of his knowledge and expertise in Bologna prior to his departure.

Over seventeen manuscript pages, Laureti's *Istruttione* follows the water's flow from the entrails of the hills south of Bologna to the fountain's spouts in the city's main square.⁷³

⁶⁶ Grasso, "Laureti, Tommaso, detto il Siciliano."

⁶⁷ Tuttle, *The Neptune Fountain in Bologna*, 145–157. This fountain was entirely designed by Laureti, and executed by the same stonecutters who also worked on the architectural elements of the Fontana del Nettuno.

⁶⁸ Ibid., 55–103. The sculptor's full name, Jean de Boulogne, was italicised as 'Giambologna', which has become the standard way to refer to the artist.

⁶⁹ Ibid., 55–103 (for Giambologna's bronzes) and ibid., 131–161 (for Laureti's work on the water supply). Laureti also received other hydraulic commissions, most notably in the villa and garden of Cardinal Filippo Guastavillani at Barbiano: see Grasso, "Laureti, Tommaso, detto il Siciliano."

⁷⁰ Laureti, "Istruttione del Laureti intorno alla Fonte agl'Illustrissimi Signori Quaranta del Reggimento." In Tuttle, *The Neptune Fountain in Bologna*, Appendix: Doc. 36, 208–214.

⁷¹ Tuttle, *The Neptune Fountain in Bologna*, 158.

⁷² Laureti, "Istruttione intorno alla Fonte, dedication to Cardinal Filippo Guastavillani." In Tuttle, *The Neptune Fountain in Bologna*, Appendix: Doc. 37, 214.

⁷³ As Laureti himself outlines in the preamble to his "Istruttione," in ibid., Appendix: Doc. 36, 208.

Laureti dutifully pointed out that he was not responsible for the entirety of the system: work on reviving the 1520s water conduit, just as Pius IV had ordered, had been directed by Domenico Passarino, a Bolognese mason.⁷⁴ Laureti had been tasked to augment this water supply, so he followed “all the indications given by good authors concerning the search for water” and selected an adequate spot at Valverde.⁷⁵ There, he dug drainage adits tapping water veins within the hills, which were faced with bricks and vaulted. These converged into an octagonal chamber where the water was allowed to decant, before flowing through a series of further purifying pools and wells, until it reached the final section of the ancient Roman aqueduct of Bologna. This was reopened to carry the water to the city’s Porta San Mamolo, where it was joined by the renovated 1520s water conduit.⁷⁶

The final stretch of the water supply system, which ran underground until Bologna’s main square, receives particular attention in the *Istruttione*. Laureti had devised a conduit of watertight pipes: to explain how their earthenware segments fitted together, he included drawings, as well as recipes for two different types of waterproof mortar. Stone joints were added at regular intervals, with a dual purpose: while some included vents to let the air out as the conduit was filled with water, others featured openings which permitted the passage of a rope.⁷⁷ As Laureti explained, the rope had to feature knots; once introduced into the conduit by means of a float, it could then be moved to and fro between two openings, the knots scouring the pipe as they brushed against its sides.⁷⁸ Displaying the same concern for the water supply system’s future upkeep, Laureti also explained how stone plaques embedded in an adjoining wall indicated the position of vertical shafts under the street surface, allowing workers to reach the underground conduit.⁷⁹

Laureti was not, on the other hand, concerned with administrative organization, and made no recommendations about it. That question may have already been settled with the Bolognese authorities when Laureti set pen to paper or, more plausibly, this absence may be explained by the relatively small scale of the system, which supplied two public fountains only. At the end of his *Istruttione*, Laureti included ideas on how to expand the system and increase the water supply, by tapping additional sources – but such works were

⁷⁴ Though he is not mentioned in Laureti’s *Istruttione*, his name is recorded in Cesi’s account book for the whole hydraulic project: see Tuttle, *The Neptune Fountain in Bologna*, 137. Work on reopening the 1520s water conduit began before Laureti was hired and was completed by 1564.

⁷⁵ “[T]utti quelli indicii, che scrivono i buoni auttori intorno all’investigar delle acque.” Laureti, “Istruttione” in Tuttle, *The Neptune Fountain in Bologna*, Appendix: Doc. 36, 208.

⁷⁶ Tuttle, *The Neptune Fountain in Bologna*, 141–145.

⁷⁷ Laureti, “Istruttione,” 209–212. For a discussion of Laureti’s text see Tuttle, *The Neptune Fountain in Bologna*, 143–145.

⁷⁸ Laureti, “Istruttione,” 213.

⁷⁹ *Ibid.*, 210.

never carried out, either in his lifetime or afterwards.⁸⁰

Laureti's *Istruzione* has survived in no fewer than five manuscript versions, all copies of the original, which appears to be lost.⁸¹ Whilst two of these were likely presentation copies prepared on Laureti's behalf for his patrons, the existence of a further three suggests that the *Istruzione* was still deemed useful in later decades.⁸² In the 1600s, for example, Guglielmo Fava transcribed and annotated Laureti's *Istruzione*: as Tuttle has suggested, this was probably because he was responsible for the renovation works carried out on the water supply system at the time, together with Cristoforo Seta.⁸³

If the name of Giambologna has remained associated with Bologna's Fontana del Nettuno to this day, the sculptor's fame has overshadowed Laureti's contribution – which unlike Giambologna's was not limited to the fountain statuary, but extended to the whole water supply system. Tuttle's monograph on the fountain, published posthumously in 2015, included a transcription of Laureti's *Istruzione* in the Appendix. As well as reassessing Laureti's role in Cesi's fountain project, Tuttle has made this important handbook available for a wide audience.

2.5 Giovanni Antonio Nigrone's *Vari disegni*, Naples (1585–1609)

One of the largest cities of early modern Europe, Naples overlooks a large gulf along the Tyrrhenian shore of southern Italy. A ducal then royal capital in the Middle Ages, it entered the Aragonese orbit in the fifteenth century, and in the early modern period it was the residence of a Spanish viceroy.⁸⁴ Without a major river, Naples depended for its water supply primarily on the complex underground system known as the Formale Reale (or Regio), fed by the Bolla aqueduct, which distributed water via reservoirs carved out of tuff and a network of clay and lead pipes.⁸⁵ As a growing population pushed this infrastructure to its limits, the densely settled coastal areas, due to their topography and higher elevation, had to rely increasingly upon groundwater wells and rainwater cisterns to meet their needs.

Giovanni Antonio Nigrone was the scion of a Neapolitan family with some connec-

⁸⁰ Tuttle, *The Neptune Fountain in Bologna*, 157. Bologna's water supply system ended up being completely overhauled in the nineteenth century, like that of many other European cities.

⁸¹ All five copies are in the Biblioteca Comunale dell'Archiginnasio in Bologna; we have relied on the edited version published as Laureti, "Istruzione" in Tuttle, *The Neptune Fountain in Bologna*, Appendix: Doc. 36, 208–214.

⁸² Sambin de Norcen, "Introductory note" to Laureti, "Istruzione" in Tuttle, *The Neptune Fountain in Bologna*, 206–207.

⁸³ Seta was the city's *fontaniere* (fountaineer), while Tuttle records the title of 'Cavaliere' (Knight) for Fava, suggesting the latter was of higher social status. See Tuttle, *The Neptune Fountain in Bologna*, 158.

⁸⁴ For a recent introduction to the history of Naples, with earlier bibliography, see Astarita, ed. *A Companion to Early Modern Naples*.

⁸⁵ Carnevale, "Tecnici e imprenditori dell'acqua nella Napoli moderna," 79.

tion to Florence. In 1585 he left Naples, likely fleeing legal issues, for Rome, where he worked for Cardinal Ferdinando de' Medici at the Villa Medici, and where he also claimed to have corrected errors in the Acquedotto Felice. In March 1590, he followed his patron to Florence, where he designed fountains for the Palazzo Pitti and Medici villa at Pratolino; it was also in Tuscany that he studied Hero of Alexandria's writings on pneumatics and automata. After his return to Naples only a couple months later, he served as "fontanaro e ingegniero de acqua" (fountaineer and water engineer) for the Tribunale della Fortificazione, overseeing the technical maintenance of the drinking water supply network, monitoring concessions to prevent frequent water theft, and ensuring public hygiene following incidents of contamination in the reservoirs. In this capacity, he directed public works such as the Poggio Reale street fountains, completed between 1603 and 1604, and worked for noble families such as the Carafa and Orsini. In 1607, he obtained a license from the Roman Inquisition to read censored astrological treatises to explore links between water engineering and celestial phenomena.⁸⁶

At some point after his return to Naples, Nigrone received an institutional order from an authority (whose identity he does not specify) to provide a comprehensive report on all matters relating to water in the city. Though Nigrone clearly had the intention of publishing his report, he was never able to do so, perhaps owing to the death of his patron Paolo Regio, Bishop of Vico Equense, in 1607. Accordingly, in a later dedicatory letter for his manuscript, drafted around 1609 and addressed to the Neapolitan official and collector Giovan Simone Moccia, Nigrone cites the persuasion of friends as the catalyst for writing, and frames the project as fulfilling a request from his eldest son, Orazio, for an explanation of natural phenomena such as fires and earthquakes and their effects on waterways.⁸⁷

Written in clear, direct prose, and blending Tuscan and Neapolitan dialects for practical accessibility, Nigrone's manuscript is organized into a comprehensive encyclopaedic structure, divided primarily into the themes of hydraulic engineering, natural philosophy, history, and practical knowledge. Although it originally appears to have been conceived as a single body of text in folio format, the manuscript is now preserved in two volumes. This division resulted from a reorganization carried out by the Capuchin friars of the convent of S. Efreim Nuovo between the seventeenth and eighteenth centuries.⁸⁸ Volume I, titled *Vari Disegni*, primarily contains the visual material, comprising 325 folios dedicated to fountain designs; Volume II, titled *Vari Discorsi*, focuses on theoretical and technical texts, consisting of 218 folios.

The manuscript treats Naples as a central, living entity, whose survival and splendour

⁸⁶ Tchikine, "Giovanni Antonio Nigrone," 179–190.

⁸⁷ Gentilcore, "Between Practical Knowledge and Self-Promotion," 24.

⁸⁸ Nigrone, *I disegni e i discorsi*, vol. I, 23.

depend on the expert management of its water, its history, and its terrain. Accordingly, the work examines the city from its subterranean foundations to its aristocratic heights. Nigrone meticulously details the city's hydraulic system, explaining the infrastructure of the Formale Reale and the distinction between underground masonry canals (*formali*) and surface clay pipes (*intufolature*). He documents critical public health issues, such as the discovery of human and animal corpses in water reservoirs, and denounces the fraud and corruption of water officials who illegally diverted supply.

Nigrone proudly declared himself a “fountaineer and water engineer,” and believed that such “practical men” should oversee matters of urban hydraulic governance.⁸⁹ Their hands-on experience lent them both authority and credibility; indeed, in his view, only “people knowledgeable in this profession” could be entrusted with accurately measuring water concessions and detecting illegal diversions and other frauds.⁹⁰ That said, he also asserted that engineers ought to also have a firm grasp of the “four elements, the spheres, the underworld, spirits, and other things,” lamenting that “no one these days knows anything about these treatises.”⁹¹ In Nigrone's view, knowledge of this broad array of fields supported the work of water management; a firm grasp of astrology, for example, could help with locating and conducting waters hidden underground.⁹² His interests were indeed wide-ranging: the manuscript discusses street paving, agriculture, Naples's history and apocryphal origins, seismic risks, and architectural and urban measures that could be taken to mitigate them. Almost always, however, such topics are treated in relation to water management.⁹³ This also includes his mapping of the geography of elite power and leisure: Nigrone lists the noble patrons for whom he designed fountains in prestigious districts, some of which he also drew (Fig. 1), and provides a treatise on the therapeutic virtues of the thermal baths in Pozzuoli and Ischia.

⁸⁹ After his address to the reader, Nigrone affirmed that “la seguente opera è tutta disegnata, dipinta, lavorata, scritta e composta per mano mia di Giovanni Antonio Nigrone di Napoli, fontanaro e ingegnere di acqua,” Nigrone, *I disegni e i discorsi*, vol. I, 399. “La terra allagata e tutti questi danni vengono perché non c'è un uomo pratico che le veda spesso e le sappia aggiustare,” *ibid.*, 221. The passages quoted here and through the rest of this section are from the edition's “Trascrizione interpretativa,” which modernizes Nigrone's spelling and orthography.

⁹⁰ “[D]ove sono e precisamente nella città di Napoli e delle frodi di dette acque che son fatte, fanno e faranno per non essere governate da persone sapienti in tal professione,” *ibid.*, 219.

⁹¹ “[I]l vostro Nigrone, autore del presente libro, essendo egli ingegnere di acque, va parlando e scrivendo dei quattro elementi, delle sfere, dell'inferno, spiriti e altre cose ... poiché della mia professione nessuno di questi tempi sa una particella di questi trattati,” *ibid.*, 243.

⁹² *Ibid.*

⁹³ As Loffredo, “La questione dell'attendibilità,” 167, notes, “Il manoscritto affronta temi molto eterogenei, ma la vocazione idraulica è preponderante, essendo il suo nucleo fondamentale.”



Fig. 1 – Fountain design for the loggia of the palace on via Toledo (Naples) for the Royal Counselor Scipione de Curtis. Giovanni Antonio Nigrone, *Varii disegni*, MS-XII-G-59, f. 33 (Plate 6). Courtesy of the Ministero della Cultura © Biblioteca Nazionale di Napoli.

For Nigrone, images held the same relevance as the written word. *Vari Disegni* contains designs for fountains as well as detailed drawings of levelling instruments, hydraulic machinery, and experimental technologies, such as a diving apparatus. *Vari Discorsi* includes astrological charts, maps of the globe and of the heavens, climatic diagrams, illustrations of pneumatic mechanisms, and garden designs. These pictures serve a dual role, both elucidating Nigrone's technical ideas and advertising his competencies as a polymath.

Held in the National Library of Naples, Nigrone's manuscript and its author have been the subject of considerable study since the late nineteenth century. Early scholarship focused on the artistic merits of its drawings and their documentary value for reconstructing lost Neapolitan gardens, and sought to recover its bibliographical history and provenance.⁹⁴ The manuscript has enjoyed renewed interest among scholars of the history of science, art, literature, architecture, engineering, and more, whose multi- and interdisciplinary analyses have brought significant attention to Nigrone's wide-ranging contributions, culminating in 2024 with the publication of a critical edition of his manuscript.⁹⁵

2.6 Francesc Socies' *Llibre de les fonts de la Ciutat de Barcelona* (1650)

Though sited on the Mediterranean coast between the mouths of the Besòs and Llobregat rivers, Barcelona's drinking water supply in the early modern period was relatively limited. It depended on a system of *mines d'aigua*, qanats that conveyed water to the city from the nearby aquifers of the Collserola mountains. This urban drinking water system began to take shape in the fourteenth century, and progressively expanded through the addition of new sources and conduits between the late fourteenth and fifteenth centuries.⁹⁶

Seasonal climatic fluctuations always affected how much water reached the city, but in the early seventeenth century, a prolonged drought that dramatically curtailed supply prompted a significant overhaul of the system. It began in 1626, after a period of relatively abundant rainfall, and lasted into the 1640s, affecting Barcelona and much of Catalonia. The water levels of the rivers and qanats declined precipitously, decreasing the supply of water to the city's fountains and, at times, forcing the suspension of milling activity. To address this problem, from 1626 through the 1630s, municipal authorities undertook

⁹⁴ In 1880 Volpicella, *Giovan Battista del Tufo*, first recognized the manuscript's value in documenting historic Neapolitan gardens; Angelo Borzelli's 1902 biographical essay, *Giovanni Antonio Nigrone*, rescued Nigrone from obscurity; the manuscript's drawings were used as a key iconographic source for lost gardens in Mormone, *Disegni per fontane*.

⁹⁵ See for example Edelstein "Acqua viva e corrente," 187–220; Tchikine, "L'anima del giardino," 129–153; Mansi, "Le fontane di Giovanni Antonio Nigrone"; Loffredo, "La villa di Pedro de Toledo a Pozzuoli," 100–121; Tagliagamba, "I manoscritti di Giovanni Antonio Nigrone," 85–98; and the essays in Nigrone, *I disegni e i discorsi*, vol. II. For the critical edition of Nigrone's manuscript, see *ibid.*, vol. I.

⁹⁶ Guàrdia and Hostench, "Saber i pràctiques hidràuliques," 123–154.

projects to extend *mines d'aigua*, tap new sources, and maintain the existing channels to improve flow efficiency.⁹⁷ Although period sources frequently invoke the drought as a justification for these interventions, they cannot be understood solely as a response to climate stress. Instead, the drought merely amplified the vulnerabilities of a system already under considerable pressure due to its limited and environmentally contingent sources and entrenched conflicts over management and access rights.

The value of reliable information about Barcelona's drinking water system and its management became especially apparent in this context. Appointed by the city in 1620, Francesc Socies served as water officer and fountaineer (*mestre de les fonts*) for more than 30 years and was responsible for renewed efforts to maintain and expand the system during the 1630s. In 1648, the Barcelona city government petitioned him to "write a book of the said fountains ... for the clarification of his successors."⁹⁸ In commissioning Socies, an elderly man with no direct heirs, to set down his knowledge in writing, the city aimed to safeguard and regulate access to this knowledge, for their request to Socies specified that the book would remain "perpetually ... in the house of the present city."⁹⁹

Socies delivered the 262-page *Llibre de les fonts de la Ciutat de Barcelona* (Book of Fountains of the City of Barcelona) to the city government on 14 November 1650.¹⁰⁰ The text, which is organized into 116 short chapters, discusses the major pipe bringing water to Barcelona, its distribution to public and private fountains across the city, and explores its catchment, that is, the *mines d'aigua* of the Collserola mountains. Concerned with the health of Barcelona's residents, Socies prioritized supply to public and collective-use fountains and sought to regulate private access so as to prevent water theft. Throughout the text, he referenced his hands-on experience and demonstrated his intimate knowledge of the network by consigning site-specific maintenance advice to future managers, sometimes referring to documents preserved in the city archive. He also encouraged these readers to take notes of future changes to the water system in the margins of the book pages, so as to ensure that the *Llibre de les fonts* would form a living, up-to-date record.¹⁰¹

The handbook's chief contribution lay in offering a detailed guide to ensuring that the flow of water was as efficient as possible, addressing perennial problems that became critical in the context of drought: managing pressure, clearing sediment that blocked pipes and, above all, controlling water theft. By meticulously tracing the path of water, the text addresses the major physical challenges of the time: regulating flow without loss of pres-

⁹⁷ Gorostiza, Martí Escayol, and Barriandos, "Controlling Water Infrastructure," 913–927; Barriandos and Gorostiza, "El context climàtic del Llibre de les fonts," 213–245.

⁹⁸ AHCB, CCiAM, Registre de Deliberacions, 02.01/1B. II-159, 1650, f. 325v.

⁹⁹ Ibid., ff. 325r–326v.

¹⁰⁰ AHCB, CCiAM, Manuscrits, 01/1G-076, *Llibre de les fonts*. Available at <https://catalegarxiu-municipal.bcn.cat/detail/130417682>.

¹⁰¹ Martí Escayol, "Vetx los anys com més anam són més estèrils de pocas ayguas," 155–187.

sure over distance. This required a holistic understanding of the hydraulic variables of the system: the initial flow, the friction accumulated within long conduits, the precise changes in level across the city's topography, and the need to maintain a constant gravitational gradient. The approximately 60 illustrations, featuring sectional drawings, elevations, and scaled plans, helped Socies to explain his findings and demonstrate the effects of pipe volume, slope, and length on the flow of water across the network (Fig. 2).

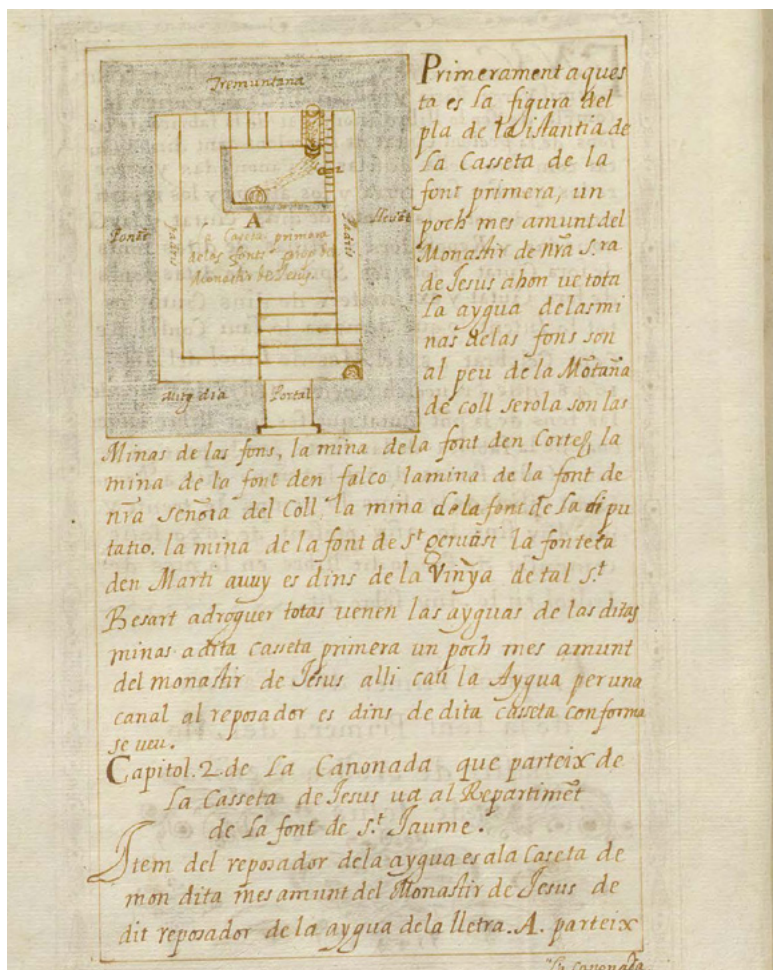


Fig. 2 – Plan of the first fountain house, near the Monastery of Nostra Senyora de Jesús, Barcelona. Arxiu Històric de la Ciutat de Barcelona (AHCB), Consell de la Ciutat i Ajuntament Modern (CCiAM), Manuscrits, 01/1G-076, *Llibre de les fonts*, chapter one.

The *Llibre de les fonts* enabled Barcelona's municipal government to strengthen its control over the circulation of water within the city. Socies described how he had relocated pipes from the interiors of private buildings to channels beneath the streets to prevent illegal connections. He also developed an iconographical key intended to help public authorities locate this hidden infrastructure. By interspersing his text with a series of 74 crosses that corresponded to identical ones incised into building facades, he keyed components of the urban network to his written apparatus.

The creation of the book illustrates the politics of knowledge in early modern Barcelona. The city government sought to institutionalise forms of knowledge traditionally within the exclusive purview of city water officers and transmitted within families, from father to son or son-in-law. In 1614, years before Socies took office, the city government had already requested that the water officer hand over to the city's chief scribe "the book that ... [he] possesses concerning the secrets of the fountains" so that it might be copied. The absence of further records suggests that the officer did not comply with the request and instead transmitted it to his son-in-law, who succeeded him in the post and preceded Socies.¹⁰²

The first modern reference to the *Llibre de les fonts* dates to 1917, when the historian Francesc Carreras i Candi highlighted its significance, noting that the manuscript was an extraordinary document that "deserved all honours" in the history of Barcelona's water services.¹⁰³ However, it was not until the 1990s that Antònia Maria Perelló Ferrer provided the first comprehensive study of the manuscript, of Francesc Socies, and of the professional practice of fountaineers within the context of seventeenth-century civil architecture.¹⁰⁴ The manuscript was subsequently featured in the 2011 exhibition *La revolució de l'aigua a Barcelona*.¹⁰⁵ In each of these cases, it was presented as an extraordinary source, only situated within a broader tradition with the publication of a complete critical edition in 2022.¹⁰⁶

3. Discussion

Already at first glance, both similarities and differences among the six handbooks presented here are numerous. In this discussion, we will focus in particular on similarities across these technical-administrative compendia, and what they tell us about their nature as technical *and* political sources. First, however, let us summarize some of their most salient differences. Hydrographically, some handbooks were concerned with a single aqueduct or drinking water supply system, while others considered a whole river basin. Their contexts ranged from territorial states and their capitals to Free Imperial Cities and provincial cen-

¹⁰² Gorostiza, "Francesc Socies," 45–90; Gorostiza, "Guerres d'aigua i paper," 247–287.

¹⁰³ Carreras y Candi, *Geografía General de Catalunya*.

¹⁰⁴ Perelló Ferrer, *L'arquitectura civil del segle XVII a Barcelona*.

¹⁰⁵ Guàrdia, *La revolució de l'aigua a Barcelona*.

¹⁰⁶ Martí Escayol, Gorostiza, and Cazeneuve i Descarrega, *El Llibre de les fonts*.

tres within larger polities. The background and status of their authors was equally varied, from city councillors and professional painters to artisan-practitioners and municipal or state officials. Whether acting of their own volition or in response to a commission, they each set pen to paper for a host of different reasons, ranging from professional handover, to explicating a system expansion or overhaul, to resolving problems such as flooding or drought, or some combination of these factors. What resulted were handbooks ranging in length from a few leaves to hundreds of pages, some beautifully presented and lavishly illustrated, others little more than working drafts.

Crucially, however, our authors all *did* set pen to paper, drawing upon their professional experiences to write about water management. Despite the variety manifest across these texts, then, it was their authors' shared decision to encode their site-specific hydraulic knowledge for their rulers and successors in an instructive, practicable manner that justifies treating them as a distinct genre.

The codification of information about water management was highly significant, for this kind of knowledge and expertise was normally tacit, transmitted orally to apprentices who were more often than not related to the office holder.¹⁰⁷ In some instances, as was the case in Barcelona, we know that written instructions facilitated this transmission from father to son, but they were jealously guarded and have left no trace in the archive. Part of this knowledge and expertise was also shared by a large number of people, comprising not only the municipal officials and overseers who penned our six sources, but also the varied professional figures they worked with, from specialised artisans to day labourers, some in public employ, others freelancers. Here, by contrast, we have six instances of handbooks which were produced by a single author for – and sometimes at the request of – the public administration, and which have therefore survived in their records. This highlights the double nature of these sources, at once technical and political, which we will analyse in turn.

3.1 Handbooks as technical sources: archives of embodied skill, claims to specialisation

A purely technical analysis of this corpus reveals a sophisticated, pragmatic mastery of hydraulic principles centred on flow dynamics. For the bulk of the handbooks treating urban water supply systems, a paramount technical preoccupation was the problem of pressure equalization – an engineering solution directly aimed at ensuring the reliable and equitable distribution of water across the urban fabric, from public fountains to privileged institutions. For di Pace, the sole author discussed here who focused on riverine flood mitigation, stabilizing riverbeds and improving channel capacity were chief concerns. Most of the authors under consideration here were also concerned with sediment – particularly its transport, accumulation and effects on hydraulic systems – thereby underscoring how

¹⁰⁷ Ferretti, “‘Imminutus crevit,’” 116.

these systems, and their histories, consist of more than water alone.¹⁰⁸

Several of these handbooks, in addition to technical description, also provided cartography and visual records as didactic or heuristic tools. This is evidenced by the detailed foldable panoramas in Jacques Le Lieur's manual, by Laureti's and Nigrone's drawings, as well as by Socies's practice of cross-referencing carved street markings with identical drawings in the manual's margins to locate hidden infrastructure. These works are thus far from static inventories; they constitute a prescriptive engineering culture that actively engaged with the period's most critical water management challenges.

As Pamela Smith has argued, couching skills and expertise in writing served a dual purpose: preserving practical knowledge and claiming social status in a text-based world.¹⁰⁹ The preservation of knowledge and expertise could be threatened by critical junctures of generational transition or the expert's departure, leading to codification in writing rather than oral transmission. Marpeck, Socies and di Pace, for example, all wrote their reports shortly before their death. In Bologna, by contrast, Laureti drafted his *Istruzione* just before departing for Rome, seeking to leave a record of his expertise.

These urban hydraulic manuals functioned as "technologies of credibility."¹¹⁰ By systematically documenting solutions to concrete problems – such as leaks, fraud, and epidemics – and by narrating their successful interventions to municipal authorities, hydraulic experts professionalized their trade and constructed a model of authority based on expert testimony and public utility. In doing so, these texts anticipated the core protocols of experimental science – the importance of reliable witnessing, detailed material description, and the persuasive communication of results – but they did so from within the "trading zones," that is, the interstitial social spaces where Latin-educated scholars (often humanists or natural philosophers) engaged in sustained communication and collaboration with experienced artisans and workshop-trained professionals, that existed between artisanal practice and municipal governance.¹¹¹

The authors' claim to essential expertise rested on strategically different foundations of knowledge. While Marpeck, Di Pace, and Socies built their authority on an erudition of practice – their lived experience constructing and maintaining water networks and their unparalleled familiarity with the urban and regional environments where they worked – Nigrone cultivated an erudition of synthesis, weaving together workshop skills with references to natural philosophy. Several authors, including Le Lieur and Nigrone, also show awareness of ancient sources, especially the Roman hydraulic expert Frontinus, who had

¹⁰⁸ Parrinello and Kondolf, "The Social Life of Sediment."

¹⁰⁹ Smith, *From the Lived Experience to the Written Word*.

¹¹⁰ Shapin, *A Social History of Truth*.

¹¹¹ Long, "Trading Zones," 840–847. For a recent discussion of the boundaries of knowledge within such trading zones, see Marcon, "Boundaries of Knowledge."

similarly authored a handbook of water management.¹¹² All authors, with the exception of Marpeck, also give nature an important epistemological place: by recommending that interventions be done in accordance with its laws – chief among them the flow of water – rather than against them, they position themselves as privileged interpreters of the natural order. Their shared goal was indeed to use authorship as a means of self-legitimation, transforming a manual trade into recognized science and climbing the social ladder of knowledge.

Self-legitimation for the handbooks' authors as hydraulic experts came at the expense of the visibility of the underlying collective labour. Several of our sources mention the large teams of workers, be they craftsmen or conscripted labourers, required to carry out the hydraulic projects and ongoing maintenance described, with Marpeck, Di Pace, Nigrone, and Socies all emphasising the importance of providing effective leadership to them. The authors thus positioned themselves as essential intermediaries between municipal or princely authorities and these workers.¹¹³ Presented as an anonymous collective, the latter nonetheless provided crucial labour and skills, some of which are likely to have been tacitly appropriated by our authors, and presented in their handbooks without acknowledgement.¹¹⁴

This article thus contributes to the scholarly study of early modern hydroculture by examining it as a case of practical knowledge formation from below, a process driven equally by artisanal experience and a strategic desire for public communication. Water management and the expansion of hydraulic systems called for a unified vision and coordinated long-term planning, a challenge that required the mobilization of expert knowledge, a large-scale strategy, and sustained maintenance. These handbooks were thus fundamental epistemic instruments. They generated collective forms of water knowledge – knowledge solidly rooted in social experience, work, and material practice – through the codification of empirical knowledge based on problem solving. Accordingly, we position these water management handbooks as a necessary material and social precedent for seventeenth-century experimental philosophy in general, and for the establishment of modern hydraulic theory in particular, which is conventionally traced back to the publication of Benedetto Castelli's *Della misura dell'acque correnti* (1628), the first treatise to offer a mathematical description of flow dynamics.¹¹⁵

¹¹² On the importance of ancient sources for early modern hydraulic experts, see also Morgan, *Nature as Model*, 124–148.

¹¹³ On the status of experts as intermediaries, see Ash, "Introduction," 13–18.

¹¹⁴ For an attempt to recover the skills of anonymous, female hydraulic labourers see Mukerji, *Impossible Engineering*.

¹¹⁵ See on this process, at least as it developed in Italy, Maffioli, *Out of Galileo*; and Maffioli, "A Fruitful Exchange/Conflict," 197–228.

3.2 Handbooks as political sources: strategic value of water control

These hydraulic handbooks emerged in urban and hydrographic contexts where water was a strategic asset and a tool of political control, and by extension, where knowledge about water became equally strategic. This status was driven by several converging factors: a significant growth in urban population, which required the expansion of water networks (and increased the complexity of the supply and distribution systems); the increasing autonomy of municipal governments from traditional guild structures; the preservation of the rigid social hierarchies of *ancien régime* societies, which structured and legally and materially restricted access to water; and environmental pressures such as recurrent floods or droughts, which intensified pre-existing water conflicts and made evident the value of control over water. The confluence of these factors, among others, triggered a competition for control over hydraulic knowledge and, as a consequence, in some cities pitted the water craftsmen who possessed the expertise against the institutions they served.

The aim of urban administrations was to codify and transfer to public oversight knowledge that had previously been personal and familial. This process of committing practical, day-to-day knowledge to writing followed an institutional logic of control, aimed at ensuring future management and the continuity of hydraulic infrastructure in the absence of the expert's direct heirs. The very act of writing transformed the tacit, private, and ephemeral knowledge of master artisans into stable, normative documents that could be appropriated by the urban administration. Consequently, many handbooks also functioned as legal instruments, capable of ratifying the city's property rights over strategic resources like water against competing powers, such as the Church. Whether a system of piped drinking water or a river basin, the water networks profiled in each handbook were understood as socio-political environmental systems of great magnitude and complexity. Managing them required a coordinated effort combining expert practical knowledge, large-scale planning, and sustained maintenance over time. Consequently, the authorities of the era approached water management as a challenge as political as it was technical, whose solution demanded the mobilization of the government's full logistical and coercive power.

Long and Smith also situate the textual production of artisanal knowledge within its political context, arguing that the consolidation of modern centralized territorial states created an urgent demand for technical expertise, both to produce advanced military technologies and to craft the material representations of authority essential to state-building.¹¹⁶ We suggest that this framework applies with equal force to the domain of water

¹¹⁶ Long, *Openness, Secrecy, Authorship*, 102–142; Smith, *From the Lived Experience to the Written Word*. On the “use of the built environment as evidence for the authority of state,” see Smith, *Architecture in the Culture of Early Humanism* (quote on 50–51), and on the related “manifest-taccon” of public authority in early modern cities, Griffiths, *Information, Institutions, and Local Government*.

administration in the realm of city-state, territorial state, and municipal governance alike. Far from being mere passive recipients of their superiors' demands, several of the authors we study also strategically mobilised their knowledge to suggest administrative reform. In doing so, they argued that the increasing specialisation of their expertise and the rising status of their profession should be matched by a corresponding specialisation in administrative structures.

We therefore argue that these handbooks had a public purpose, functioning as meeting points between the individual and the institutional voice. We frame them in the type of social writing that Kilburn-Toppin and Waddell have defined. Unlike the "literature of the ego," social writing was intended for a community and not only the individual. This purpose was manifested in a hybridity of styles: a single manuscript could integrate the tone of a personal diary, the structure of an institutional chronicle, the rigor of a scientific treatise, the precision of cartography, and the detail of administrative records.

The imperative to secure urban water supplies, prevent catastrophic flooding, and ensure public health was a fundamental concern of early modern governance, directly linked to fiscal stability, social order, and the legitimization of government.¹¹⁷ When, in his best-selling *Reason of State* (1589), Giovanni Botero explained that it was the "duty" of rulers to "drain swamps ... and aid and support those who undertake similar works," he articulated something that civic and state administrators had known intuitively for centuries: the prudential management of water was central to the protection and promotion of the *bonum commune*, on which their authority chiefly rested.¹¹⁸ Handbooks, technical manuals, reports, and surveys on water management – commissioned by city councils, dedicated to ruling princes, or presented as unsolicited advice to the authorities – were therefore crucial instruments of the art of government. By codifying practical knowledge about fountains, aqueducts, springs, and river defences in written and drawn form, these texts transformed personal and private knowledge into a systematic administrative resource. This allowed municipal governments to standardize and assert control over the natural environment and the bodies of their subjects. Thus, the rise of this specific stream of technical literature was a direct response to the hydrological imperatives of state-building in the early modern period, reflecting a strategic mobilization of expertise to manage territory, project power, and ensure urban survival.

¹¹⁷ See for example Geltner, *Roads to Health*; Mukerji, *Impossible Engineering*; Ash, *The Draining of the Fens*; Tomory, *The History of the London Water Industry*; Else, *The Politics of Water*.

¹¹⁸ Botero, *The Reason of State*, 134–135. On the medieval origins of the political ideology of the *bonum commune* (common good) see Kempshall, *The Common Good in Late Medieval Political Thought*, and Dumolyn, "The Common Good." For more on Botero's ideas about the importance of water management to the art of government, see Murphy, "Giovanni Botero."

4. Conclusion

This article has presented six examples of handbooks of practical water knowledge produced in early modern Europe. Juxtaposed and compared for the first time, they make one thing abundantly clear: these are not exceptional expressions of some local genius, but instances of a broader genre which deserves recognition and study as such. This genre, the hydraulic handbook, was both technical and political, and reflected a strategic reconfiguration of site-specific practical knowledge as a vector of power and authority in early modern Europe. Hydraulic handbooks functioned simultaneously as archives of embodied practical knowledge, as claims to specialised expertise, and as instruments in the service of the broader political objective of water control. They appeared during the sixteenth and seventeenth centuries as growing cities and states with expanding administrative structures increasingly sought to control rivers and hydrographic systems, or to manage and expand water supply – in a word, to govern waters.

In response to the political demand for hydrological control and urban stability, then, the primary function of water management handbooks was to codify and resolve practical, urgent problems – from managing droughts and floods to ensuring equitable water distribution. This process transformed the previously tacit, private, and ephemeral expertise of fountaineers, engineers, and builders into stable, normative, and administrable documents. They were, in essence, books born of necessity, intended for daily use and consultation by municipal officers and their successors to sustain social life.

The administration of water and hydraulic networks transcended the merely technical to become a central political instrument. If technical instruction in the workings of specific systems was crucial for the next generation of hydraulic experts, who would go on to manage these systems day-to-day, then from the point of view of governing elites, the control of water was essential to maintain order, public health, social hierarchies, and economic stability. Consequently, the practical knowledge codified in contemporary handbooks served a dual purpose: it was a fundamental epistemic instrument that generated experience-based and collectively validated knowledge for practitioners, and it was also a strategic tool of governance. These handbooks allowed the authors – often artisans trained in workshops – to legitimize their identity as experts and elevate their social status in the face of both the period's academic hierarchy and the large number of labourers actually needed to perform hydraulic work. At the same time, these handbooks had a particular value within *ancien régime* societies, where the regulation of a vital resource reinforced existing power structures. Thus, more broadly, our analysis argues that knowledge in this context was strategically reconfigured as a vector of power, credibility, and social control, prefiguring works such as Castelli's seminal treatise, and integrating technical practice within the fabric of political authority.

The knowledge and expertise presented in this article also began life orally, as a conver-

sation in the Barcelona city archives. Our own reasons for codifying them into writing are more prosaic than those of early modern hydraulic experts, but one aim does motivate us as much as them: the desire to transmit what we know to others. We hope that this article will serve as encouragement to bring more handbooks of early modern water management and hydraulics to the light and, crucially, into conversation with each other.

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Projecting and painting: codifications of the camera obscura, 1568–1711

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Abstract

The camera obscura is best known to historians of science and historians of philosophy for its role in early theories of human vision and cognition. Art historians have discussed the instrument mostly as a predecessor to the photographic camera. Building on recent literature that combines these strands of scholarship, I argue that the codification and circulation of the main philosophical and artistic problems of the camera were more closely intertwined than previously believed. I show that, throughout the sixteenth and seventeenth centuries, discussions of the setup of the camera obscura as a painting tool and of the conceptualization of its optical projection often coincided. For both, finding the distances between the lens, object, and image was a persistent problem until mathematicians provided explicit solutions, around 1700. Therefore, I argue, the conceptualization of these distances in projection and the codification of the camera obscura's material use for painting were inextricably linked.

Keywords

camera obscura, practical mathematics, geometrical optics, circulation of knowledge, codification of practices

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1. Introduction

Everyone knows with what ease one can, by means of a single convex lens, represent naturally, in a dark place, the objects outside of it [...] it is moreover so easy to render this invention useful for painting that the care of treating the matter at such a length as we do here will appear, without a doubt, unnecessary.¹

The camera obscura had been around for a long time when Willem Jacob 's Gravesande (1688–1742) published his short treatise, the “Usage de la chambre obscure pour le dessein,” in 1711. The instrument was widely regarded as analogous to the human eye in early modern natural philosophy. It had been used in astronomy to study the sun without having to look at it directly since the early sixteenth century. And from the second half of the sixteenth century onwards, various authors suggested using the instrument to produce stable images on a sheet of paper, so that these images could be studied or directly copied.²

The aim of this article is to cast light on the circulation of this last use of the camera obscura: its use as a technical innovation in painting, as a copying machine *avant la lettre*. Evidence on such circulation directly from practitioners is sparse. There are few sources on the working methods of painters, and the use of the camera obscura in painting generally does not leave unequivocal traces. Because of that, existing studies have relied on anecdotal textual sources and reconstructions of painting techniques to establish that specific individuals, including prominent figures in art history, used the camera obscura. Hence, it is clear there was some circulation. Yet the available evidence indicates that, before the eighteenth century, those using the instrument were part of a small minority.³ In other words, and in contrast to what 's Gravesande's claims suggest, the use of the camera ob-

¹ 's Gravesande, “Usage,” [i]. “Tout le monde sçait avec quelle facilité on peut, par le moyen d'un seul verre convexe, représenter au naturel dans un lieu obscur, les objets qui sont au dehors [...] Il est d'ailleurs si aisé de rendre cette invention utile pour le dessein, que le soin de traiter cette matière aussi au long qu'on le fait ici, paroîtra sans doute peu nécessaire.” Throughout, translations are mine unless indicated otherwise, and attempt to maintain the conceptual terminology in the originals.

² For chronologies of the camera obscura, see Waterhouse, “Notes,” Hammond, *Camera Obscura*, Kemp, *Science of art*, 188–199, Steadman, *Vermeer's Camera*, 4–24, and Lefèvre, “Camera Obscura.”

³ Scholarship on the camera obscura and painting has centered on the question of when painters started to use the camera, and particularly on its possible use by Johannes Vermeer (1632–1675). Steadman, *Vermeer's Camera*, offers compelling arguments for Vermeer's use of a camera. Other painters associated with the camera obscura in the literature include Caravaggio, Van Wittel, and Canaletto. For discussion, see, e.g., Gorman, “Art,” Dupré, “Introduction”; Lüthy, “Hockney's Secret Knowledge,” and Steadman, “Canaletto's Camera.”

scura as a painting instrument seems to have been slow to take off. Why was that the case?

To answer this question, I draw on a body of early modern texts recommending the camera obscura as a tool for artists. Such texts appeared first in mid-sixteenth-century Italy and spread over Latinate Europe during the seventeenth. They were mostly written by mathematicians as part of treatises on the geometry of perspective painting. Many of their authors reveal substantial knowledge of the techniques used by “practitioners.”⁴ Such texts are well known to the historical scholarship on the camera obscura and art. Yet they have been cited predominantly as illustrations of the fact *that* camera obscuras were in use for painting.⁵ On the other hand, philosophically oriented scholarship on the camera obscura has mainly been concerned with how such texts used the camera obscura to explain the functioning of the human eye.⁶ Instead, I look more specifically at *how* these texts described the functioning of the camera obscura, and if those descriptions might have aided its use in painting. I document both historical developments in the conceptualization of projecting images with the camera obscura, and concrete advice on the material setup needed for its potential innovative use in painting.⁷

My evidence reveals a remarkable overlap between a persistent problem in geometrical optics, on the one hand, and continued lack of precision in descriptions of the camera obscura as a copying machine, on the other hand. For both, the lack of precision is directly connected to the absence of an explicit technique for finding the distances between image, lens, and object. I build on earlier studies on similar problems for mirrors and the telescope to explain these conceptual difficulties. For telescopes, the more central instrument to seventeenth-century optics, questions of image location were solved early in the second half of the seventeenth century.⁸ But, as I explain below, the camera obscura posed an even

⁴ For my purpose, little is at stake in how “practitioners” is defined here. What matters is that the authors of treatises on geometrical perspective techniques tended to have knowledge of painters’ techniques. On perspective techniques and painting techniques, see e.g. Dupré, “Historiography.”

⁵ See the literature cited in notes 2 and 3.

⁶ On early modern optical theories, see Smith, *From Sight to Light*, 333–349. On the challenges that optical theorists faced, see e.g. Pantin, “Simulachrum,” Chen-Morris, *Measuring shadows*.

⁷ Camera obscuras had still other uses. For example, various metaphysical and religious connotations were ascribed to such instruments, especially in works of seventeenth-century Jesuit authors such as Athanasius Kircher, and Caspar Schott, as well as in that of their student Johannes Zahn. On these dimensions, see e.g., Vermeir, “Kircher.” For a helpful collection of printed images of their camera obscuras, including Zahn’s, Schott’s and Kircher’s, see Warwick, “The ‘Sky Optick.’” A discussion of this variety of writings on the camera obscura is outside the scope of this article. I here concentrate on works that attempted to describe either the projection of images or the use of the camera obscura for painting.

⁸ For the problem of image location in geometrical optics, see Shapiro, “*Optical Lectures*,” Dupré, “Ausonio’s Mirrors”; Malet, “Conceptualizations,” Shapiro, “Images,” Malet, “Kepler’s legacy.”

more complicated distance problem, for which specific solutions appeared in print only in the final decade of the seventeenth century.

That the relatively slow uptake of the camera in painting was related to this rather poor conceptual grasp of what happens inside the camera obscura is suggested by the timeline. Explicit procedures for how to set up the camera as a copying machine were published only after solutions to the theoretical problem were codified. But once the theoretical problem was fixed, exact instructions on how to get a sharp image on a sheet of paper inside followed soon. 's Gravesande's treatise on the camera obscura was very likely the first to combine both. Although his treatise has been mentioned by various historians, no study of it exists and the existing literature does not draw attention to the fact that 's Gravesande codified a solution to an outstanding practical problem.⁹ Here, by 'codified solution', I mean a set of descriptions, quantitative or not, arranged such that, if followed closely, they would allow one to solve the problem at hand. I argue that 's Gravesande's description of a procedure to set up the camera obscura as a copying machine allowed this specific use of the camera to circulate at a much larger scale than before.

Although one might be skeptical of such a link between codifying a solution to a seemingly theoretical problem and the onset of widespread material use,¹⁰ the rest of 's Gravesande's treatise shows how quantification mattered to making the instrument user-friendly. The treatise contains two designs of portable camera obscuras adapted to painting, described in sufficient detail for others to rebuild them. Both instruments, but especially the one depicted in Fig. 1, automatized the procedure of getting the image in focus. The treatise specified how to use the instruments and showed that they corresponded to the quantitative precepts of geometrical optics. That is, it showed and proved how to bring

None of these studies pays much attention to developments on the camera obscura in the period after Kepler. As Cocquyt, "Instrumental Practices," 86, remarks, during the seventeenth century, "optical rules were not universally applied, but instead depended on particular phenomena [...] imaging in a camera obscura setting, where 'real' images are being produced, was treated differently from imaging in telescopes."

⁹ Both Delsaute, "Camera Obscura," 114 and Steadman, *Vermeer's Camera*, 136–137 refer to the novelty of the instrument designed by 's Gravesande (see Fig. 1) without addressing the specific instructions given. Andersen, *Geometry*, 341–342 draws attention to geometrical demonstrations given by 's Gravesande and calls him "the first to go into any detail about how the instrument functions relative to a particular perspective projection" but neither discusses his advice on setting up the machine, which comprises the bulk of the text.

¹⁰ Such skepticism is expressed, for example, in the recent but already seminal Smith, *Lived Experience*. See, on page 4, "artists and artisans in early modern Europe did not need writing to produce things and make knowledge"; and page 8, "writing was not necessary to transmit [...] information from one generation or region to another." Even if I agree with Smith on the possibility of transmission without writing, my argument is not about circulation *per se*, but instead about the scale of circulation.

an image in focus in just a few steps. Whoever had such a machine built could hence proceed to copy an image without a need for a theoretical or an empirical understanding of the distances between the lens, the sheet of paper, and the object. That is, by following this description, one could greatly reduce the amount of empirical experience needed to operate the camera obscura.¹¹

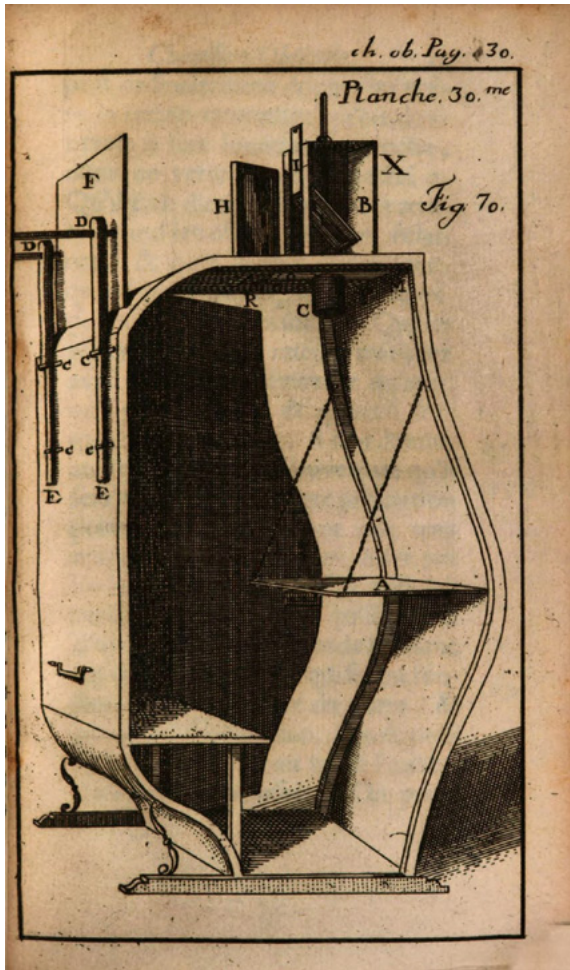


Fig. 1 – The less wieldy but more precise of 's Gravesande's camera obscuras, set up to copy engravings. The engraving to be copied is placed at F, a lens and mirror are placed inside the tube C and box X, and a sheet of paper on table A. An image of the engraving placed at F appears in focus, and in equal size on the sheet of paper, and can be directly copied. 's Gravesande, *Essai*, plate 30.

¹¹ Perhaps surprisingly for readers living in a world in which even barely adequate inventions are monetized, 's Gravesande made the design of his instrument freely available so others could rebuild it. See section 8 below for more details on his *modus operandi* with regard to instruments. A recent reconstruction of 's Gravesande's machine is discussed in Steadman, "Canaletto's Camera," 151–152: "[our replica of 's Gravesande's] camera works [...] It is quite feasible to use the instrument to make 'Canaletto-like' sketches. It is not difficult to trace or to maintain focus."

To be sure, the point of this article is not to argue that it was impossible to use the camera obscura for painting before 's Gravesande. As noted above, various painters did use the instrument before. Among those who wrote on the camera, its "ease" of use had even become somewhat of a rhetorical topos, as we will see. 's Gravesande was aware of painters' techniques and acknowledged that he had received advice from a painter for his *Essai de perspective* (1711), a treatise on perspective geometry to which his text on the camera obscura was appended.¹² Neither do I want to argue that 's Gravesande was singlehandedly responsible for the uptake of the camera obscura as a copying machine in the eighteenth century. Uptake certainly depended on more than the availability of codified knowledge alone. Many other factors mattered, not least how an instrument such as the camera obscura fitted into existing painting practices and aesthetic attitudes.¹³ As I asserted above, however, the timeline does suggest a connection between the presentation of the camera obscura as a user-friendly machine and its circulation among practicing painters. Textual and material evidence for use of the camera in painting is very sparse before 1700 but grows rapidly from about the 1720s onwards. As John Hammond stated long ago: "during the eighteenth century many instrument makers were producing [the camera obscura] and advertising it for sketching. The apparatus appears to have been a normal piece of equipment for travellers and amateur artists."¹⁴

My argument on circulation is based on the assumption that using the camera obscura for painting or drawing was made much easier when user-friendly descriptions of the instrument became available. That is, I argue such codification changed the scale on which circulation took place. Whether that be true or not, this article shows (1) that no such user-friendly descriptions were available before 1711, (2) that the first such description

¹² 's Gravesande, *Essai*, [xviii–xix]: "j'ai eu le bonheur de rencontrer un habile Peintre [...] je lui suis redevable de plusieurs observations, auxquelles sans lui je n'aurois peut-être jamais pensé"; this painter remains unnamed.

¹³ See Kemp, *Science of art*, 190 on the camera obscura and early modern views on the imitation of nature. One reason contemporaries of 's Gravesande gave against the use of the camera obscura was the claim that the image on the sheet presented an "unnatural perspective." As a commentator on 's Gravesande, Jombert, *Methode*, 139, put it: "la maniere dont nous voyons les objets de la nature dans la chambre obscure, est différente de celle dont nous les voyons naturellement [...] L'effect en est à la vérité plus piquant, mais il est faux." As this comment appears in the middle of an abridged, pirated edition of 's Gravesande's treatise, it has been mistakenly attributed to 's Gravesande himself by some historians, starting with Hyatt Mayor, "The photographic eye."

¹⁴ Hammond, *Camera Obscura*, 40, see 20–103 for Hammond's wider assessment of its spread. Like Hammond, studies such as Lüthy, "Hockney's Secret Knowledge," and Wenczel, "Camera Obscura" have found no evidence for a wide use of the camera in art before the mid-eighteenth century. Lefèvre, "Camera Obscura," 5, asserts that "there is not one example of a camera obscura or even a single part of one that dates from the 17th century."

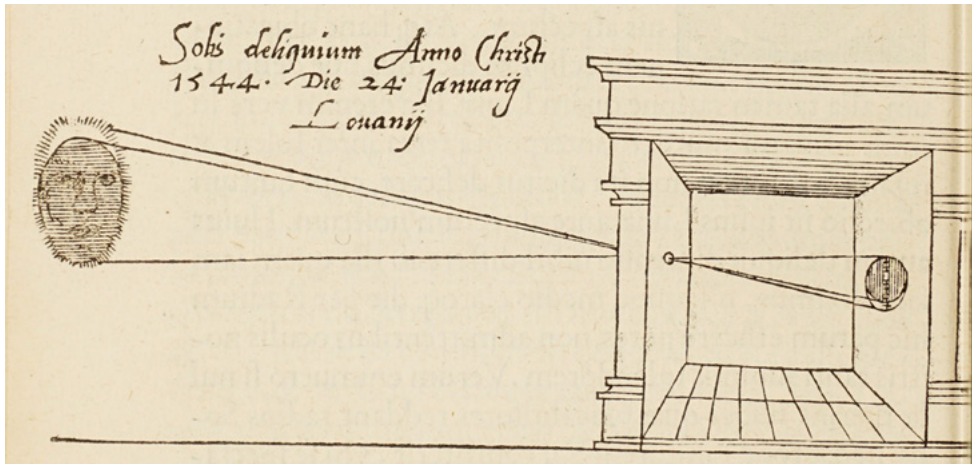


Fig. 2 – The earliest printed illustration of the use of a camera obscura in astronomy, by Gemma Frisius, *De radio astronomico*, 31v.

was directly based on a geometrical codification of the camera's functioning, and (3) that throughout the period here considered, the codification of material use was intertwined with conceptual advances in geometrical optics.

Section 2 of the article looks at the camera obscura itself and discusses what part of the geometry of lenses and light matters to its use in painting. In section 3, I look at the earliest textual source on that use, a mathematical book from 1568, and show its lack of conceptualization of the camera obscura. Sections 4–7 present the historical evidence for my core argument about the overlap between developments in the codification of the functioning of the camera and in descriptions of how to use it for painting. In section 8 I return to 's Gravesande's camera to show why it is plausible that his specific description of the camera indeed impacted the circulation of its use for painting. In the conclusion, I consider what the case of the camera obscura tells us about the relations between mathematical theory, material practice, and technological innovation in early modern science more generally.

2. Focusing the object: the conundrum of the camera obscura

In its simplest form, the camera obscura is a “dark room” in which, in present-day terms, an image of an external object or set of external objects is projected by rays of light falling through an aperture. The image appears inverted on a wall or sheet opposite to the aperture. Camera obscura-like phenomena can and do appear accidentally under strong sunlight and mentions of this phenomenon can be found in texts from ancient China

and Greece.¹⁵ Deliberately blacked-out rooms with a small hole in one wall were used in Renaissance astronomy to observe solar eclipses safely. This technique was described by Leonardo da Vinci (1452–1519) and depicted in print by Gemma Frisius (1508–1555).¹⁶ Projecting images of eclipse, in which the object to be represented was the sun itself, was a well-established and straightforward practice by that time (see Fig. 2).

The camera obscura as a painting device, however, is more complex. It does not project the sun directly but rather specific objects lit by the sun. Even when such objects are brightly lit, the image inside is usually rather mute, unless a convex lens is placed just behind the aperture to refract the rays of light. If handled well, this lens will make the projected image much brighter and sharper than the simple pinhole camera does. However, speaking from personal experience, setting up a camera obscura with a lens such that it projects a traceable image is not a straightforward matter.¹⁷ To get a bright and focused image, one has to find the appropriate orientation for the camera obscura and closely control the distances between the objects, lens, and image, and possibly those of mirrors that correct for the inversion of the image. Present-day optics uses the “thin lens approximation” to find those distances: $1/f = 1/o + 1/i$. Here, o is the distance between the external object and the lens; i is the distance between the place at which the projected image of the object is “in focus” and the lens; and f is the “focal length” of the lens, a constant depending on the properties of the lens in use. For a given o and f , the formula thus gives the distance at which the projected image will be in focus: the place where a sheet of paper should be placed. Alternatively, given the distances of the object and the screen to the lens, the formula gives the focal length of the lens needed to focus the image.

The object distance and the image distance are concrete and measurable, and relatively unambiguous. The focal length, however, is more complicated. It is the key property of a convex lens and depends on its curvature and refractive index. Even in present-day settings, focal length, and the directly associated focal points, are regularly measured by empirical approximation instead of calculated, for example by opticians who want to check the optical power of a pair of glasses. Operationally, this is best done in the special case in which rays of light fall onto the lens parallel. That is the case when the object to be depicted is sufficiently far away. In that case, the $1/o$ term decreases towards zero and can be ignored. Thus, for a far-away object, f and i in the formula above will be approximately equal: the image distance equals the focal length.

This equality between image distance and focal length, which only holds in the specific

¹⁵ Hammond, *Camera Obscura*, 1–5.

¹⁶ See e.g. Steadman, *Vermeer's Camera*, 4–7.

¹⁷ Although I am far from an expert, I have tried to set up camera obscuras with different lenses and in different places and struggled a great deal with finding appropriate components and setting the distances between them. I thank Tiemen Cocquyt, for the discussion and for showing me what concretely matters in setting up a camera obscura.

case of far-away objects, is vital to understanding troubles of historical actors with expressing clearly how a camera obscura functioned. The equality occurs particularly when the camera is used for astronomical purposes: when the object is the sun, rays of light fall in parallel and the “focal length” and the distance from the lens at which the projected image is “in focus,” are equal. This is why the distance problem is more complicated for the camera obscura than for the telescope: if one wants the camera to represent, say, a tree or a person a few meters removed from the lens, one cannot ignore the $1/o$ term. However, for Renaissance and early modern treatises on the camera obscura, it was not those cases but instead the astronomical case that tended to be the most important. Hence the ‘standard’ explanation of optical artifacts was one in which there was no need for a distinction between the image distance and the focal length.

Indeed, such a distinction is absent in historical texts. These texts tended to use the word “focus” to describe the place at which an image was best represented. But in expressing the distance between that place and the lens, they tended to use the same terms irrespective of whether a camera obscura or a telescope was used. They thus lumped what are now called the image distance and focal length. Effects of this lumping persist in present-day popular use. In optics, “focus” remains a technical term: a focus is defined as a *place* at which light rays from the same point of origin converge. But, in casual use, it can also refer to a *distance*: either a focal length or the image distance. Furthermore, as the Latin term for fireplace, “focus” historically had specific connotations not directly relevant to projected images. It was applied to burning mirrors before glass lenses were available, and also was a specific geometrical term: the foci are specific points of reference in the construction of curves such as ellipses and parabolas. Thus, “focus” in general meant the place where lines, whether of heat, of light, or purely mathematical, converged.¹⁸

More generally, terms such as ‘camera obscura,’ ‘image,’ ‘focus,’ and ‘projection,’ were all moving targets in the period considered. What is more, they were often moved by questions and issues other than that of using a camera obscura for painting. The problem of finding a clear representation of a nearby external object was not the most pressing problem to those concerned with the science of optics or optical instruments. Nevertheless, as we will see, many authors believed it was a question worth addressing. During the seventeenth century, writers on the camera became increasingly convinced that it was a problem that could be solved in geometrical terms. That is, they believed that it was a problem to which the solution could be codified in mathematical terms.

¹⁸ On such use of “focus” in the work of Kepler, Cavalieri, and others, see Shapiro, “Images.” The metaphor of “focusing on,” now almost as common in academic writing as phrases such as “the way in which,” of course has the same root. To avoid confusion, I try to avoid such metaphorical use of the term focus here.

3. *The false start of the conceptualization of the camera obscura*

The oldest published text that describes how to use the camera obscura for painting is Daniele Barbaro's *La pratica della prospettiva* (1568),¹⁹ a text remarkably similar to 's Gravesande's later work on perspective. Barbaro (1514–1570) aimed to provide a compendium on mathematical perspective “of great use to painters, sculptors and architects.”²⁰ Barbaro appended his description of the camera obscura, a term he did not use, at the end of his book, under the header “natural ways to put [things] into perspective.” It seems he considered the camera to be an addition or alternative to the geometrical perspective constructions the book was dedicated to. Those mathematical techniques contrast with his lengthy and ambiguous description of the “most beautiful experience around perspective” he had with the camera:²¹

If you want to see how nature poses the things [...] you will make a hole in the shutter of a window of the room from where you want to look, as large as the glass of an eyeglass is. And grab an eyeglass of an old person, that is to say one that has some body in the middle [i.e. a convex lens] and is not concave like the eyeglasses of young people who are short-sighted. And set this glass into the fitted hole, then close all the windows and the doors of the room, such that there is no light apart from what comes from the glass. Then take a sheet of paper and set it opposite the glass at such a distance that you minutely see all that is outside of the house on the sheet. This happens more distinctly at a particular distance. This [distance] you will find by moving the sheet towards or away from the glass, until you find the convenient site. Here you will see the forms on the paper as they are [...] For this experience it is required that there be a clear and fair sun, because the light of the sun has great force in drawing out the visible species, as you will experience to your great delight. In this experience you will make a selection of the glasses that work best. If you want to cover the glass so much that you leave a little bit of the circumference in the middle, such that it be clear and exposed, you will see an even more vivid effect thereof. Thus seeing on the paper the outlines of the things, you can with a brush mark on the paper the whole perspective that will appear on it [...].²²

¹⁹ Girolamo Cardano and Giambattista Della Porta are often mentioned to have described a camera obscura with a lens in 1550 and 1558 respectively. Della Porta in fact wrote about mirrors. Cardano referred to a lens in a closed room, but asserted it created “dull images” and did not mention copying them. See e.g. Waterhouse, “Notes,” 274, Kemp, *Science of art*, 189, Steadman, *Vermeer's Camera*, 8, and Ilardi, *Renaissance vision*, 220.

²⁰ See the title page of Barbaro, *Perspectiva*. Andersen, *Geometry*, 152–158, asserts Barbaro's book was largely derivative.

²¹ Barbaro, *Perspectiva*, 192, “modi naturali di mettere in prospettiva”; “una bellissima isperienza d'intorno alla Perspectiva.”

²² Ibid., 192–193. “Se vuoi vedere come la natura pone le cose [...] farai uno bucco nello scuro

Thus, Barbaro introduced the idea of painting with the camera to the learned world. Given the way he described it and the absence of any claim to invention, it seems likely that he described a practice he had carried out himself, or at the least witnessed. If that is correct, Barbaro's text provides evidence of circulation of the camera as a painting tool. But it does not provide any evidence on the scale of this circulation. Besides the idea of painting with the camera, Barbaro also introduced the main problem: that of finding the distance at which the image – a term he did not use – is seen clearly on the sheet. Barbaro, however, did not give any details on where to move the sheet to distinctly see “the things.”

In fact, Barbaro did not provide any clear guidance on making “the outlines of the things” on the screen “more distinct.” Instead of codifying solutions to specific issues – as he did give for mathematical perspective problems – for the camera obscura, he advised trial-and-error methods. His readers would have to vary the distance between the lens and the screen and try out varying eyeglasses themselves, until something convenient was found. Barbaro's advice to use convex lenses and to cover part of the lens – with what would later be called a diaphragm – is sound but left unexplained.²³

Clearly, readers who had experience with both lenses and perspective paintings would be able to set up the instrument. But those who lacked knowledge of optics would probably have found little help in Barbaro's text. Not only was Barbaro unhelpful on distances, he also failed to mention various nuisances with the setup he described. Most importantly, the projection inside his camera obscura will have appeared inverted both left to right and upside down. This could be solved by additional mirrors or lenses but Barbaro did not mention those. Besides that, Barbaro's text did not talk about how to control the com-

d'una finestra della stanza di dove vuoi vedere, tanto grande quanto è il vetro d'un occhiale. Et piglia un occhiale da vecchio, cioè che habbia alquanto di corpo nel mezzo, & non sia còcavo, come gli occhiali da giovani, che hanno la vista curta. & incassa questo vetro nel bucco assaggiato, serra poi tutte le finestre, & le porte della stāza. sicche non vi sia luce alcuna, se non quella, che viene dal vetro, piglia poi uno foglio di carta, et ponlo incontra il vetro tanto discosto, che tu veda minutamente sopra'l foglio tutto quelle che è fuori di casa, ilche si fa in una determinata distanza più distintamente. ilche troverai accostando, overo discostando il foglio al vetro, finche ritrovi il sito conveniente. Qui vi vederai le forme nella carta come sono [...] A questa isperienza bisogna, che ci sia il Sole chiaro & bello, perche la luce del Sole ha grande forza in cavare le specie visibili, come con tuo piacere ne farai la isperienza, nella quale farai scielta di quelli vetri, che fanno meglio, & se vorrai coprire il vetro tanto, che vi lasci una poca di circonferenza nel mezzo, che sia chiara è scoperta, ne vederai anchora piu vivo effetto. Vedendo adunque nella carta i lineamenti delle cose, tu puoi con uno penello segnare sopra la carta tutta la Perspettiva, che apparerà in quella [...]. I have rendered “u” as “v” wherever appropriate. Existing translations in Waterhouse, “Notes,” Dupré, “Galileo,” 246, and Ilardi, *Renaissance vision*, 220 are more liberal in using terms such as “lens” or “image,” which I avoid because I want to draw attention to the lack of conceptual clarity in Barbaro's text.

²³ On the importance of diaphragms, especially to compensate for defects in lenses, see Cocquyt, “Instrumental Practices,” 54–57.

position: his camera obscura would not simply let one “minutely see all that is outside of the house.” But objects at different distances appear with different clarity and distinctness, depending not only on those distances themselves but also on the refracting capacities of the lens in use. Given this largely vague description, we should in my view be skeptical about whether Barbaro’s text would have helped to spread the use of the camera obscura for painting.

4. *Conceptualizing optical instruments and projection*

Barbaro did not explain well what happened inside the camera. Nowhere in his text did Barbaro talk about controlling the image’s size, depth, or focus. In fact, he did not use concepts such as ‘image’ or ‘focus’ to describe the convergence of rays after passing the lens, nor did he use terms such as ‘picture’, ‘image’, or ‘representation’ to conceptualize what appeared on his screen. In other words, he used no technical vocabulary to codify the process of projection from the lens onto the sheet. But such terms started to develop in the decades after Barbaro’s work.

Barbaro’s text was not devoid of theoretical concepts altogether. In describing what was visible of the objects outside, he used “visual species,” which “the light of sun” “draws out” or “extracts.” The term species came from perspectivist optics, a field of natural philosophy which had as its main subject the explanation of human sight and visual cognition. In the medieval optics of the likes of Roger Bacon and Vitello, “species” referred to the entity that supposedly established a connection between the perceived objects and the perceiver, that is, between the object and the eye. Perspectivist optics comprised certain geometrical construction techniques to explain vision. But it was not concerned with codifying mathematical perspective techniques that comprised the main body of Barbaro’s book, and neither did it include images projected by convex lenses or concave mirrors.²⁴

Such artifacts as convex eyeglasses circulated widely in Italy by the middle of the fifteenth century,²⁵ which makes it likely that projections were experienced, at the least accidentally. Yet not much survives in terms of systematic investigations of their functioning before the time of Barbaro. The first clear attempts to do so overlap with Barbaro’s both in time and in their conceptual approach. Authors such as Francesco Maurolico (1494–1575), Giovanni Battista Benedetti (1530–1590), and Giambattista Della Porta (1535–1615) took over elements from medieval perspectivist optics specifically to analyze the functioning of optical instruments such as mirrors, lenses, and combinations of

²⁴ On *species*, see for instance Smith, *From Sight to Light*, and Pantin, “Simulachrum.” See Dupré, “Kepler’s optics” on strains between the practices of mathematical perspective and perspectivist optics.

²⁵ On the circulation of lenses, see Ilardi, *Renaissance vision*. On developments in and control of lens quality, see Cocquyt, “Instrumental Practices.”

them. Thus, they drew on the same theory of vision from which Barbaro took the concept of “species.”²⁶

An early example of such appropriation was Ettore Ausonio’s (ca. 1520–ca. 1570) short discussion of the properties of a spherical concave mirror, which dates from around 1560. Ausonio was a practicing physician, alchemist, and maker of instruments such as astrolabes, dials, and burning mirrors. As Sven Dupré points out, Ausonio’s interest in perspectivist optics was closely related to the practice of making such instruments, more than to the perspectivists’ central topic of perception. For the spherical mirror, Ausonio took advantage of the “cathetus rule,” a geometrical construction used by the perspectivists to determine where, after reflection in mirrors, the “imago” would be perceived by the human eye. Ausonio used the same rule to find the “point of inversion” of spherical mirrors. This point of inversion is the place where, if the eye approached it, the image would turn upside down. Ausonio, however, also identified this point with the place where a spherical mirror would produce combustion. This issue of combustion was not proper to perspectivist optics, which means that Ausonio appropriated, in a strong sense, elements from perspectivist optics: he took a specific technique out of its theoretical toolkit and applied it to a problem outside of the field.²⁷

The concept of the point of inversion and its relation to combustion became of major importance to Della Porta’s studies of optical artifacts such as mirrors and lenses. Della Porta was the author of the *Magia naturalis* (1558, 2nd, more relevant edition, 1589), a book concerned with a broad collection of natural experiments and phenomena. As Arianna Borrelli has argued with respect to his optics, Della Porta “devote[d] himself to the observation, description, and formalization of effects without having to introduce any overarching explanatory notions.”²⁸ That is, like Ausonio, Della Porta was interested in producing phenomena with instruments, independently of developing a broader theory of perception. For lenses and glass spheres, one of Della Porta’s most important insights was that combustion and the point of inversion were not always at the same location. Della Porta found that the location of the point of inversion changes when the perceiver or object moves, while the burning point does not.²⁹ Thus, Della Porta’s discussion showed that Ausonio had confused a location that depended on the relative positions of the observer and object, with a fixed point that was determined by the material setting.

²⁶ On Maurolico, see Dupré, “Galileo,” 256–260, on Benedetti, see Goulding, “Binocular vision,” on Della Porta, see below.

²⁷ This section on Ausonio is based on Dupré, “Ausonio’s Mirrors,” 145–180, Dupré, “Kepler’s optics,” 515–517.

²⁸ Borrelli, “Thinking with optical objects,” 49. In Della Porta, *Magiae naturalis*, see book XVII, chapter X for the lenses and chapter XIII for the sphere, see Borrelli, “Thinking with optical objects,” 44–45 for commentary.

²⁹ Zik and Hon, “Della Porta.”

However, Della Porta's own attempts to find the location of points at which projections appear in focus suffered from similar issues. He, too, used the cathetus rule to construct the location of the "imago." This geometrical construction technique relied on drawing various straight lines. First, it connects the eye and the object to be seen via the mirror, assuming equal angles of incidence and reflection. Second, it constructs the "cathetus line," which is the line drawn from the object to the mirror, hitting the surface of the mirror perpendicularly. The rule states that the image, "imago," is located behind the mirror, at the intersection of this cathetus line and the continuation of the reflected line that reaches the eye.³⁰ The construction gives the same results as modern approaches for plane mirrors and solutions that are empirically adequate for some situations involving curved mirrors. Yet the solutions for refraction are generally not. For a lens, specifically, refraction takes place at both its surfaces, which would require a much more complicated construction. Della Porta was aware of this problem but chose to draw the cathetus line perpendicular to one of the two refracting surfaces. These solutions are not satisfactory, which Della Porta was undoubtedly aware of. Yet he lacked any other technique to locate the points he wanted to find, making the flawed technique the best he had.³¹

The cases of Ausonio and Della Porta show that rules taken from perspectivist optics could treat various cases of reflection reasonably well but had little to offer on refraction. Much of that had to do with the specific terms and aims of perspectivist optics. This is exemplified by its term "imago," widely used by Della Porta and others. In perspectivist optics, the term imago was the image of an object as processed and perceived in the human mind. As A. Mark Smith asserts, in perspectivist optics, "all images [were] psychologically constructed."³² Perspectivist optics was meant to explain the appearance of images such as those seen through a mirror, images of which the location changes when the perceiver moves. It was not suited to deal with burning points or projected images, which are independent of the location of the observer.

Della Porta's description of how to get a sharp image inside the camera obscura evinces this point. Della Porta stated that one must "place a white paper opposite the opening, and adapt the people to the light, bringing them closer, [or] further away, until the Sun carries a perfect image on the presented sheet," a picture that he stated could be traced by someone "knowledgeable of painting." Like Barbaro, Della Porta advised trial-and-error methods to find the distance between the objects and the lens needed to produce a good

³⁰ On the cathetus rule, see e.g. Smith, *From Sight to Light*, 59–62. On its problems, see Goulding, "Binocular vision," 500–512, Borrelli, "The eye," 305–308.

³¹ Borrelli, "Thinking with optical objects," 55–59.

³² Smith, *From Sight to Light*, 318. Dupré, "Inside the *Camera Obscura*," 222, affirms that "[a]lthough projected images were empirically familiar [...], they were conceptually alien to the medieval perspectivist tradition," see also Borrelli, "Thinking with optical objects," 43–46.

image, without guidance.³³ The point of my argument is that Della Porta could not have given a more codified solution to the location of a projected image exactly *because* the techniques he used were suitable only for finding certain classes of perceived images, and not for finding the location of projected images.

5. Kepler on perceived and projected images

Images perceived through a mirror are materially different from projected images. Present-day optics refers to them as “virtual images” and “real images,” respectively. Real images are images formed by rays converging to a specific place: these real images, usually created by a convex lens, can be projected in that specific place, or perceived near that place by an observer. Virtual images, on the other hand, are formed by rays seemingly diverging from a specific place. These virtual images are usually perceived as lying behind a mirror, and cannot be projected on a surface.

This distinction is often attributed to Johannes Kepler (1571–1630). In his *Ad Vitellionem paralipomena* (1604), and building on the work of Della Porta, Kepler distinguished between “pictures” and “images.”³⁴ Although the title suggests Kepler’s book was a commentary on Vitello’s perspectivist optics, Kepler had much wider aims. As the imperial mathematician in Prague, he prepared horoscopes for Rudolf II and continued Tycho Brahe’s astronomical work, for which he searched for observational precision in astronomy. This shows in the *Paralipomena*. Besides a discussion of perception, the book gave seminal treatments of light rays and of the effect of the camera obscura, both aimed at improving astronomical observation.³⁵

Kepler defined the “image [*imago*]” as something created by a human mind. He stated that “the image is per se nothing, we could say imagination.”³⁶ The “picture [*pictura*],” on the other hand, he defined as “the figures of objects that really exist on paper or upon another surface.”³⁷ What made these figures “really exist,” according to Kepler, was that they were created by the convergence of rays of light. As Dupré puts it, “unlike images, which

³³ Della Porta, *Magiae naturalis*, 266: “Oppones foramini papyrum albam, ac tandiu homines ad lumen accommodabis, appropinquabis, elongabis, dum perfectam imaginem Sol in obiectam tabulam referat, picturae gnarus colores superponendo ubi sunt in tabula.”

³⁴ Kepler’s distinction does not map exactly to the modern distinction, as is forcefully argued in Malet, “Keplerian illusions,” see also Borrelli, “The eye,” for a recent discussion.

³⁵ On Kepler’s importance to developments in optics more generally, see, e.g., Smith, *From Sight to Light*, on Kepler’s intellectual context and aims, see Chen-Morris, *Measuring shadows*.

³⁶ Kepler, *Optics*, 77; id. *Ad Vitellionem*, 60.

³⁷ Kepler, *Optics*, 210; id. *Ad Vitellionem*, 193 “figurae rerum vere in papyro existentes, seu pariete, picturae dicantur.”

were products of the imagination, pictures were made by rays of light only.”³⁸ Kepler asserted that, at the place where rays of sunlight converge after refraction, the “illumination is strongest, so much so that gunpowder in cold water is ignited when the sun is intensely hot.”³⁹ Thus, Kepler stressed the material dimension of these “pictures,” and the phenomena that they could create.

For Kepler, pictures also played a major role in explaining human vision. According to Kepler, the cause of vision was the formation of a picture on the retina in the back of the eye, where rays of light converged after passing the pupil and refracting on the crystalline lens of the human eye: that is, exactly analogous with what happens in the camera obscura.⁴⁰ The picture thus described the causes of human visual perception. But how humans perceived things would not be determined exclusively by this geometry, and this is where images came in. According to Kepler, the mind assessed the location of the image by an act of interpretation, particularly via a triangulation process that usually involved binocular perception.⁴¹ Given that this was a mind-dependent process, it was prone to human errors, he argued. For Kepler, the image was therefore not a faithful representation of the location of the object. As Antoni Malet has put it, “to Kepler those images are illusions resulting from deceived vision.”⁴² This entailed that the locations of the “image” and of the “pictura” were not the same. The picture was determined fully by the geometry of refraction and light rays. But, Kepler argued, at the place where a projected picture could appear, the eye would see great confusion, and no direct perception of this picture was possible.⁴³

Thus, even if it did play a role in Kepler’s explanation of perception, the picture was separated from the interpretive act of perception. It was based on the intersection of light rays alone and was to be constructed following the geometry of light rays and refraction. This made the concept of picture suitable to the study of effects produced by optical instruments in a way that perspectivist optics was not. That his notion of the picture was adapted to studying the camera obscura was not a coincidence: Kepler had started his new conceptualization of optics from that very instrument. Thus, Kepler’s new optical theory could do work towards both the specific theoretical aims of perspec-

³⁸ Dupré, “Inside the *Camera Obscura*,” 243.

³⁹ Kepler, *Optics*, 211; id. *Ad Vitellionem*, 194.

⁴⁰ Kepler, *Optics*, 222–223; id. *Ad Vitellionem*, 207–208. For the importance of the camera obscura to Kepler, and its implications, see Chen-Morris, *Measuring shadows*.

⁴¹ On Kepler and triangulation, see Malet, “Keplerian illusions,” Goulding, “Binocular vision.”

⁴² Malet, “Keplerian illusions,” 4.

⁴³ Dupré, “Inside the *Camera Obscura*,” 239; Kepler, *Optics*, 191; id. *Ad Vitellionem*, 178. As Borrelli, “The eye,” 309–310 stresses, Kepler’s picture would only appear if a material surface was present at its location. No perception of the picture was possible without such a surface, which makes the picture qualitatively different from the modern notion of real image.

tivist optics and the specific instrumental aims of the likes of Ausonio and Della Porta.⁴⁴

There is direct evidence that Kepler himself used the camera obscura for drawing. In a letter to Francis Bacon, an English visitor, Henry Wotton, described how Kepler had used the camera to draw landscapes. It can be gathered from the letter that Kepler used a tent, a “convex glass” and a “concave glass” – likely a mirror – to do so. Kepler’s setup of the camera obscura might well have looked like the one ’s Gravesande’s published 91 years later.⁴⁵ Yet no clear description of a camera obscura by Kepler exists. He did, however, give various “cautions” on how to use the camera for painting, which do reveal his material skills with the instrument. For a pinhole camera without a lens, he stated that a larger hole gives a brighter but less sharp picture. For the distance of the sheet of paper, he similarly stated the picture would get sharper but dimmer when the sheet was moved further from the hole.⁴⁶ For a camera with a lens, he gave less detail, mentioning that there was an inverse relation between the distance of the object and that of the image: “The place of the picture of nearby things is farther from the glass; and of distant things, nearer,” stating that this followed from the theoretical propositions about light rays that he gave before.⁴⁷

Surely, this advice would have helped those without experience only a little more than the advice of Barbaro or Della Porta. Yet Kepler’s advice is qualitatively different. Rather than advising trial and error without any guidance, Kepler did state a rule of thumb and backed it up with theory. But it is still a far cry from a codification of problems related to setting up a camera for painting. This was probably not for a lack of trying. Kepler dealt at length with lenses in his second major optical work, the *Dioptrice* (1611). After hearing of Galileo’s success with the telescope, Kepler set out immediately to give a theoretical account of how the instrument could make faraway objects appear larger, a phenomenon contemporaries found equally spectacular and puzzling.⁴⁸ The *Dioptrice* contains many propositions on the convergence of rays after passing thin equiconvex lenses, such as are used both in the telescope and in the camera obscura. But Kepler had no general way to construct the “punctum concursus,” what is called a focal point in present-day optics. As Malet describes, Kepler “only had a largely qualitative knowledge of the location of focal points.”⁴⁹ For combinations of a lens with another optical artifact, such as needed for a

⁴⁴ On reading Kepler as bringing together elements from perspectivist optics and from the more instrumental optics, see Dupré, “Inside the *Camera Obscura*,” Dupré, “Kepler’s optics.”

⁴⁵ For this letter, sent by Henry Wotton to Francis Bacon in 1620, see e.g. Chen-Morris, *Measuring shadows*, 98, Steadman, *Vermeer’s Camera*, 11–12; on 137–138 Steadman draws attention to the possible likeness to ’s Gravesande’s camera.

⁴⁶ Kepler, *Optics*, 68–69; id. *Ad Vitellionem*, 53.

⁴⁷ Kepler, *Optics*, 212; id. *Ad Vitellionem*, 195.

⁴⁸ See, e.g., Cocquyt, “Like water,” on Isaac Beeckman’s struggle to find a mechanism that could explain the telescope’s magnification, for which he drew on Kepler’s *Dioptrice*.

⁴⁹ Malet, “Kepler and the Telescope,” 109. See Kepler, *Dioptrice*, 12–15 for a couple of particular

telescope and a camera that corrects for inversion, Kepler had no mathematical codifications.⁵⁰ As in Della Porta's case, Kepler's limited description of how to use the instrument for painting can be linked to the absence of a technique to find the distance at which images or pictures would appear after refraction.

6. *The location of the image in the camera obscura post-Kepler*

Kepler's optical work became seminal in various ways. It led to renewed philosophical debates on what happened inside the camera, on rays of light, species, images, and the nature of optical phenomena more generally.⁵¹ His concepts of image and picture were also picked up. Together with his techniques to construct the location of images, they became part of the standard technical equipment of geometrical optics in the seventeenth century. Much optical theorization focused on the same issue to which Kepler had dedicated his *Dioptrice*: the functioning of the telescope.⁵²

Telescopes contained a combination of at least a lens plus an additional lens or curved mirror. One of these optical artifacts would be held as close as possible to the eye for observation. Much theory related to finding the distance between the two optical pieces needed to allow the observer to see a clear image, as well as to the magnification specific setups could achieve. Kepler himself had not used his concept of picture to understand what happened if one looked through a telescope, seeing this as an act of perception instead.⁵³ Yet his *Dioptrice* made clear that the perceived image, too, had a location that could be constructed geometrically. Moreover, getting this image location right made a material difference when dealing with an instrument such as the telescope: a telescope in which the distance between the optical elements is off, is simply a bad telescope.

Even if it did not have particular solutions, Kepler's work did offer a geometrical algorithm to find these distances between the optical parts and the human eye: it had to be done by tracing rays of light. Throughout the seventeenth century, the problem of image location was attacked by many mathematicians, including René Descartes (1596–1650), Christiaan Huygens (1629–1695), and Isaac Newton (1642–1727).⁵⁴ Within geometrical

solutions. On focal points in the *Dioptrice*, see also Malet, "Keplerian illusions."

⁵⁰ Malet, "Keplerian illusions," 5–6, Shapiro, "Optical Lectures," 127.

⁵¹ On seventeenth-century debates on the nature of projected images, see Pantin, "Simulachrum."

⁵² On geometrical optics and the telescope in the seventeenth century, see e.g. Dijksterhuis, *Lenses*, 24–51, Malet, "Conceptualizations," Malet, "Kepler's legacy," Shapiro, "Images," Borrelli, "The eye." Cocquyt, "Like water," 122, however, shows how Isaac Beeckman and his acquaintances used a simple camera obscura in the 1630s to gauge the quality of telescope lenses, thus connecting the camera obscura to ongoing developments.

⁵³ On Kepler's understanding of the telescope, see Malet, "Conceptualizations."

⁵⁴ On their work in geometrical optics, see, e.g., Shapiro, "Images."

optics, authors increasingly came to reduce the explanation of specific optical phenomena to finding the path of light rays. They also developed increasingly advanced mathematical techniques for solving specific problems. Their central issue became a more abstract mathematical problem: to locate the point at which rays of light converge after any type of reflection or refraction, independent of material constraints. It was at that point of convergence that Kepler's projected picture could be made visible. However, it also came to be considered the point at which an observer would perceive Kepler's image, if the eye was moved a little behind it, relative to the point of refraction or reflection. Although a distinction between perceived and projected images was still present, by the 1660s and 1670s, James Gregory, Isaac Barrow, and Isaac Newton defined the two types of images as being geometrically the same, making their notion of image fully dependent on light-ray tracing.⁵⁵

Thus, the central problem of optics was widely considered as one to be solved by geometrical construction techniques.⁵⁶ Several results with important consequences for understanding the camera obscura came about during the century. In his *Dioptrique* (1637), Descartes found the sine law for refraction. This gave him an exact measure for how far refracted rays are inclined towards the normal, a question on which Kepler could give empirically adequate answers only for small angles of incidence.⁵⁷ However, it also led to a more complicated mathematics. Descartes found that spherical lenses could not focus rays of light perfectly but that a perfect focus, in which all rays of light originating from the same spot converge to a single point again after refraction, could only be achieved with lenses of specific but more complex curvatures, for example with a lens of a hyperbolic shape. But such a shape proved near impossible to achieve in lens grinding.⁵⁸

Descartes's *Dioptrique* was a general treatise on optics, perception, and light rays, much in the sense of Kepler's *Paralipomena*. It also contained a description of how to set up a camera obscura for painting, running over two pages. Descartes stated that, once the camera with a lens was put in place, one must consider that

[...] having the sheet at a certain determined distance, the images appear very distinctly, and that, if we move it a bit further away or towards the glass, they begin to be less [distinct]; [...] if we place the glass a little beyond the hole in one way or another, the sheet must also be moved closer or further away from [the glass]; and that [the image] depends partly on the shape of the glass, and partly also on the distance of the objects: for if we leave the object in the same place, the less curved the surfaces of the glass are, the further the sheet must be

⁵⁵ On Gregory, see Malet, "James Gregorie," on Barrow, Shapiro, "Optical Lectures."

⁵⁶ Although the geometrical approach to optics was widespread, other approaches continued to exist. Athanasius Kircher, for example, considered optics from a much wider perspective, which included metaphysical and religious dimensions, see e.g., Vermeir, "Kircher."

⁵⁷ Malet, "Kepler's legacy," 289.

⁵⁸ Dijksterhuis, *Lenses*, 13–16; Dijksterhuis, "Constructive thinking."

moved away from it [...] And that the larger the glass is, the clearer and brighter the images appear.⁵⁹

In this advice, Descartes mentioned various elements key to setting up a camera obscura correctly, such as the relation between the curvature of the lens and the distance at which the image will appear and the importance of lens size. However, his advice is still qualitative. Thus, notwithstanding further progress in optical geometry, descriptions of the use of the camera for painting remained much the same. In his *La perspective curieuse* (1652), a book of mathematical perspective techniques aimed at painters, much like Barbaro's, Jean-François Nicéron described the camera obscura as "an optical experience that perfectly teaches perspective." Yet he did not apply any of his mathematical apparatus to it. He advised that "we must remove the sheet from the hole, until we find the point or the place most proper from representing the images." His advice, too, echoed Barbaro's by then century-old work.⁶⁰

7. From the geometrical conceptualization of the image to the camera

In the 1660s, as Malet asserts, "the crucial notion of image formation in optical instruments appeared [and] provided new ways of analyzing the properties of optical instruments."⁶¹ This new crucial notion was put forward by Isaac Barrow, the professor of mathematics at Cambridge, who however discussed neither instruments nor configurations of lenses. Barrow's solutions were highly mathematical and decoupled from material use. Although Barrow's geometrical construction techniques would in principle have been sufficient to locate the image of a telescope and the camera obscura, Barrow seems to have had little interest in building optical instruments himself.⁶²

This was patently different for Newton, Barrow's student and successor at Cambridge. As is well known, Newton came up with a new design for a reflecting telescope in the late 1660s. A different design for a reflecting telescope, which, as the name suggests, switches the usual convex lens for a concave mirror, had been suggested in print by Gregory in 1663, and

⁵⁹ Descartes, *Dioptrique*, 46–49: "[...] a certaine distance déterminée a laquelle tenant le linge, les images paroissent fort distinctes, & que pour peu qu'on l'esloigne, ou qu'on l'approche d'auantage du verre, elles commencent à l'estre moins; [...] si lon met le verre vn peu au delà du trou de part ou d'autre, le linge en doit aussi estre d'autant approché ou reculé; Et qu'elle depend en partie de la figure de ce verre, & en partie aussy de l'esloignement des obiets: Car en laissant l'obiet en mesme lieu, moins les superficies du verre sont courbées, plus le linge en doit estre esloigné [...] Et que plus [le verre] est grand, plus [les images] paroissent claires & illuminées."

⁶⁰ Nicéron, *Perspective*, 21–22.

⁶¹ Malet, "Kepler's legacy," 300.

⁶² Shapiro, "Images," 304–307, especially 306, where Barrow is quoted as having included only "that part of optics which is more properly mathematical."

was known to Newton.⁶³ For both Gregory and Newton, telescope design was closely connected to conceptual work in geometrical optics. Building on Gregory's and Barrow's earlier work, Newton's *Optical Lectures* of 1670–1672 contained many new contributions to that geometrical optics. However, these lectures remained unpublished and virtually unknown until after Newton's death. His first publication to deal with similar matters was his much later *Opticks* (1704), in which Newton discussed and applied his geometrical techniques for finding image locations, such as those in the camera obscura, with ease (see Fig. 3).⁶⁴

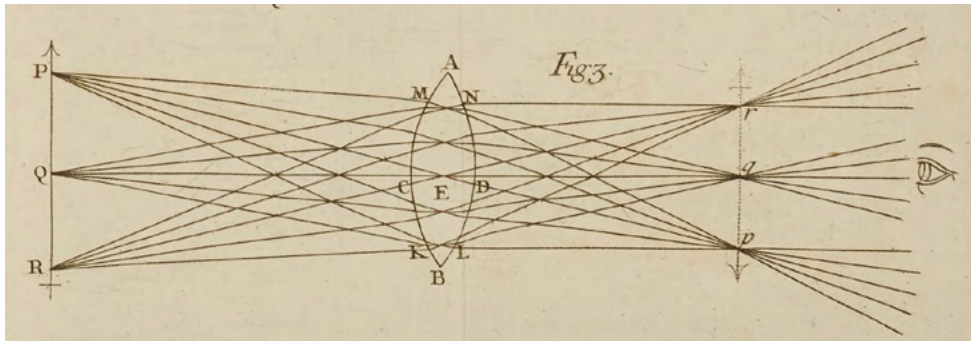


Fig. 3 – Newton's diagram for explaining the location of the image rqp of object PQR after refraction of rays of light in the convex lens, given at the beginning of Newton, *Opticks*, plate 1, fig. 3.

Work by Barrow and Gregory was available in the 1660s, however, especially to English savants. They knew about the camera obscura, too. Robert Hooke presented the instrument to the Royal Society at various meetings and wrote two short notes on it. In 1668, his "A Contrivance to make the Picture of any thing appear on a Wall" appeared. In it, Hooke gave a description of how to set up the camera obscura, stating that "Between this Object, and the Place where tis to be represented, there is to be placed a broad Convex-glass, ground of such a convexity, as that it may represent the Object distinct on the said place; which any one, that hath any insight in the Opticks, may easily direct."⁶⁵ Hooke did nothing to codify the central problems of the camera and even seemed to imply that it could easily be used. We may speculate that, given his own expertise with instruments, mathematics, and drawing, he did not see what others might possibly find confusing about

⁶³ Malet, "James Gregorie," 140–143 describes how Newton dog-eared the pages of Gregory's *Optica promota* in which a reflecting telescope was described.

⁶⁴ Shapiro, "Images," 307–308.

⁶⁵ Hooke, "Contrivance," 743.

painting with the camera.⁶⁶

Yet if this was the case, he was wrong. Although Hooke carried out more experiments with a camera obscura, evidence indicates that he convinced very few others to use a similar instrument.⁶⁷ This was the case notwithstanding various other presentations, including one of 1694 in which Hooke had glowing praise for the instrument and listed all kinds of things that could be depicted with it. But even there he was no more specific on how to make sure that the image in the camera obscura was in focus: his description did not make it a user-friendly machine.⁶⁸ Only one image of Hooke's camera obscura has been printed (Fig. 4), which was of even less use. It makes the camera look like an oversized helmet, not a workable tool.



Fig. 4 – Hooke's camera obscura, as posthumously depicted in Derham, *Experiments*, 295.

⁶⁶ On Hooke's mathematical skills, see e.g. Guicciardini, "Invisibility and impact."

⁶⁷ See Hunter, "Mr. Hooke," on his work with the camera. Hunter, page 313 suggests that John Evelyn might have had a camera obscura similar to Hooke's by 1705.

⁶⁸ Derham, *Experiments*, 292–296.

As far as I can ascertain, work that attacked the problem of the location of the image in the camera obscura with geometrical construction techniques appeared only in publication in the 1690s. Explanations for this must remain speculative, but the difficulty of the mathematics involved in early solutions might very well have played a role. As Alan Shapiro has detailed, Barrow had provided solutions for the “relative image” – equivalent to the present-day “image location” – of any lens. This included lenses which had little bearing on problems one would face working with material optical instruments. Barrow did so with extensive tables of categories and subcategories of lenses; Shapiro calls the solution “excessively complex and cumbersome.”⁶⁹

In his 1692 *Dioptrica Nova*, William Molyneux instead discussed image locations for more concrete types of lenses and mirrors, as well as the camera obscura and telescope. In contrast to the more theoretical work of Barrow and Gregory, whom he cited, Molyneux explicitly discussed the image location for projected images as a separate topic, as is made clear in the subtitle of his work, “A Treatise [...] Wherein the Various Effects and Appearances of Spherick Glasses, both Convex and Concave, Single and Combined, in Telescopes and Microscopes [...] are Explained.”⁷⁰

For the camera obscura, Molyneux concentrated on what happened in various particular setups of the camera obscura. This included the one needed for painting: with light projected into a room by a single equiconvex lens, and rays converging to a place inside that room. He distinguished between cases of “Distant Objects” and “Nigh Objects,” explaining that the first gave rays falling parallel on the lens, whereas in the second case, diverging rays fall on the lens.⁷¹ This second case, that of nearby objects, is of course the one that is most relevant when using the camera obscura for painting. And it is for that case that Molyneux explicitly codified a solution to the distance problem. He called the place where rays of light coming from a nearby object would converge the “respective focus.” This he kept separate from the “focus” simple, “absolute focus,” or “focal length” which was the distance from the lens at which rays from far-away objects would converge. He provided a solution for finding the “respective focus” in terms of the “focus” simple. This solution, the first codification of the problem of image distance in the camera obscura, is mathematically equivalent to the modern thin-lens equation.⁷²

It remains unclear what inspired Molyneux to go into more detail on particular projections, as few detailed studies on Molyneux’s work exist. He dedicated his book to the Royal Society of London, on which he had based the Dublin Philosophical Society that

⁶⁹ Shapiro, “*Optical Lectures*,” 151.

⁷⁰ Molyneux, *Dioptrica*.

⁷¹ *Ibid.*, 41.

⁷² *Ibid.*, 42, see Prop. V. If respective focus is i , and the focal length is f , Molyneux’s solution, given in proportional terms, is $o:f:f:o:i$, which can be reduced to the equation given above in section 2.

he had founded in 1683. Spreading natural philosophy was certainly one of his aims. But Molyneux also held various political positions in Ireland, including that of Surveyor General of Fortifications and Buildings.⁷³ As such, looking at buildings through telescopes and making precise sketches of their outlines were material practices Molyneux was most likely quite familiar with.

In the twelve years that separated Molyneux's *Dioptrica Nova* and Newton's *Opticks*, various other solutions to distance problems of thin equiconvex lenses, the common type needed for the camera obscura appeared in print. These can all be reduced to the present-day thin lens approximation.⁷⁴ At the turn of the eighteenth century, codified solutions to the key distance problem in the camera obscura, solutions that are still accepted in the present, thus became available. Yet Molyneux's treatment remained the one most relevant to the problem of painting. None of these treatments returned to practical descriptions of how to build a camera obscura for the practice of painting. After stating his solution, Molyneux himself went into more complex matters instead: first a lengthy demonstration and after that solutions for optical constructions of less relevance to that practice.⁷⁵

8. *The codification and circulation of 's Gravesande's camera obscura*

The step from a codified solution to the geometrical problem to a description of practice is very much present in 's Gravesande's treatise. Published as an appendix to his *Essai de perspective*, in smart duodecimo format, the treatise on the camera obscura covers 36 short pages. It starts with four pages on theory, introducing terminology such as "focus." Pages 5–11 describe the machine here depicted in figure 1 in painstaking detail, and pages 11–32 cover how to use the machine for various purposes, including "representing objects in their natural disposition," mirrored left to right, depicting a countryside, and "representing paintings or engravings" so that they can be copied directly. Each of these gets a separate section and is followed by a short geometrical proof. All proofs rely on the techniques developed in the decades before 's Gravesande.⁷⁶ The proof for engravings contains a statement about geometrical proportions between "the focus of the glass," "the height

⁷³ Molyneux is well known for his contacts with Locke but otherwise understudied. See the dated Simms, *Molyneux*, for biographical detail.

⁷⁴ These include Picard (1693), Halley (1693), Hartsoeker (1694), and Huygens, whose early optical works were published posthumously in 1703, see Shapiro, "Optical Lectures," 151, and Dijksterhuis, "Constructive thinking," 75.

⁷⁵ Molyneux, *Dioptrica*, 43–46 for the demonstration, 46–50 for cases in which the rays do not focus after passing the lens, that is, in modern terms, situations in which no real image is produced inside the camera.

⁷⁶ 's Gravesande, "Usage," 11: "Représenter les objets dans leur disposition naturelle," 25: "Représenter des Tableaux ou des Taille-douces."

of the Machine above the table,” and “the distance of the glass to the painting” – in present-day terms: the focal length, the image distance, and the object distance. This statement is equivalent to Molyneux’s, and to the modern thin-lens approximation.⁷⁷ Thus ’s Gravesande codified the distances at which images were in focus and described the entire procedure of building a camera obscura and setting it up for painting.

’s Gravesande’s description was user-friendly and allowed his readers to rebuild the instrument. This would leave him without direct monetary gain from the design and raises questions about his motives. ’s Gravesande himself stated that his aim was simply helping others to construct this machine and particularly to “save others the fatigue” involved in getting everything right,⁷⁸ and it seems indeed he made no money out of the machine. But this is not to say that ’s Gravesande did not benefit at all. The book put him in touch with leading mathematicians of the time, including Johan Bernoulli, and helped his career take off.⁷⁹

The details of his career may mitigate skepticism about whether ’s Gravesande was truthful about his rather generous interest in helping others. In 1717, ’s Gravesande was appointed to a professorship in mathematics and astronomy at Leiden University, on the strength of his previous mathematical work. He went on to design many other instruments for teaching and research purposes. Many of these instruments were described and depicted in his widely popular *Physices elementa mathematica*. Here, too, ’s Gravesande gave detailed depictions and descriptions of the instruments that would allow others to rebuild them.⁸⁰ Most of these instruments were built for him by the instrument-maker Jan van Musschenbroek. Van Musschenbroek built and sold additional copies of these machines without patenting them.⁸¹ ’s Gravesande’s instrumentarium included various other optical instruments, such as a magic lantern, a heliostat, and a large set of convex and concave mirrors. Many became standards in eighteenth-century cabinets of scientific instruments, spreading ’s Gravesande’s work and fame.⁸²

The camera obscura was not included in the *Physices elementa mathematica*. But it was discussed in print many other times. A review of ’s Gravesande’s treatise of perspective of

⁷⁷ ’s Gravesande, “Usage,” 26–27.

⁷⁸ Ibid., [ii–iii], “dans la construction méchannique d’une machine propre à faciliter le dessein, on ne pouvoit pas prévoir plusieurs choses que l’expérience seule peut apprendre [...] Comme on avoit fait tout ce chemin là, on a crû devoir en épargner la fatigue aux autres.” On building the machine, see also my comment in note 11.

⁷⁹ Van Besouw, “Impeccable credentials.”

⁸⁰ On the book, its aims, and its instruments, see Van Besouw, “’s Gravesande.”

⁸¹ De Clercq, *Musschenbroek workshop*.

⁸² On ’s Gravesande’s magic lantern and later copies of it by figures such as Pieter van Musschenbroek and Jean-Antoine Nollet, see Hankins and Silverman, *Instruments*, 49–54, especially page 50: “[’s Gravesande’s magic lantern] became the model for all [magic] lanterns during the subsequent century and was surpassed only [...] in 1820.”

1711 concentrated particularly on the two camera obscuras, and 's Gravesande was approached by the German savant Zacharias von Uffenbach in 1723 to further explain the working of the specific machines.⁸³ A reprint of the original text appeared in 1717 and a translation into English in 1724. The entry on the camera obscura in an English Dictionary of 1726 noted that "Gravesande [...] has given the Description and Use of two Machines" and that they were "the best that have as yet been made."⁸⁴ In 1738, Robert Smith gave a description of the camera obscura that looks much like 's Gravesande's in his *Compleat System of Opticks*. By then, the instrument was widespread, or at least so asserted Smith: he described the machine as "[T]he portable *camera obscura* [...] commonly sold in the shops."⁸⁵

Without further evidence of what happened between 1711 and 1738, the argument that 's Gravesande had an impact on the wider circulation of the machine must remain somewhat "post hoc, ergo propter hoc." Yet I believe these citations point to plausible mechanisms by which 's Gravesande's treatise might have reached people willing and able to build camera obscuras for themselves, and to use them for painting.

9. Conclusion

This article has focused on one seeming historical paradox: that the camera obscura circulated as a popular artists' tool only after having been around for a couple of centuries. This paradox starts to disappear when we look in detail into how and when its use was codified. Descriptions of the camera obscura remained vague on key issues for over a century. Throughout the seventeenth century it was possible to use the camera for painting, but only if one was willing to invest time in learning how to do so by trial and error. This cost of learning was reduced substantially when user-friendly descriptions such as 's Gravesande's became available. Hence, the presence of codified description of the camera could enhance circulation, and might plausibly have done so.

The case of the camera obscura offers more general lessons for the role of codification in technological innovation, and the circulation of technical inventions. Although 's Gravesande's case might seem to be a clear case of "applying theory" to a "practical problem," the longer history refutes the idea that innovation takes place as a simple ap-

⁸³ Le Clerc, "Essay." For the correspondence, see Niedersächsische Staats- und Universitätsbibliothek Göttingen, 2 Cod. Ms. Uffenbach 20: Bd. I, 522–532. See also the mention in Jombert, *Methode* (1755), which reproduces part of 's Gravesande's treatise. Many more such mentions of 's Gravesande are present in dictionaries and encyclopedic works until at least the early nineteenth century.

⁸⁴ Stone, *A New Mathematical Dictionary*, "Camera Obscura."

⁸⁵ Smith, *System*, 386.

plication of theoretical, propositional, or conceptual knowledge.⁸⁶ Rather than talking about the circulation of unspecific “practical knowledge,” we would do well to focus on the practices actually being described, and possibly codified. For much of the history of the camera obscura, the material dimension came first. From Barbaro at least up until Descartes, material practices with the camera obscura were the direct source of conceptual developments. All of those who wrote on the camera obscura were “practitioners”: they all showed awareness of the complexities of setting up experiments in the camera, and in dealing with lenses.

Theoretical developments in optics were inseparable from material, empirical manipulation until after Kepler. Only when Kepler had provided an algorithm for further work, did one specific part of optics start to develop in more isolation from material practice: the geometrical problem of image location.⁸⁷ But after the key problem of image location was settled in the 1660s, theory was not “applied” back to instrumental practice directly. ‘s Gravesande’s contribution was to derive solutions to very specific problems in the camera from the general solutions, and to find ways to materialize these solutions so that these problems would not appear if the camera obscura was set up for specific painting purposes. ‘s Gravesande did not simply apply theory. He found a way to *reconstruct* geometrical techniques to give specific answers to questions that practitioners faced when trying to use the instrument.

⁸⁶ For a critical historical take on the idea that innovation takes place through applying theory to practical problems, see Godin, *Models of Innovation*.

⁸⁷ Many other parts of optics still depended very much on material issues. As Cocquyt, “Instrumental Practices,” 9 remarks: “throughout the seventeenth century, the import of optical instruments was continually redefined through their embeddedness in evolving conceptual frameworks, and their adaptation to changing user practices.”

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– ESSAY REVIEWS –





The geometer's and engineer's workshop: An archaeology of papers, intellectual techniques, and practices of knowledge in Vincenzo Viviani

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Title of reviewed book

Simon Dumas Primbault, *Un galiléen d'encre et de papier. Une histoire matérielle des brouillons de Vincenzo Viviani (1622-1703)*. Paris: Éditions de la Sorbonne, coll. Homme et société, 2024, 320 pp.

Abstract

Moving past traditional intellectualist frameworks that privilege printed treatises as monuments of pure conceptual progress, in *Un galiléen d'encre et de papier* Simon Dumas Primbault undertakes an archaeology of working manuscripts within the *Fondo Galileiano* at the National Central Library of Florence (BNCF). By examining Vincenzo Viviani's rough drafts (*brouillons*), codicological parameters, ink variations, layout grids, and paper management, Primbault aims to demonstrate how physical writing surfaces functioned as active cognitive "paper tools" for theoretical derivation and administrative practice. The review traces three core dimensions of Viviani's intellectual identity: first, his role as Galileo Galilei's "last disciple," curating and editing the master's archive to construct a protective legacy compatible with Medici patronage and Catholic orthodoxy; second, his work as a "divining geometer," deploying mathematical humanism, conjectural reconstruction (*divinatio*), and synthetic geometry directly on the page (*géométrie d'encre*); and third, his active career as Medici First Engineer, where field notebooks, drawing practices (*disegno*), and statecraft intersected with theoretical research. Additionally, the essay contextualizes Viviani's 1692 *Aenigma Florentinum* challenge against Gottfried Wilhelm Leibniz, highlighting a pivotal transition from classical synthetic geometry to infinitesimal calculus.

Keywords

Vincenzo Viviani, Galileian science, engineering, *disegno*, geometry

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1. *The archaeology and materiality of science*

For much of the twentieth century, the historiography of early modern science operated within an intellectualist framework. Scholars such as Alexandre Koyré and Marshall Clagett viewed the scientific transformations of the seventeenth century primarily as a series of conceptual revolutions. In their analyses, intellectual progress was reconstructed through finished printed treatises, which were treated as complete, self-contained monuments of theoretical reason.¹ The narrative focused on grand conceptual shifts: the mathematization of nature, the formulation of classical mechanics, the concept of universal gravitation, the birth of infinitesimal calculus etc. Within this conceptualist paradigm, the physical media of intellectual work – the sheets of paper, the composition of ink, the physical cutting and pasting of drafts, the structural layout of calculation grids, and the erasures that marked changes in thought – were treated as administrative detritus. Working manuscripts were viewed mostly as physical carriers for pre-existing mental ideas, possessing no independent analytical value for understanding scientific evolution.

Over the past four decades, the history of science has undergone a significant reorientation through what has been termed the material, practical, and spatial turn. Scholars such as Steven Shapin, Simon Schaffer, Mario Biagioli, Lorraine Daston, and Peter Damerow argued that scientific knowledge is fundamentally shaped by physical settings, social codes, instrumental practices, and media technologies.² Simon Dumas Primbault's volume, *Un galiléen d'encre et de papier. Une archéologie des brouillons de Vincenzo Viviani (1622-1703)*, applies this material perspective to early modern mathematics and engineering. The study shifts scholarly focus away from published works and toward working manuscripts, moving the analytical axis from the finished textual product to the material process of its development. The subject of inquiry extends beyond the formal mathematical and structural propositions formulated by Vincenzo Viviani to encompass the physical and institutional operations of the scholar's workshop through an investigation of his intellectual techniques.

The primary empirical foundation for Dumas Primbault's study is the extensive collection of manuscript papers held within the *Fondo Galileiano* at the National Central Library of Florence (BNCF). This archive constitutes one of the most comprehensive surviving manuscript records of seventeenth-century scientific activity in Western Europe. Through an examination of rough drafts (*brouillons*), marginal annotations, loose memorandum slips, thematic excerpt notebooks, reading indexes, field registers, and administrative correspondence, Dumas Primbault reconstructs how abstract theoretical formulations were tied to the manipulation of physical media.

¹ Koyré, *Études galiléennes*; Koyré, *From the Closed World*; Clagett, *The Science of Mechanics*.

² Shapin and Schaffer, *Leviathan and the air-pump*; Biagioli, *Galileo, Courtier*; Daston, ed., *Science in the Archives*; Damerow, *Abstraction and Representation*.

The volume draws upon and expands the concept of “paper tools,” an analytical category developed by historians of science to describe how physical writing surfaces function as active cognitive spaces rather than passive landing pads for thought.³ A blank sheet of paper, an open register, or a recycled margin served as a manipulable layout where spatial organization, grid arrangements, variations in ink viscosity, folding patterns, and physical cutting directly influenced the development of formalized ideas. Codicological parameters such as paper formats, chain lines, wire lines, watermarks, iron-gall ink oxidation levels, and scribal trimming habits reveal how the physical page served as a working surface where scholars calculated, diagrammed, organized textual excerpts, and revised proofs.

To carry out this analysis, Dumas Primbault combines codicology, paleography, historical bibliography, reading history, and the sociology of early modern court administration. Through these combined methodologies, Vincenzo Viviani (1622–1703) is re-evaluated outside the boundaries of tradition. Rather than being framed purely through a biographical lens or dismissed as a derivative figure operating in the shadow of Galileo, Viviani emerges as an administrator and technical scholar whose work combined synthetic geometry, manuscript preservation, state engineering, and courtly advancement into a single framework managed through ink and paper.

This methodological framework carries a clear risk of overinterpretation, a limitation that warrants explicit critical attention. When historians analyze working manuscripts through a material lens, there is a persistent temptation to ascribe complex cognitive strategies to physical artifacts that may simply be the result of mundane constraints. A change in ink density, an asymmetrical page layout, a crossed-out line, a dry-point scratch, or a recycled piece of paper may not represent a deliberate epistemological pivot or a calculated heuristic technique. Such features often stem from mundane circumstances: limited paper supplies, deteriorating quills, hasty notes taken under difficult field conditions, routine administrative habits, or unreflected scribbles. By treating every physical mark as a window into the practitioner’s cognitive architecture, the material archaeology of science risks over-reading draft physicalities, transforming ordinary workshop habits into complex theoretical choices. Maintaining a distinction between deliberate intellectual methods and routine physical activities remains a key challenge for this analytical approach.

2. *The last disciple*

Vincenzo Viviani’s public standing and professional identity were closely linked to his status as the final disciple of Galileo Galilei. This designation functioned as the primary institutional and social resource around which Viviani built his authority within the Medici court and the broader European republic of letters.

³ Jardine, “State of the Field: Paper Tools.”

Viviani entered Galileo's household at the villa of Il Gioiello in Arcetri in 1639 at the age of seventeen, securing his position through recommendations from Florentine figures including Clemente Settimi and Famiano Michelini. Galileo was by then completely blind, in declining health, and kept under strict papal surveillance following his 1633 condemnation by the Roman Inquisition. He required an amanuensis, reader, and assistant capable of conducting geometric calculations and managing his ongoing correspondence. Viviani resided in Arcetri for nearly three years until Galileo's death in January 1642, sharing his assistant duties with Evangelista Torricelli during the final months of the master's life.⁴

During his time at Arcetri, Viviani acquired foundational skills in mechanics, astronomy, and Euclidean geometry, while adopting the working habits of the Galilean network. He served as the physical hand that drew geometric figures for the blind astronomer and the eyes that read incoming letters and classical texts. This cohabitation created a sense of obligation in Viviani, who viewed himself as responsible for protecting and transmitting the intellectual and material heritage of his master.

Following Galileo's death in 1642, and the subsequent death of Galileo's son Vincenzo in 1649, Viviani took possession of a large, disorganized collection of Galilean papers. This archive contained letters, draft treatises, calculation sheets for projectile trajectories, mechanical notes, geometric diagrams, and laboratory records. Viviani categorized, trimmed, pasted, and rearranged loose sheets, adding his own handwriting to supply missing transitions, re-labeling diagrams, and altering conceptual sequences. His goal was to present a continuous, coherent narrative of Galilean thought that aligned with both Catholic orthodoxy and Grand Ducal interests.⁵

In 1654, Viviani wrote a biographical narrative titled *Racconto storico della vita del Sig.r Galileo Galilei*, which was published only in 1717. In the *Racconto*, Viviani sought to protect Galileo's historical legacy by muting its theological implications, while simultaneously positioning himself as the primary intellectual heir to the Galilean tradition. This narrative strategy allowed him to consolidate his social standing at the court of Ferdinando II and Cardinal Leopoldo de' Medici.

However, the sustained focus on memory preservation had long-term consequences for Viviani's historical reputation. For centuries, historians viewed Viviani's intellectual work primarily through his connection to Galileo. His efforts to preserve Galileo's legacy ultimately obscured his individual work in synthetic geometry, classical philology, structural architecture, and hydraulic engineering. Dumas Primbault's study examines the individual career behind this historical narrative, pointing out how Viviani operated as an autonomous scholar fully engaged in the technical institutions of his era.

⁴ Notable biographical accounts include Favaro, "Amici e corrispondenti di Galileo Galilei. XXIX. Vincenzo Viviani"; Righini Bonelli, "L'ultimo discepolo."

⁵ See Favaro, "Documenti inediti per la Storia dei Manoscritti Galileiani."

3. *The divining geometer*

Viviani's mathematical work was grounded in the principles of mathematical humanism. For seventeenth-century geometers working within the classical tradition, mathematical advancement was achieved not by breaking with ancient authority, but by recovering, translating, and restoring the lost geometric texts of classical antiquity.

Within this scholarly environment, the practice of *divinatio*, or conjectural reconstruction, served as a rigorous philological and mathematical methodology. The process relied on a distinct pipeline of empirical and textual inputs: scholars collected surviving fragments, introductory lemmas preserved by later commentators such as Pappus of Alexandria, and partial summaries transmitted through Arabo-Latin manuscript traditions. These diverse textual components were brought together on the working page, where the geometer engaged in conjectural deduction to reconstruct missing propositions and synthesize lost geometric proofs using Euclidean logic. The output of this procedure was a restored classical treatise, which allowed the practitioner to generate advanced mathematical results while presenting them within an ancient framework.

Viviani devoted a significant portion of his research career to two major projects of *divinatio*. The first was the reconstruction of Book V of Apollonius of Perga's *Conics*, a lost work devoted to maximum and minimum lines drawn to conic sections. Viviani worked in secret for years to reconstruct these propositions using synthetic geometric methods, aiming to publish his version before the Arabic text discovered in Florence could be translated by Giovanni Alfonso Borelli. His results were published in 1659 under the title *De maximis et minimis*. His second project was the restoration of the lost books of Aristeus the Elder (*De locis solidis*, completed in 1646, printed in 1673, and published in 1701).

In chapters 1 and 3 of the volume, Dumas Primbault documents the information management techniques Viviani used to handle the textual and mathematical data required for *divinatio*. Viviani organized commonplace books by specific geometric categories, and compiled bibliographical inventories that recorded textual variants, printing histories, and comparative translations across Latin, Greek, and Arabic versions of classical mathematical sources. His working copies of printed books and manuscript drafts feature dense cross-referenced marginalia and layered revisions, where reading a classical text directly prompted the derivation of new proofs.

In Dumas Primbault's reconstruction, Viviani saw geometry as a physical practice carried out on the page (*géométrie d'encre*). Diagrams were not secondary visual aids for completed thoughts, but active working tools through which mathematical relationships were derived. The detailed physical analysis of Viviani's draft sheets shows how the geometer interacted with figures on the page. Galileo's last disciple used inks of different densities and shades to distinguish auxiliary constructions from primary curves, left compass pinholes that preserve the chronological order of drawing steps, and relied on rasures and

cancellations that preserved earlier attempts within a sequence of revisions.

Drawing on these material evidences, Dumas Primbault argues for Viviani's strong theoretical commitment to the synthetic Euclidean and Apollonian traditions, emphasizing how the spatial manipulation of geometric figures using straightedge and compass remained central to the formulation and proof of theoretical proposition. As said, the analytical focus on physical draft details carries a risk of methodological overinterpretation. Interpreting every pinhole, faint guideline, or ink correction as a conscious step in a mathematical derivation can overstate the deliberate nature of standard drawing habits. Physical traces may reflect ordinary drafting practices: re-inking a dry pen, correcting a slipping compass, using available paper efficiently, or fixing an immediate visual error. Attributing systematic cognitive meaning to every physical mark on a manuscript draft risks misinterpreting routine physical adjustments as intentional theoretical choices. Dumas Primbault, however, is always cautious in his analysis.

4. *Portrait of the engineer as a conflicted man*

Throughout history, scholars have often drawn a strict boundary between theoretical science and practical engineering.⁶ Dumas Primbault aims to show that, in Viviani's work, these two domains shared common intellectual and physical roots within the culture of drawing (*disegno*) in seventeenth-century Florence.

Alongside his mathematical studies with Galileo, Viviani received formal instruction in architecture, perspective, and drawing from Baccio del Bianco, a painter, military engineer, and stage designer. Through this training, Viviani entered the tradition of the *Accademia delle Arti del Disegno* in Florence, an institution established by Giorgio Vasari in which artistic practice, architectural design, and applied geometry shared a single analytical foundation. Viviani acquired proficiency in linear perspective, chiaroscuro shading for volume rendering, shadow projection, and land surveying techniques.

A key section (ch. 2) of Dumas Primbault's volume analyzes Viviani's field notebooks (*appunti di sopralluoghi*). When assigned by the Medici administration to inspect river channels, assess military fortifications, or design bridge repairs, the young engineer carried small, portable notebooks designed for field use. These notebooks document the initial recording of engineering data, containing quick freehand sketches of river bends, eroding banks, soil strata, and masonry cracks. Written descriptions, altimetric numbers, water flow measurements, and even records of meetings with landowners were wrapped directly around these drawings.

Dumas Primbault shows that for Viviani, drawing functioned as an analytical tool for ordering complex physical landscapes into structured geometric representations. This pro-

⁶ See, in this regard, Schatzberg, *Technology*.

cess unfolded across a structured multi-stage workflow. In the initial field survey stage, the engineer recorded empirical observations in portable octavo or duodecimo notebooks, capturing river morphology, bank erosion, and structural damage alongside altimetric and hydraulic data. During the subsequent studio drafting stage, these field sketches were converted into scale drawings using rulers, compasses, linear perspective, and ink washes to achieve geometric rationalization. Finally, in the administrative stage, these plans were integrated into formal court reports (*relazioni*), where clean-copy drawings accompanied written arguments to guide magistrates and the Grand Duke in technical and financial decision-making.

Beginning in the 1650s and continuing over four decades, Viviani held administrative and technical positions within the government of the Grand Duchy of Tuscany, serving Grand Duke Ferdinando II, Cardinal Leopoldo de' Medici, and Grand Duke Cosimo III. He was appointed First Engineer of the *Magistrato degli Uffiziali dei Fiumi*, the state body responsible for river regulation, soil conservation, and land reclamation across Tuscany. He later served as Architect and Superintendent of Grand Ducal Buildings. These appointments required Viviani to balance his abstract geometric research with the practical demands of civil administration. In chapter 4, Dumas Primbault examines the large body of technical reports (*relazioni*), surveys, and official assessments produced during Viviani's administrative career. His technical duties were divided into two main areas of responsibility: hydraulic management of the territory and structural architecture.⁷

In hydraulic engineering, Viviani developed plans to regulate the Arno River to reduce flood risks in Florence, designed drainage systems for the Val di Chiana, supervised the diversion of mountain streams, and managed riverbank constructions and coastal marshlands. In structural architecture, he performed technical evaluations of major public buildings, most notably conducting an extensive structural assessment of Brunelleschi's dome at Santa Maria del Fiore. In his report on the dome, Viviani mapped structural crack patterns (*screpoli*) and applied geometric principles to analyze vector thrusts and force distributions, ultimately advising against invasive structural alterations and reassuring the court regarding the stability of the building. This heavy administrative workload created continuous tension with his personal research goals. In a manuscript letter written in 1697 to Marquis Salviati, the seventy-five-year-old Viviani expressed deep personal frustration over his professional circumstances. He lamented that his time and energy had been consumed by endless court-ordered assignments, including long journeys through bad weather to inspect broken dikes and settle water-rights disputes between local landowners. He expressed regret over being unable to complete his planned theoretical treatises on Apollonius and Euclid due to these administrative demands. This document, analyzed by Dumas Primbault in chapter 7, illustrates the practical trade-offs required of early modern technical scholars who relied on state employment to support their scientific work.

⁷ Cf. Barreca, "Between matematici and architetti d'acque."

5. *Beyond infinity*

Between 1689 and 1690, the elderly Viviani met and corresponded with Gottfried Wilhelm Leibniz during Leibniz's stay in Florence. This meeting brought two distinct mathematical approaches into direct contact. The contrast between these paradigms was fundamental across every dimension of mathematical practice. Synthetic geometry, as practiced by Viviani, relied on Euclidean spatial intuition, proportional ratios between physical magnitudes, and diagrammatic proofs presented in formal Latin or Italian prose, treating geometric curves as static spatial loci. Conversely, the differential calculus developed by Leibniz operated through infinitesimal variables, algorithmic operational rules, and symbolic equations, treating curves as dynamic functional equations.

To demonstrate the capability of synthetic geometry over the new algebraic methods developing in Northern Europe, Viviani issued a public mathematical challenge in 1692, known as the *Aenigma Florentinum*, or *Forma xilographica*. He framed the challenge as an architectural problem, asking how a hemispherical dome could be pierced by four equal openings such that the remaining spherical surface area could be exactly squared using only a straightedge and compass. Mathematically, the problem required calculating the intersection of a hemisphere of radius R with intersecting cylinders of radius $R/2$, tangent to the central axis. The intersection of these two surfaces forms a space curve known as Viviani's Curve. Viviani proved synthetically that the area of the hemispherical surface remaining after the four openings were removed was equal to four times the square of the sphere's radius, eliminating the transcendental number π from the final expression.

Viviani intended the *Aenigma* to demonstrate that classical synthetic geometry possessed tools capable of solving complex spatial problems without relying on symbolic algebra. However, the outcome ran counter to his expectations. Upon receiving the challenge, Leibniz, Jakob Bernoulli, Johann Bernoulli, the Marquis de l'Hôpital, and John Wallis solved the problem within hours using differential and integral calculus. They used the challenge to publicly demonstrate the efficiency of infinitesimal calculus. Dumas Primbault's examination of Viviani's draft manuscripts in chapter 5 reveals his disappointment at how quickly European mathematicians converted his problem into an application of the new calculus, marking a broader transition in European mathematics away from classical synthetic methods.⁸

All in all, Simon Dumas Primbault's *Un galiléen d'encre et de papier* offers a comprehensive study of early modern scientific practice by examining the material records of Vincenzo Viviani's workshop. By focusing on working drafts, physical notes, administrative records, and drawing practices, the author situates Viviani within the institutional and practical context of seventeenth-century Tuscan science. The volume highlights three key

⁸ See Roero, "Leibniz and the Temple of Viviani."

dimensions of early modern intellectual life. First, it documents how scientific work relied on physical media, showing that choices regarding paper, ink, diagram layout, and document organization were directly integrated into the process of theoretical derivation. Second, it presents the Galilean school not as a fixed set of doctrines, but as an evolving tradition that was continually re-interpreted, adapted, and organized by its members. Third, it demonstrates the close connections between practical engineering and theoretical geometry in Viviani's career, showing how visual drawing methods, field surveys, and public administrative duties informed his work on classical texts and his engagement with contemporary European mathematics.

At the same time, the volume highlights the primary methodological vulnerability of the material archaeology of science. In its effort to extract cognitive meaning from every physical feature of a working manuscript, this approach can easily drift into overinterpretation. Historians must maintain a clear distinction between deliberate intellectual strategies and routine physical actions, recognizing that faint guidelines, ink intensity changes, paper folds, or casual notes often reflect ordinary drafting habits or material constraints rather than calculated theoretical choices. While Dumas Primbault successfully eschews the danger of overinterpretation, guarding against this tendency remains essential for maintaining balance in the material history of science.

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L'anomalia virtuosa. Le origini dell'Istituto e Museo di storia della scienza di Firenze

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English title

The Virtuous Anomaly: The Origins of the Institute and Museum of the History of Science of Florence

Title of reviewed book

Marco Beretta, *Mezzo secolo di Storia della Scienza al Museo Galileo. Andrea Corsini e Maria Luisa Righini Bonelli*. Milano–Udine: Mimesis, 2025, 286 pp.

Abstract

The institutional and historiographical trajectory of the Institute and Museum of the History of Science in Florence is examined through the foundational work of its first two directors, Andrea Corsini and Maria Luisa Bonelli. The analysis highlights how the Florentine institution developed a unique “anomaly” within the Italian landscape, pioneering a methodological shift that elevated scientific instruments and material culture to the status of legitimate historical documents. Utilizing unpublished archival materials, the paper illustrates how Corsini’s institutional vision and Bonelli’s expertise successfully established the history of science as an autonomous discipline grounded in its physical artifacts.

Keywords

Museo Galileo, scientific institutions, scientific instruments, historiography of science

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Ralph Waldo Emerson sosteneva che un'“istituzione è l'ombra allungata di un solo uomo.”¹ La tentazione che spinge ad identificare un'istituzione con la titanica impresa di un uomo o di pochi sparuti uomini è, spesso, una tentazione potente ma non priva di rischi. In particolare, quando si parla di istituzioni scientifiche il rischio è piuttosto evidente. La fama dello scienziato, le scoperte scientifiche, l'impegno e la dedizione profusi finiscono per costituire fattori rilevanti nel tracciare la storia dell'istituzione, finendo per privilegiare l'individuo al contesto. A questo rischio sfugge abilmente Marco Beretta nel volume *Mezzo secolo di Storia della Scienza al Museo Galileo. Andrea Corsini e Maria Luisa Righini Bonelli* (2025). Uno dei numerosi meriti del libro consiste proprio nella capacità di raccontare la storia di una delle più significative istituzioni scientifiche italiane, intrecciando la vicenda personale e professionale dei primi due direttori con il contesto storico, politico e scientifico del tempo, offrendo così un quadro esaustivo delle vicende che hanno caratterizzato la nascita ed il successivo sviluppo dell'Istituto e Museo di Storia della Scienza di Firenze (oggi Museo Galileo). Lo studio di Beretta si inserisce in una più vasta iniziativa volta a celebrare i cento anni dell'Istituzione fiorentina ma è, anche e soprattutto, da considerarsi una prima, importante ricostruzione degli eventi che portarono alla sua nascita e ai suoi primi, travagliati, decenni di vita. Attraverso questa prospettiva diventa possibile comprendere e ricostruire la vicenda che, nel quadro della storiografia scientifica italiana, viene, dall'autore, definita “l'anomalia dell'Istituto e Museo di Storia della Scienza di Firenze” (p. 11). Cercheremo di fare chiarezza, in queste note, del perché, a nostro avviso correttamente, l'autore chiama “anomalia” la vicenda del Museo fiorentino. Non casualmente il libro prende le mosse dalla vicenda storica legata alla nascita del Regio Museo di Fisica e Storia Naturale a Firenze, fortemente voluto dal granduca Pietro Leopoldo e inaugurato, nel 1775, nei locali di Palazzo Torrigiani dove, ora, è situato il Museo della Specola. Confluirono, nel Museo leopoldino, gli antichi strumenti medicei e i nuovi strumenti della scienza moderna, dagli astrolabi ai preziosi vetri del Cimento agli strumenti della fisica moderna. Una sala venne dedicata ai preparati anatomici in cera.² Questo nucleo di collezioni attraverserà con varie vicissitudini il diciannovesimo secolo e sarà, come vedremo, il vero oggetto del desiderio della nuova istituzione scientifica e del suo primo direttore Andrea Corsini. Fiorentino, laureato in Medicina, assistente presso l'Istituto di Igiene di Giorgio Roster, Corsini manifesta precocemente i suoi interessi per la storia della scienza. Nel 1899 fonda, insieme a tre amici (Bellincioni, Pampaloni, Mazzoni), un'associazione denominata Pro-cultura. Nel manifesto programmatico dell'associazione si intravedono gli intenti di scoperta e valorizzazione del patrimonio culturale italiano, con dichiarati scopi pedagogici. Si colgono, già in questo contesto, lo spirito e gli intenti che animeranno l'attività del medico fiorentino. Nel 1907 partecipò alla fondazione della Società italiana

¹ Emerson, *Fiducia in se stessi*, 64.

² Pasta, *Scienza, politica e rivoluzione*; Contardi, *La casa di Salomone a Firenze*.

di storia critica delle scienze mediche e naturali, da considerarsi, di fatto, la prima associazione nazionale degli storici della scienza. Dal 1910 la Società cominciò a pubblicare una *Rivista di storia critica delle scienze mediche e naturali*. Nel 1912 si tenne il primo congresso della Società. Proprio in questa occasione espose una linea di tendenza della ricerca storica che appare particolarmente significativa.³ Egli era convinto che fosse necessario superare gli steccati disciplinari ed affrontare la ricerca con un respiro più ampio rispetto agli angusti recinti del settorialismo disciplinare. L'intento era, innanzitutto, quello di emancipare la storia della scienza dalla storia della medicina e aprirla a nuovi orizzonti tematici e disciplinari. Rivendicava, inoltre, per la storia della scienza, lo stesso *status* accademico di altre discipline storiche (arte, letteratura, filosofia) e, a tal fine, chiedeva l'istituzione di cattedre. Soprattutto, l'operazione di Corsini aveva una funzione decisiva nel sollevare la storia della scienza dalla condizione subordinata di ancella delle varie discipline, come se occuparsi di storia della chimica o di storia della fisica fosse una sorta di passatempo secondario rispetto all'impegno richiesto dalla ricerca scientifica. Questa prima formulazione di un programma per la storia della scienza risulta decisiva. Se, da un lato, Corsini sottolineava la necessità di conferire una dimensione di piena autonomia alla storia della scienza, dall'altro, era indispensabile creare gli strumenti più idonei per diffonderla. Su queste due direttrici si incentra tutta l'attività del medico fiorentino. L'istanza di promozione della storia della scienza in Italia incontrava il parere favorevole del più illustre storico della scienza italiano del tempo: Aldo Mieli. Nel 1913 Mieli pubblicò, sulla *Rivista*, di cui era, da poco, diventato redattore per le scienze naturali, un articolo dove si denunciava lo stato disastroso dell'insegnamento universitario della storia della scienza, la mancanza di biblioteche ed istituzioni specializzate.⁴ Mieli, inoltre, auspicava la fondazione di una Società Italiana di Storia della Scienza che unisse tutti i cultori e gli studiosi delle varie discipline e promuovesse tutte le politiche ed azioni più adatte a diffondere l'insegnamento e l'istituzione delle cattedre universitarie. Il *j'accuse* di Mieli era nella sostanza condiviso dal medico fiorentino, pur avendo, quest'ultimo, un approccio diverso nel procedere alla istituzionalizzazione della storia della scienza.

Il convegno della Società Italiana di Storia Critica delle Scienze Mediche e Naturali, tenutosi a Bologna nel 1922, costituisce una tappa importante per il progetto di Corsini di dar vita ad una istituzione scientifica a Firenze. Infatti, presentò una relazione intitolata "Urgenza di assicurare il patrimonio storico scientifico italiano e mezzi di provvedervi." La denuncia dello stato di abbandono è chiarissima:

Orbene, mentre i quadri, gli oggetti di arte, sono stati in questi ultimi tempi ordinati, raccolti, inventariati, talché non vi è piccolo paese che non abbia la sua pinacoteca, la sua mostra

³ Corsini, "Relazione sull'importanza," 4.

⁴ Mieli, "Per promuovere in Italia," 344–347.

archeologica, il suo museo più o meno locale, che ognuno può visitare, quanti sono i luoghi in cui si sappia che vi è alcuna di queste raccolte scientifiche e la si possa vedere? Eppure del materiale ve ne è; ce ne accorgiamo quando dobbiam fare delle faticose ricerche, perché allora per informazioni private si giunge ogni tanto a scoprirle. Ne è detto che nei grandi centri le cose vadano sempre meglio! Vi sono anche in sedi universitarie, collezioni chiuse a chiave, ove mai nessuno entra, delle quali i professori o i direttori non si occupano perché roba vecchia, e gli assistenti ed i custodi meno che mai; anzi se qualche volta si rammentano di esse e necessita lor qualche vetreria o qualche vaso per mettervi dentro quel che nel momento fa comodo, e per far ciò tolgono quel che fino allora vi era stato.⁵

Il disappunto appare evidente quando sottolinea come l'incuria e la trascuratezza finiscono per investire quelli che “spesso sono oggetti, sono carte, sono libri di interesse storico non trascurabile.”⁶ Se, per quanto riguarda la *pars destruens*, Corsini non risparmia critiche e denuncia apertamente il grado di abbandono in cui versa il patrimonio storico scientifico in Italia, la *pars construens* è invece un vero e proprio manifesto programmatico di ciò che è necessario fare. Al fine di recuperare e tutelare questo straordinario patrimonio culturale diventava necessario chiamare a raccolta gli storici della scienza ed impegnarli ad un progetto comune che consisteva in alcuni punti essenziali: 1) catalogare tutto ciò che ancora non è stato catalogato, recuperando gli inventari esistenti, aggiornandoli; 2) selezionare che cosa deve essere mostrato al pubblico, decidendo se mantenerne la collocazione o esporlo in una sede più adatta; 3) arginare l'incuria verso tali oggetti sensibilizzando docenti universitari ad un maggior controllo delle condizioni degli strumenti presenti nei laboratori. Corsini insisteva molto su quest'ultimo aspetto. E a buon diritto. Perché si trattava di un aspetto essenziale. Sensibilizzare la comunità scientifica sul valore di strumenti appartenuti ad epoche passate e che adesso sono in disuso significa conferire il necessario spessore storico agli oggetti e di conseguenza il loro *status* di fonti per la ricerca storica. Il disegno di Corsini, se pur *in nuce*, appare già delineato in questi anni che precedono la fondazione del Museo fiorentino. Beretta sottolinea con efficacia come il congresso di Bologna del 1922 sia stato un momento di svolta nella storia della scienza italiana, un primo, importante successo poiché gli storici della scienza venivano considerati, almeno formalmente, su un piano di parità con gli storici della medicina.

Si trattava, ora, di avviare un concreto processo di realizzazione delle molte idee emerse dal congresso di Bologna: Beretta ricostruisce puntualmente i vari passaggi che portarono Corsini al raggiungimento del suo obiettivo fondamentale, ovvero la fondazione di un istituto universitario dedicato alla storia della scienza che valorizzasse il patrimonio scientifico presente nella città di Firenze ma che non esaurisse la sua vocazione dentro i

⁵ Corsini, “Per il patrimonio...,” 349–350.

⁶ *Ibid.*

limiti della storia cittadina. Il patrimonio storico scientifico meritava una struttura stabile e istituzionalizzata. Corsini si mosse così per dare vita a un gruppo di lavoro dedito alla valorizzazione della storia della scienza in Italia e alla tutela del suo patrimonio. Nasce così, nel maggio del 1923, il Gruppo per la tutela del patrimonio scientifico nazionale.⁷ A presiederlo è Antonio Garbasso, sindaco di Firenze, fisico, autorevole professore dell'Università di Firenze e, soprattutto, fedele sostenitore del regime fascista. Per Corsini è una figura indispensabile per raggiungere gli scopi prefissati. Corsini è il vicepresidente del Gruppo e si attiva fin da subito con un programma che prevede: 1) il riordino e il restauro delle collezioni scientifiche pubbliche e private; 2) la promozione della storia della scienza verso il grande pubblico attraverso conferenze, uscite guidate, aperture straordinarie dei musei scientifici; 3) la stretta collaborazione con i vari enti preposti alla tutela della natura e del paesaggio. Il 7 marzo 1925 il sogno di Corsini diventa realtà. Il Rettore dell'Università di Firenze Giulio Chiarugi gli comunicava che il Senato Accademico aveva approvato la sua richiesta di istituire un "Istituto di Storia delle Scienze," affidandogli l'incarico di Direttore. Il 7 maggio fece seguito l'inaugurazione ufficiale. In realtà, si trattava di una stanza in Via Alfani negli edifici degli istituti medico-chirurgici annessi all'Ospedale di Santa Maria Nuova. Non è tanto il valore del primo nucleo di strumenti scientifici, raccolti nelle stanze del neonato istituto, quanto il piano che Corsini intendeva attuare a risultare di particolare interesse. Infatti, uno degli obiettivi fondamentali consisteva nell'acquisizione della strumentaria antica conservata alla Specola. Ora, il progetto di acquisizione degli strumenti e dei cimeli conservati alla Tribuna di Galileo si faceva sempre più concreto, anche se Corsini si muoveva con la necessaria prudenza. In realtà, non si trattava di un'operazione volta alla mera spoliatura di un patrimonio appartenente ad un'altra istituzione ma rientrava in un più generale processo di costituzione di un luogo destinato alla scienza e che avesse, nei suoi intenti essenziali, un carattere decisamente innovativo. La raccolta, valorizzazione e conservazione del patrimonio scientifico intendeva promuovere un modello di ricerca storica che si fondava sul carattere eterogeneo delle fonti. Oltre ai testi scientifici anche le fonti non verbali acquistavano la valenza di fonte da studiare ed interpretare. Ecco spiegata l'insistenza non solo sugli strumenti della Specola che costituiscono la testimonianza più significativa di un passato scientifico di grande rilevanza ma anche sulle fonti iconografiche che, a loro volta, potevano rappresentare una fondamentale risorsa per la storia della scienza. Si andava così delineando una nuova figura di storico della scienza e della sua dimensione professionale. Tolta dalla condizione di sussidiarietà rispetto alla ricerca scientifica vera e propria o alle altre più consolidate tradizioni storiografiche, la storia della scienza poteva diventare una disciplina autonoma, con le sue fonti specifiche. E, in questo ambito, le fonti non verbali acquisivano dunque lo stesso valore delle fonti verbali. L'istituzione si presentava con un carattere ambivalente. Se da un lato, si registrava la necessità

⁷ Cfr. Lauri, "Roba da museo," 15–23.

di orientarla verso l'acquisizione, la conservazione e la catalogazione di tutto quel materiale relativo alla storia della scienza con finalità anche espositive e certamente pedagogiche, dall'altro, l'istituzione fiorentina doveva assolvere anche al compito di promuovere una ricerca storica effettiva, avviare un processo di formazione di studiosi in grado di valorizzare lo studio storico della scienza attingendo a tutte le fonti che l'istituzione metteva loro a disposizione.

Un primo passo nella direzione di un istituto con le caratteristiche appena definite è certamente l'Esposizione nazionale di Storia della Scienza del 1929. Inaugurata alla presenza del Re, l'idea di una mostra che avrebbe esibito i cimeli scientifici toscani e gli strumenti relativi alle scienze fisiche e biologiche era già stata accarezzata da tempo all'interno del Gruppo per la tutela del patrimonio scientifico nazionale. Benché l'obiettivo politico che si celava dietro la Mostra fosse quello di rivendicare il primato nazionale in ambito scientifico in sintonia con la retorica propaganda del Regime, Corsini vide l'opportunità di sensibilizzare l'opinione pubblica nei confronti del patrimonio storico-scientifico e dei luoghi dove si aveva intenzione di conservarlo al fine di restituirlo alla libera fruizione degli studiosi.⁸ La mostra ebbe un notevole successo ma, soprattutto, consentì di ottenere in deposito le collezioni mediche e lorenese di strumenti scientifici. Con questo prezioso patrimonio storico scientifico il progetto di Corsini si avviava al suo compimento. L'anno successivo si liberarono i locali di Palazzo Castellani in Piazza dei Giudici. Il Direttore non si lasciò sfuggire l'opportunità e vi trasferì l'Istituto ed il nuovo Museo di Storia della Scienza. Il 18 maggio 1930 Benito Mussolini inaugurava il Museo Nazionale di Storia della Scienza. L'istituzione fiorentina rappresenta di fatto un *unicum* nel panorama delle istituzioni scientifiche italiane. I nuovi locali permettevano di ospitare gli oggetti in spazi adeguati, e si poteva finalmente dar vita all'osmosi fra conservazione e ricerca storica che stava alla base del progetto di Corsini. Ciò che finora era rimasto sulla carta era diventato realtà: una casa comune per tutti gli storici della scienza. Uno degli aspetti 'anomali', per richiamarsi all'espressione usata dall'autore del volume, consiste proprio in questo: l'istituzione doveva essere al tempo stesso manifestazione visibile del patrimonio storico scientifico e laboratorio di ricerca storica, dove gli oggetti assumevano il duplice ruolo di oggetto espositivo e oggetto di studio storico.

Beretta indaga efficacemente gli anni successivi alla fondazione: ricostruisce i rapporti fra Corsini e il mondo scientifico italiano ed internazionale; il rischio costituito dall'attivismo di Guido Ucelli e il suo progetto di creare un Museo della scienza e della tecnica a Milano che entrava di fatto in rotta di collisione con i progetti corsiniani per il museo ed istituto fiorentino; il difficile rapporto con il velleitarismo del Regime fascista alla costante ricerca dell'affermazione del primato della scienza italiana; i cronici problemi relativi alla situazione finanziaria del museo. Lo fa dando voce ai protagonisti, attingendo ad un

⁸ Su questi temi si vedano le considerazioni di Barreca, "Il 'dilettante appassionato,'" 30.

serbatoio di documenti spesso poco conosciuti se non addirittura ignoti. In particolare, questa attenzione ai documenti conservati all'Archivio del Museo Galileo risulta preziosa nel ricostruire il passaggio avvenuto nel dopoguerra dalla direzione Corsini alla direzione di Maria Luisa Bonelli. Giovane studiosa di letteratura spagnola, nel 1942 Bonelli entrava nello staff del Museo. Negli anni a venire contribuirà non solo a risollevarne le sorti del Museo fiorentino dopo il disastro della guerra ma riuscirà a trasformarlo in una delle istituzioni più prestigiose al mondo nel campo della storia della scienza. Guidata da una curiosità insaziabile e del tutto digiuna di storia della scienza, Bonelli si impegnò costantemente e con un'energia straordinaria per approfondire le proprie conoscenze e contribuire in modo significativo alla crescita dell'istituzione fiorentina. Centrale le appariva la ricerca storica svolta attraverso la consultazione di fonti documentarie. Studiare gli strumenti scientifici, la loro storia ed il ruolo che ebbero sia come oggetti espositivi sia come strumenti di ricerca scientifica significava affidarsi alle fonti d'archivio. Solo così si sarebbero potute offrire risposte ai molti dubbi, alle molte domande che lo studio di uno strumento poneva necessariamente. La sua attenzione ai documenti, sui quali compiva costanti ricerche, le permetteva di collocare gli strumenti e le collezioni, in genere, all'interno del contesto storico e culturale a cui appartenevano, offrendo così un'interpretazione che non si esauriva nella sola dimensione tecnico-operativa. In questo senso, il saggio scritto in collaborazione con Isabella Truci e intitolato "L'Istituto di fisica e scienze naturali di Firenze alla luce di nuovi documenti d'archivio" costituisce un esempio paradigmatico.⁹ Il saggio mostra efficacemente il metodo storiografico adottato dalla Bonelli: ricostruisce la storia del collezionismo mediceo-lorenese affidandosi con rigore e competenza alle fonti manoscritte settecentesche e offrendo così una prima, pionieristica ricostruzione delle vicende storiche delle collezioni che stanno all'origine del Real Museo di fisica e Storia Naturale di Pietro Leopoldo. Il saggio è diventato il punto di partenza imprescindibile per chiunque (*quorum ego*) abbia intrapreso una ricerca storica sulle origini del collezionismo scientifico in Toscana nel diciottesimo secolo. Il metodo adottato e applicato in numerose circostanze, consisteva nel partire dallo strumento di cui si definiva il nome esatto, chi lo aveva ideato, chi lo aveva realizzato ed una volta indagati questi aspetti, lo si collocava all'interno del contesto storico scientifico e culturale a cui tale strumento era appartenuto. In realtà, questo approccio alla storia della scienza finiva per essere minoritario e confinato ai margini dell'orizzonte storiografico che negli anni Cinquanta e Sessanta si stava delineando in Italia. Il convegno internazionale, organizzato nel 1966 alla Domus Galileiana dal direttore Polvani, vide prevalere una interpretazione della storia della scienza intesa come una disciplina strettamente legata alla storia della filosofia. Questo nuovo indirizzo di ricerca finiva per porre decisamente in secondo piano il metodo di indagine adottato

⁹ Righini Bonelli e Truci, "L'Istituto di Fisica e Scienze Naturali," 135–155. Su questi aspetti cfr. Miniati, "A Feminine Touch," 1–21.

dalla Bonelli, nonostante la sua indubbia originalità. Tuttavia, l'attività di curatrice delle collezioni museali e la sua straordinaria capacità organizzativa le permisero di guadagnare una credibilità internazionale riservata a pochi studiosi di storia della scienza. Costanti furono i rapporti con i maggiori storici della scienza mondiali che fecero del Museo un luogo privilegiato di studio e di conoscenza, fornendo, a loro volta, quelle preziose competenze di cui Bonelli aveva bisogno (fra i tanti, Silvio Bedini, Marie Boas Hall, I. Bernard Cohen, Henry Guerlac). Beretta approfondisce quest'aspetto e restituisce alla figura della curatrice prima, e della direttrice dopo, la sua affatto marginale dimensione nella comunità di studiosi. L'autore del volume, inoltre, segue passo dopo passo tutta l'attività museale di Bonelli. Attingendo ad una notevole mole di documenti d'archivio, ha ricostruito le vicende che legano Bonelli alla stesura dei cataloghi, all'allestimento di mostre, all'organizzazione di convegni come quello svoltosi a Firenze e Milano nel settembre del 1956. E decisivo fu il contributo della studiosa al momento della nascita di una nuova rivista per il Museo. Dietro alla realizzazione di *Physis. Rivista internazionale di storia della scienza* è rintracciabile l'idea propria sia di Corsini ma anche e, soprattutto, di Bonelli, di un periodico che affrontasse in modo analitico lo studio storico degli strumenti scientifici. Nelle pagine della rivista, nei primi anni Sessanta, emerge con chiarezza come l'impronta metodologica prevalente fosse quella di privilegiare lo studio storico degli strumenti scientifici. Questo fu il tratto, distintivo e originale, della rivista fin dai suoi primi anni.

Questa impronta sarà sempre più marcata dopo il 1961, anno della morte di Corsini e della successione alla guida del Museo da parte di Bonelli. La direzione della studiosa fu caratterizzata da anni molto difficili. Dovette affrontare il dramma dell'alluvione del 1966, mostrando coraggio e dedizione grazie ai quali riuscì a salvare molti strumenti del Museo dalla catastrofe. E fu proprio in questa occasione che le competenze maturate negli anni finirono per risultare essenziali. Senza l'opera di catalogazione scientifica delle collezioni, senza le ricerche storiche relative agli strumenti e ai modelli esposti, il loro recupero, restauro e ripristino non sarebbero stati possibili. Seppe inoltre cogliere l'importanza del restauro, che divenne una competenza rilevante per la storia materiale della scienza e per il collezionismo scientifico in particolare. Quando, nel 1979, fu insignita della Sarton Medal (prima italiana e prima direttrice di un museo a riceverla), il lavoro straordinario compiuto nell'istituzione fiorentina le fu finalmente riconosciuto. Bonelli si spense due anni dopo, nella consapevolezza di aver fatto tutto il possibile per assicurare al Museo la stabilità di cui necessitava.

Tre anni dopo la sua scomparsa, sul *Giornale critico della filosofia italiana* uscì un articolo di Jacques Roger, intitolato "Per una storia storica delle scienze." Lo storico francese lanciava un appello a restituire la storia della scienza alla storia. Si trattava di aprire le porte a una ricerca che sapesse utilizzare ogni genere di fonti, al pari di qualsiasi altra disciplina storica. Le fonti non verbali come gli strumenti scientifici potevano e dovevano dunque essere considerati fonti storiche analizzate e studiate tanto quanto le fonti verbali.

Era ciò che Corsini e soprattutto Bonelli avevano fatto. Emancipando lo strumento scientifico dalla dimensione di reperto curioso o di oggetto esteticamente apprezzabile, i due direttori del Museo fiorentino ne avevano compreso la valenza storica e anche, è importante sottolinearlo, la funzione pedagogica. Corsini e Bonelli non furono solo dei valenti direttori di un Museo che guidarono fra numerose difficoltà (dal Fascismo all'alluvione passando attraverso una guerra mondiale). Essi videro una nuova possibilità per la storia della scienza. Fare ricerca in questo ambito significa affrontare lo studio di oggetti materiali. Come scrive correttamente Beretta lo storico si doveva confrontare con "la materialità degli strumenti, con la fisicità delle macchine, con la concretezza dei reperti" (p. 223). Lo strumento diviene così un manufatto culturale da studiare, analizzare ed annoverare tra i documenti della ricerca. Se è vero che in questo modo le fonti per la storia della scienza si ampliavano necessariamente, è altrettanto vero che il rapporto fra scienza e storia acquistava una nuova, pionieristica dimensione.

Pier Paolo Pasolini definì le istituzioni come "misteriose" e "commoventi."¹⁰ Il libro di Beretta chiarisce molti 'misteri' della storia dell'istituzione fiorentina. Inoltre, e lo scrivo a titolo di merito, non sfugge a chi legge una ampiamente giustificata, 'commozione' nel ricostruire la vicenda umana e professionale di una delle poche donne che, nel secolo scorso, seppero infrangere l'insopportabile soffitto di cristallo.

¹⁰ Pasolini, "L'enigma di Pio XII," 17–19.

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