



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

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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*.

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'abaco* 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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