History of Mechanism and Machine Science

Volume 28

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Raffaele Pisano • Danilo Capecchi

Tartaglia's Science of Weights and Mechanics in the Sixteenth Century

Selections from *Quesiti et inventioni diverse*: Books VII–VIII

Springer

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ISSN 1875-3442 ISSN 1875-3426 (electronic)
History of Mechanism and Machine Science
ISBN 978-94-017-9709-2 ISBN 978-94-017-9710-8 (eBook)
DOI 10.1007/978-94-017-9710-8

Library of Congress Control Number: 2015941275

Springer Dordrecht Heidelberg New York London

Printed on acid-free paper

Springer Science+Business Media B.V. Dordrecht is part of Springer Science+Business Media (www.springer.com)

Preface

Niccolo Fontana (1499–1557), better known as Tartaglia, is one of a loosely connected group of Italian scientists living between the middle of the fifteenth and the end of the sixteenth century, between Leonardo and Galileo. They all worked on what we call today statics, what they called the “science of weights”, following the ideas of Archimedes’ *On the equilibrium of planes*, Pappus’ “Collection”, Heron’s *Automata*, the Pseudo Aristotle’s *Quaestiones mechanicae* and Jordanus Nemorarius’ *De ratione ponderibus* (thirteenth century). The first of them is Leonardo da Vinci, but his influence in that domain is very difficult to estimate. Most of the others have reproduced, translated, commented or as they said themselves “paraphrased” those texts. Niccolò Leonico Tomeo even published the *Quaestiones* twice, first in 1525 with an extensive commentary, and then in 1573, the original text alone in his edition of Aristotle’s complete works.

In 1551, Girolamo Cardano dedicated the end of the first book of his *De subtilitate* to the equilibrium of the balance, mentioning works of Archimedes. In his *Mechanicorum liber* (1577), Guidobaldo del Monte tries to organize the study of the Pseudo Aristotle’s simple machines, balance, lever, pulley, wedge, etc. in a Euclidean way, basing the demonstrations of their properties on “common notions” and “suppositions”. Eleven years later, he gives in *duos Archimedis aequeponderantium libros paraphrasis*, as he presents it himself, a “paraphrase” of Archimedes on the “equilibrium of planes”.

In Giovanni Battista Benedetti’s *Diversarum speculationum mathematicarum et physicorum* (1585) we find a *De mechanicis* largely inspired by the *Quaestiones*. Three years later, Federico Commandino, published posthume Pappus’s original text, *Mathematicae collections*; some years before, he had published *De centro gravitatis* (1565) referring to Pappus.

Bernardino Baldi translated into Italian *Di Herone Alessandrino De gli automati* (1589) and in his *Mechanica Aristotelis problemata exercitationes* (1621) is only loosely inspired by the *Questiones*. Francesco Maurolico largely comments the same text in his *Problemata mechanica* (1613) and in his *Admirandi Archimedis* he published an A*rchimedi momentis aequalis* corresponding to the "equilibrium of planes" (Maurolico 1685).

The aim of all these men is identical to that of Galileo: to describe the world mathematically. Nevertheless, their works are nowadays largely unknown, except to specialists, despite the fact that Galileo found there the first inspiration for *Le mecaniche* and for the rest of his work on statics. However, his genius soon outshined them. For historians, those texts contain the roots of that part of Galileo's work and they help them to understand his masterpieces.

Therein lies the reason why Raffaele Pisano and Danilo Capecchi have decided to publish a reproduction of two books of Tartaglia's *Quesiti et inventioni diverse* together with an English translation. In fact, books VII and VIII are the only ones concerning the "Science of Weights" in Tartaglia's work. The first six books of *Quesiti* are concerned with artillery and war science, the last one with arithmetic, geometry and algebra. He also published Jordanus Nemorarius's *De ponderositate* (1565).

The book opens on biographical sketches that, cautiously, are based only on official documents such as Tataglia's last will and testament, as well as on contemporary biographies written by some of the authors mentioned supra.

That first part of the book ends with a general presentation of Tartaglia's whole work.

The second part shows the connections of Tartaglia's science of weights, not only with the Italian group that we presented first but also with the Arabic tradition and with Simon Stevin.

The third part is a careful presentation of the scientific content of books VII and VIII of the *Quesiti*.

The reader is then well prepared to read Tartaglia's text, a difficult task indeed, but how fruitful!

This book, with its original texts and its translations, with numerous references to other original texts as well as to the secondary literature, will be a useful tool for all those who study this particularly rich period.

Waterloo, Belgium Patricia Radelet-de Grave
2014, September

Acknowledgments

The genesis of such a lengthy book has deep roots (dating backing our early mechanics and Tartaglia research starting in 2004), and the result has been a long time in the making. Therefore, to all the directors and staff members of libraries and archives cited within the book, we express our profound appreciation for their collaboration.

We express our gratitude to Claudia Masotti for her warm and insightful homage to Uncle Arnaldo Masotti's images. We also thank Paolo Bussotti (Berlin Alexander von Humboldt Foundation, Germany), Giuseppe Patera (Lille 1 University Science and Technology, France), Gérard Hamon (IREM Rennes, France, Lucette Degryse (University of Littoral Côte d'Opale, France), Giuseppina Ferriello (Nautical Institute, Italy), Romano Gatto (Basilicata University, Italy) and John Schuster (Sydney University, Australia) for their supportive readings, illuminating conversations and suggesting. Furthermore, we thank Caroline Duroselle-Melish (Harvard Printing and Graphic Arts Department, USA), Tricia Buckingham (Bodleian Oxford Libraries, UK), Marie-Lise Faget (Service Patrimoine Bibliothèque de Bordeaux, France), Hermann Hunger (Österreichischen Akademie der Wissenschaften, Austria), Luigi Pizzamiglio (Biblioteca Carlo Viganò e Fondo Tartaglia, Italy) and Giulio Vincenti and Laura Ferrari (Biblioteca, Palazzo dell'Arsenale, Torino, Italy) for their care and dedication in properly identifying the many manuscripts and their editions that are quoted in the book; and a special thanks to distinguished professor and friend Patricia Radelet-de Grave (Catholic University of Louvain-la-Neuve, Belgium) for her accurate *Preface* and suggesting.

Finally, of great importance, we address our acknowledgments to Marco Ceccarelli, Nathalie Jacobs, Anneke Pot, respectively, Springer book Series Editor, Springer Publishing Editor-in-Chief, and Springer Editorial Assistant for their fine work and positive reception of our project on the Tartaglia's *Quesiti et inventioni diverse*.

2015, January, Lille

Remarks for the Reader

This book is devoted to the history and historical epistemology of science, in particular to the fields of geometry, mathematics, physics and Western civilization of the fifteenth to sixteenth centuries. The latter is mainly viewed as a branch of the combined history of science and foundations of sciences. We have conceived it as an integrated history and epistemology of scientific methods, combining epistemological and historical approaches to clearly identify significant historical hypotheses. We contend that such hypotheses should always be subject to epistemological interpretation by means of declared keys of investigations based on historical facts, scientific activities and original documents to trace their historical development. For, bibliographical references, the relationships between physics–mathematics and physics–geometry, and the role played by science in context are strongly stressed.

In order to recall Masotti's edition, both "Tartaglia 1554" and "Tartaglia [1554] 1959" are cited. In the References section both "de Nemore 1565" and "Tartaglia 1565", as editor, are listed for the reader's convenience. Both the names "Galileo" and "Galilei" are used to recognise their international adoption. The book is many pages long, so we have relied on numerous recalls of dates and names to help guide the reader to correct documents.

For the English translations of the Tartaglia's text we assumed as a model – with several technical variations – that of Stillman Drake (Drake and Drabkin 1969) and seldom Marshall Clagett (Moody and Clagett [1952] 1960; Brown 1967–1968; Clagett 1959). They were most helpful.

In order to make the reader comfortable reading in composite Latin, *vulgare*, Italian and English languages presented in the book, yet never losing historical rigour, we made some choices for multiple forms of names (e.g., Nicolo–Nicolò–Niccolò) and subjects (e.g., quaestio–questions–propositions). We conserved the original style of numeration to identify chapters (e.g., XIIII, XIX, etc.). About the terms "Jordani" ("Jordanus", "Iordanus") and "Iordani" (as one can often read in the secondary literature) and taking into account both Latin grammar and historical tradition (i.e, see Moody and Clagett [1952] 1960, p 173) in this book the reader will find both cited terms accordingly with specific case. We also precise that in the secondary literature *Opusculum* [or *Opvscvlvm*] *de ponderositate* (de Nemore 1565) is usual to be read as both "*Jordani Opusculum de ponderositate*" and "*Iordani Opusculum de ponderositate*". By accordingly with specific case we used both terms.

We have dedicated one chapter to original texts. In order to present facsimile texts, transcriptions and translations to best advantage, our critical comments are reported in footnotes as well.

Introduction

The practice of science, as well as its history, has for centuries been a leading component of the scholarly work of both the Eastern and Western world. The results of these efforts have mainly depended on individual scientific and disciplinary ambitions that led to their technological innovations. Scientific traditions over the years and contributions by these scientists created a scientific framework in which to interpret celestial and terrestrial phenomena.

The development of astronomy, geometry, physics, mathematics, and science, generally speaking, is also a social phenomenon because it is influenced both by the needs of the labour market and by the basic knowledge of laws of nature. Therefore, the way in which science is framed changes according to modifications of the social environment and the attribute referred to as "know-how".

In the period considered in the book in Europe, a series of wars required new financial supports and new knowledge. Moving of soldiers from one country to another permitted the spread of know-how and competence in practices that were necessary for these people to be recruited: i.e., *Tercio* in Spain, *Légion* in France, and *Regiment* in England. For this reason, and among many social factors, the military literature of the sixteenth and seventeenth century was particularly rich (fortifications, strategy, weapons, etc.). The organization and production of gunpowder evidently created a bridge towards structured recruitments, army training and attack–defence strategies. Therefore, a certain body of knowledge started to spread within early military handbooks (constructions and maintenance of war machines, mathematical and geometrical rules for weapons, battle projects, Pythagorean tables, fortifications projects, measurements and devices, etc.) in which a minimum of mathematical (calculus) basic education was required. For that reason, the scientific education of soldiers and gunners played an important role within the art of war. In the beginning, this social dynamic was randomly undefined and only later became more structured. A prime example was one of the first organized English military education schools, *Honourable Artillery Company* (1087; 1537). The company built its first *Armoury House in London* at the site of the *Old Artillery Gardens* (1622). Consequently, mathematical education and early physical arguments were provided for *Fire Master* and *Master Gunner* abilities. The latter were busy with deployment of cannon, as well as both practical and technological considerations: i.e., brass rather than iron cannonballs, geometrical dimension of a cannon's mouth, angle of fire, use of instruments (i.e., Tartaglia's *quadrante*). Traditions of families of Italian metalworkers such as Alberghetti, Gioardi, Morando, Borgognoni et al. were representative of this expertise. Thus, standards were evidently sought due to previous unsatisfactory productions of, for example, replicating a series of cannonballs. As a result, a basic but complex scientific and applied knowledge (mathematical, geometrical, physical) was required because, as is still the case today, education in the field of weapons requires more than simply expertise in artillery school (Promis 1808–1873, 1841; Jähns 1889–1891, Hall 1962, 1997; Henninger-Voss 2002). In our opinion, new advanced *geometrization* and *mathematization* of nature were, and still are, needed.

During the long period between the second half of the twelfth century and the first half of the sixteenth century, Italian cities-states were among the most advanced countries with respect to economic structure and development of science. Fundamental to the opening of new perspectives in the development of science was however the development and spread of mathematical knowledge. Starting in the thirteenth century in some Italian regions, an organized mathematical education was developed connected to the prevailing economic and social structure. The way in which mathematics education was structured in Italy between the thirteenth and the end of the fifteenth century is significant and paradigmatic to highlight the influence society can have on education. Mathematical education was organized around the so-called *Scuole d'abaco* (*Abacus schools*). Their heritage was influential for mathematical education and important mathematicians who lived in the late Middle Ages and in the Renaissance (Grant 1962; Koyré 1950; Lindberg 1976; Knobloch, Vasoli and Siraisi 2001; Harrison 2006). An emblematic case is that of Luca Pacioli (1445–1517) who, in turn, had a fundamental role in Leonardo da Vinci's (1452–1519) mathematical education (Bagni and D'Amore 2007). Furthermore the *Abacus schools* had connections with mathematicians such as Scipione dal Ferro (1465–1526), Niccolò Tartaglia (1499–1557), Gerolamo Cardano (1501–1576), Lodovico Ferrari (1522–1565), Rafael Bombelli da Bologna (1526–1572), who developed algebra and in particular studied the solutions of third and fourth degree equations. The relations among these mathematicians are significant from a scientific, social and anthropological point of view. The present book is concentrated on one of those mathematicians, Niccolò Tartaglia.

The writing of *dialogues* was not exclusive to Tartaglia. We have dedicated a section below to that topic (Chap. 4). Of further interest are his distinguished interlocutors, his *honorando* disciples, and anonymous personages such as a "pescatore" (fisherman), an "architettore" (architect), an "inzegnero" (engineer), and a "capo dei bombardieri" (artillerymen head), etc. Tartaglia's language was not only a way to write differently from the official scientific language at that time (Latin), but it was a tentative effort to establish a closer relationship between the traditions of scientists and the traditions of citizens, as well; quite correctly, Gosselin entitled his *L'Arithmétique de Nicolas Tartaglia Brescian, Grand Mathematicien, et Prince des Praticiens* (Gosselin [1578] 1613). In this sense, by including both amateurs and experts from other not necessarily scientific disciplines, he established clear evidence that the proposed "science-in-practice" would be subjected to sufficiently enquiring criticism from a wide-ranging set of perspectives. Thus, without using the current language of scientists, Tartaglia chose a simpler form of communication that is the *dialogue* (as both Plato and Lucian did in the Renaissance) between a specialist and a practitioner. There is ample evidence; e.g., at the beginning of the *Quesiti et invention diverse*, within the dedicatory letter to Henry VIII, King of England:

> Which thought made me wish (although I lack that eloquence and polish of speech which is requisite to the hearing of your Majesty) that these questions or inventions of mine, with their replies and solutions, might be offered and dedicated – not as something necessary to your Majesty (for indeed even things of profound learning, set forth and explained in elegant and lucid style, could not add to your Majesty's high perfection; let alone these of mine, that are mechanical things, plebeian, and written, as spoken, in rough and low style) but only as new things – I offer them and dedicate them to you [. . .][1]

and in the *General Trattato*:

> I am sure that many will be astonished why I wrote the above proportions, both in Latin, within the tradition of our ancient mathematicians, and vulgar, and vulgar and Latin together.[2]

The whole *Quesiti et inventioni diverse*, which is the main purpose of this book, is presented in the form of a dialogue; further, in *Book IX* (Tartaglia 1554, Pr. XXVII–XLII) an added method of communication appears, the epistolary. The questions among mathematicians evidently revolved around the problem of solution of the third degree equation; often, the tune echoed mediaeval disputes.

The book comprises ix chapters within four main parts.

At the beginning (Part I, Chap. 1) biographical sketches and philological-historical-epistemological reflections are reported.

In Chap. 2 (Part I) an historical account of S*cientia de ponderibus* and statics during ancient times and the Renaissance is presented.

We extensively analyse Niccolò Tartaglia's Books VII and VIII of the *Quesiti et inventioni diverse* (Part II, Chap. 3) from historical and epistemological standpoints. Particularly, this chapter is also devoted to *historical epistemology of science* presenting an integrated history and epistemology of scientific methods, which combine epistemological and historical approaches to identify significant historical hypotheses within the relationship between physics and mathematics (physical observations and theoretical mechanical modeling).

In Chap. 4 (Part III) we report on translations into English and transcriptions of the main works studied for our research.

Part IV is composed of two chapters. In Chap. 5, we list foreign editions of *Quesiti et invention diverse* as a component of the history. Bibliographical notes and alleged editions are commented. Finally, in Chap. 6, final remarks end the book. After the reference section, a list of main *Quesiti* accounts is presented.

We think that the composition of this book makes absorbing reading for historians and philosophers of science, as well as for scientists themselves.

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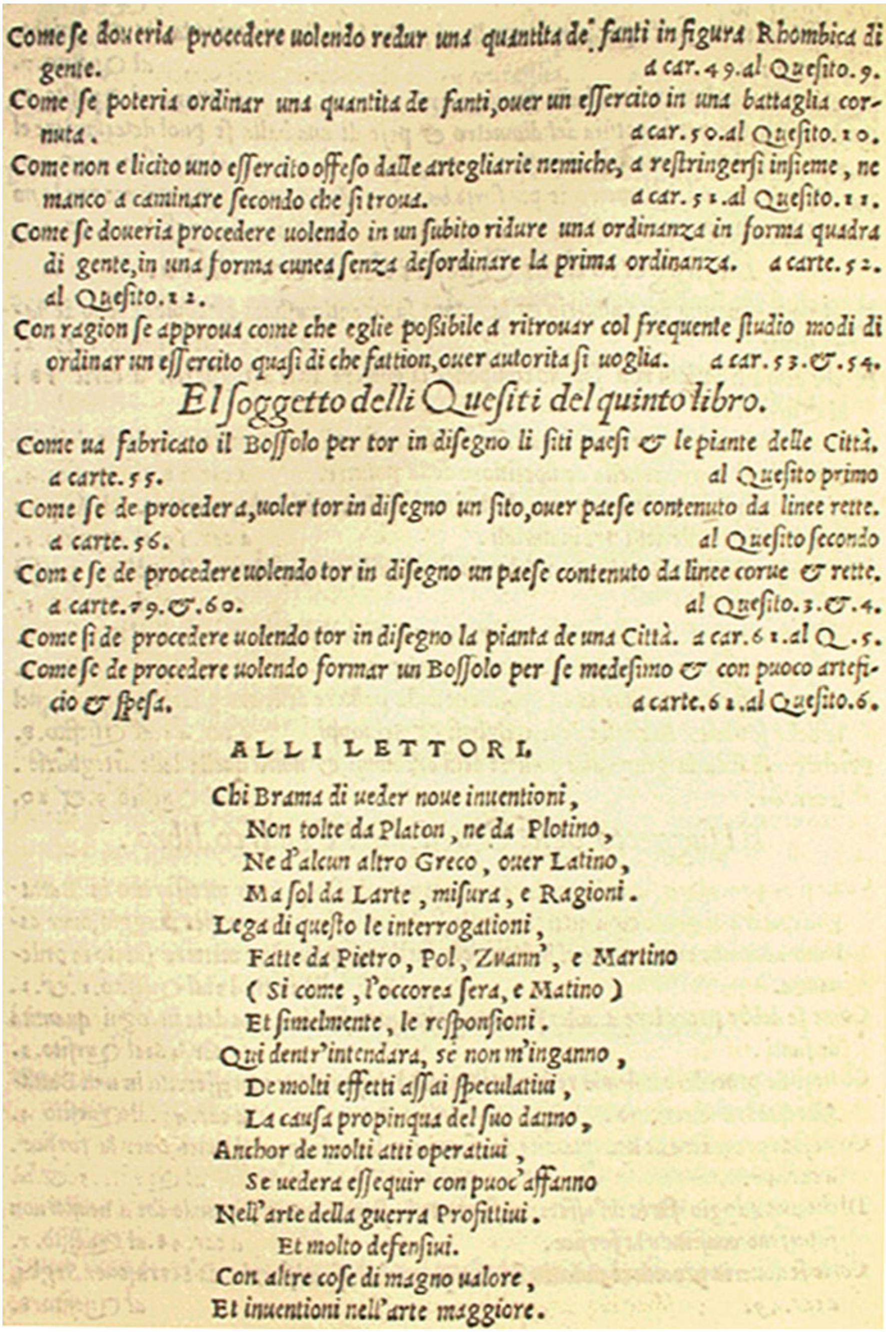
[1] Tartaglia 1554, 4v; see also *Alli Lettori*, 3v. *Idem* in: Tartaglia 1546, 1v.

[2] Tartaglia 1556–1560, II, 103r. The translations is ours. See also many passages within Tartaglia's answers in *I sei scritti di matematica disfida di Lodovico Ferrari coi sei contro–cartelli in risposta di Niccolò Tartaglia* (Tartaglia 1876, 2nd Tartaglia's answer; see also Zeuthen 1893).



Come ſe doueria procedere uolendo redur una quantita de' fanti in figura Rhombica di gente. a car. 49. al Queſito. 9.

Come ſe poteria ordinar una quantita de fanti, ouer un eſſercito in una battaglia cornuta. a car. 50. al Queſito. 10.

Come non e licito uno eſſercito offeſo dalle arteglia rie nemiche, a reſtringerſi inſieme, ne manco a caminare ſecondo che ſi troua. a car. 51. al Queſito. 11.

Come ſe doueria procedere uolendo in un ſubito ridure una ordinanza in forma quadra di gente, in una forma cunea ſenza deſordinare la prima ordinanza. a carte. 52. al Queſito. 12.

Con ragion ſe approua come che eglie poßibile a ritrouar col frequente ſtudio modi di ordinar un eſſercito quaſi di che fattion, ouer autorita ſi uoglia. a car. 53. & 54.

El ſoggetto delli Queſiti del quinto libro.

Come ua fabricato il Boſſolo per tor in diſegno li ſiti paeſi & le piante delle Città, a carte. 55. al Queſito primo

Come ſe de procedera, uoler tor in diſegno un ſito, ouer paeſe contenuto da linee rette. a carte. 56. al Queſito ſecondo

Com e ſe de procedere uolendo tor in diſegno un paeſe contenuto da linee corue & rette. a carte. 59. & 60. al Queſito. 3. & 4.

Come ſi de procedere uolendo tor in diſegno la pianta de una Città. a car. 61. al Q. 5.

Come ſe de procedere uolendo formar un Boſſolo per ſe medeſimo & con puoco arteficio & ſpeſa. a carte. 61. al Queſito. 6.

ALLI LETTORI.

Chi Brama di ueder noue inuentioni,
Non tolte da Platon, ne da Plotino,
Ne d'alcun altro Greco, ouer Latino,
Ma ſol da Larte, miſura, e Ragioni.
Lega di queſto le interrogationi,
Fatte da Pietro, Pol, Zuann', e Martino
(Si come, l'occorea ſera, e Matino)
Et ſimelmente, le reſponſioni.
Qui dentr'intendara, se non m'inganno,
De molti effetti aſſai ſpeculatiui,
La cauſa propinqua del ſuo danno,
Anchor de molti atti operatiui,
Se uedera eſſequir con puoc'affanno
Nell'arte della guerra Profittiui.
Et molto defenſiui.
Con altre coſe di magno ualore,
Et inuentioni nell'arte maggiore.

Tartaglia 1554, *Quesiti et inventioni diverse,* 3v. In the first lines, just after "ALLI LETTORI." (see image above) Tartaglia declares his main pedagogical originality promising to the readers – in form of a sonnet – that his *inventioni* do not belong to Plato or other Greek, or Latin thinker, but they derive from *Art, measurement and Reasoning* ["Chi Brama di veder nove invention, Non tolte da Platon ne da Plotino, Ne d'alcun altro Greco, over Latino, Ma sol da L[']arte, misura, e Ragioni."] (*Ibidem*).

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The original version of the Copyright Page was revised. Article note was included in Copyright page and Chapter 4. An erratum can be found at DOI 10.1007/978-94-017-9710-8_7.