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DOSIER: CINCO SIGLOS DE CULTURA MARÍTIMA Y EPISTEMOLOGÍA ARTESANAL / FIVE CENTURIES OF MARITIME CULTURE AND ARTISANAL EPISTEMOLOGY

A SHARED TRADITION: TRANSMITTING MARITIME KNOWLEDGE IN PRINT

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ABSTRACT: As Europeans ventured more frequently on transoceanic voyages in the 16th century, it became essential for navigators to be able to carry out mathematical computations. Iberian educators rose to the occasion, developing textbooks and curricula to transmit these abstract concepts. At the same time that they strove to present new mathematical techniques, these maritime authors also captured the tacit skills that had been practiced for centuries. Thus, even though few working sailors put pen to paper, it is possible to recover aspects of their epistemology from these texts. Because books traveled so easily across borders, these academic sources also had far-reaching effects, inspiring similar educational programs across maritime Europe. This article recommends adopting a comparative perspective, since much can be learned by tracing the evolution of these shared practices as they traveled from Spain and Portugal to the Netherlands, France, and England, and back again.

Keywords: Navigation; Maritime Education; Book History; Tacit Knowledge; Illustrations; Mathematics.

UNA TRADICIÓN COMPARTIDA: LA TRANSMISIÓN IMPRESA DEL SABER MARÍTIMO

RESUMEN: A medida que los europeos se aventuraron con mayor frecuencia en viajes transoceánicos en el siglo XVI, se hizo esencial que los navegantes fueran capaces de realizar cálculos matemáticos. Los educadores ibéricos estuvieron a la altura de las circunstancias y desarrollaron libros de texto y planes de estudio para transmitir estos conceptos abstractos. Al mismo tiempo que se esforzaban por presentar nuevas técnicas matemáticas, estos autores marítimos también recogían las habilidades tácitas que se habían practicado durante siglos. Así, aunque pocos marinos en activo pusieron la pluma sobre el papel, es posible recuperar aspectos de su epistemología a partir de estos textos. Como los libros viajaban tan fácilmente a través de las fronteras, estas fuentes académicas también tuvieron efectos de gran alcance, inspirando programas educativos similares en toda la Europa marítima. Este artículo recomienda adoptar una perspectiva comparativa, ya que se puede aprender mucho rastreando la evolución de estas prácticas compartidas a medida que viajaban de España y Portugal a los Países Bajos, Francia e Inglaterra, y viceversa.

Palabras clave: Navegación; Educación marítima; Historia del libro; Conocimiento tácito; Ilustraciones; Matemáticas.

" (…) este pequeno trabajo yo entendiere que os agrada dare presto a luz la Hydrografia universal", R. Zamorano, *Compendio del Arte de Navigar* (Sevilla, 1588, "Al Lector").

Two significant cultural changes occurred in parallel over the course of the sixteenth century: the quantity of printed materials exploded dramatically as the printing press facilitated textual reproduction, and during the same period Europeans sailed increasingly across the open ocean. Scholars have rarely discussed these two phenomena in tandem, as initially they seem unrelated. However, closer analysis reveals productive connections between the age of print and the age of sail. To Rodrigo Zamorano, a professor of navigation in Seville who published a nautical manual in 1588, it seemed entirely natural that a "little" book could summarize all that one needed to know about the "theory and practice" of "hydrographia" –in other words, the "art of navigation" (Zamorano, 1588, f. 1). In fact, by some criteria, books are superior to human instructors: filled with definitions, diagrams, and tables, they are repositories of expertise on a wide range of topics that could be brought along on voyages and consulted if the navigator ran into difficulty. Rather than needing to rely entirely on their memories, mariners could turn to printed atlases and volumes filled with dense tables of numbers. The only requirement to access these stores of wealth was literacy.

The wave of pioneering nautical manuals, written during the first century of European transoceanic navigation, was a response to new demands: the greater complexities of open-water, or "large," navigation, which required mathematical calculations and, at least sometimes, an understanding of a theoretical framework. These manuals clearly met a need; they became extremely popular, with at least six hundred unique titles, as well as many translations, published across Europe between 1500 and 1800 (Schotte, 2019, p. 10).[1] Printing allowed the technical and theoretical details about how to sail to be transmitted beyond the limits of the ships' decks, where sailors had previously learned the ropes from more senior mariners. Nautical manuals also had a significant effect on the development of maritime training. Because they address both technical and conceptual material, they can provide historians and other 21st-century readers with valuable insights into maritime practice and epistemology.

1 This brief article focuses on nautical manuals whose primary purpose is to explain the science of navigation, rather than texts such as rutters, which concentrate on sailing instructions and geographic information.

This article will explore three moments in the publishing history of nautical manuals, tracing the origins of the genre from 16th-century Iberia through its later iterations in northern Europe in the mid-17th century and onward. While recent studies (Leitão and Sánchez 2017, Leitão 2018, Leitão and Sánchez 2022) have drawn attention to the innovative first generation of Portuguese and Spanish nautical books, and the productive connections between educated authors and practitioners, this article seeks to probe what happened when those books were transmitted beyond Iberia. It also encourages maritime historians to look at physical aspects of printed materials –their format and illustrations, as well as details in the text– to gain insights about authorial intent and audience as well as sailors' experiential knowledge. At the same time, it calls for scholars of information and pedagogy to look beyond national borders to find evidence of shared practices; only by adopting a comparative perspective can we identify larger patterns that coexisted with local solutions.

The nautical book has typically been characterized as an elite, rarefied object. While early and important books dedicated to the art of navigation have been exhibited and described in bibliographies (Adams, 1995; Polak, 1976, 1983; Peters, 1989; Hoogendoorn, 2018), only a few scholars have analyzed the common features of the genre (Pérez-Mallaína Bueno, 1989; Vicente Maroto, 2002; Carriazo, 2003; Charon et al., 2005; Sánchez, 2021). Early modern sailors are often presumed to be uniformly coarse and illiterate. Martín Cortés, author of one of the most famous navigation books, did not believe sailors would be able to read his work: "siel dia de oy viera como pocos o ninguos de los pilotos saben apenas leer,/ y con dificultad quieren aprender y ser enseñados" (Cortés, 1551, f. iiiiv). This same bias led 20th-century maritime historians such as D. W. Waters to conclude that the torrent of books on maritime topics published during the 16th to 18th centuries could not have been intended for working mariners. Instead, these expensive, theoretical books were produced by and for scientifically minded, shore-bound gentlemen, and therefore would bear little connection to practice (Waters, 1958, pp. 497-499). And yet, by looking at a range of different texts, their physical format, contents, and intended audiences, we can see that from the earliest days of publication, nautical authors addressed audiences who were diverse in terms of income, education, and connection to the sea. Unexpectedly, these texts contain evidence about practices previously believed to be tacit, and equally surprisingly, they developed into essential tools that shaped both training and practice.

CROSSING OCEANS, EMBRACING TEXTS

As early modern European states realized how much wealth there was to be exploited on the other side of first the Atlantic and Indian Oceans, and then the Pacific, they quickly moved to expand their ocean-going fleets. In order to make these risky "blue water" or "large navigation" voyages safer and more lucrative, mariners and administrators rushed to develop new approaches to wayfinding for vessels sailing beyond sight of land. Previously, most voyages were "small navigation," where ships stayed close to the coasts; this allowed navigators to rely on coastal landmarks and bottom-sounding. Celestial bodies –the Sun, or the North Star– proved reliable open-water guides, but to deduce reasonably accurate measurements from their positions, mariners needed to be able to carry out a number of mathematical calculations.

Mastering the techniques of celestial navigation entailed a steep learning curve. Sailors needed to engage with a variety of new tools, including manipulating instruments, memorizing technical definitions about the structure and features of the heavens, learning how to add and multiply to adjust for particular days of the year, and reading numerical tables. The best navigators could manage all of the above –but many young and old mariners found the concepts and numbers challenging. It became clear that formal lessons were the most effective way to teach this demanding set of skills. Administrators at the Casa de la Contratación in Seville began hiring instructors; Amerigo Vespucci, the first such examiner, was named "Piloto Major" in 1508. In 1552, the Casa formalized this method of training, establishing a school headed by a chair of cosmography (Sandman, 1999; Garralón, 2008). The Portuguese developed similar institutions, with a chief cosmographer at the Armazéns da Guiné e Índia charged with teaching pilots, among other duties (Leitão and Sánchez, 2022, p. 297).

The teachers in Seville, who included Vespucci's successors Jerónimo de Chaves and Diego Ruiz as well as Zamorano, came primarily from an academic background (Sandman, 1999, pp. 104-105; Vicente Maroto, 2018). They were comfortable with the main components of higher education at the time: university lectures that drew from standard textbooks, and examinations to assess whether students understood the lectures (Schotte, 2024). Therefore, the professors brought these features –lectures, textbooks, exams– into classrooms filled with mariners who may not have been literate, paying little attention to whether these methods could effectively teach abstract concepts such as the structure of the heavens, or the steps of arithmetic.

At first, the *cosmógrafos* relied on one of the most popular university textbooks, the 13th-century "Sphere" of Sacrobosco, engagingly illustrated in the 16th century by Petrus Apianus.[2] Soon, however, the Casa's professors began writing their own manuals tailored to maritime men. In some ways, these new nautical works were a test to see how many readers would be interested in this complex subject matter. Given the broad emphasis on overseas expansion, there was no question about the topic's importance –but it was as yet unclear if an audience would pay for books about it. Therefore, authors included everything they thought might be useful for embarking on open-water voyages. They began with the sections from Sacrobosco's *De Sphaera*, which described cosmography, how the earth and heavens were arranged (Portuondo, 2009). The genre's hallmarks were definitions of the components of the universe, from the grandeur of the spheres to intervals of days and minutes. Along with that theoretical background, nautical authors printed astronomical tables –the "regiments" of the Sun and stars– that enabled mariners to determine latitude by measuring the altitude of those celestial bodies. To these, the *cosmógrafos* added a few decidedly practical details: take observations "precisely at noon," and rely on shadows like the ship's mast or "something else that [the observer] stands upright" (Medina, 1569, p. 96). Such details, mentioned but not elaborated upon, indicate the author's familiarity with the technicalities of daily navigational procedures and also hint at the balance of rigor and flexibility needed on board. The varied content and format of such volumes suggests that their authors were still unsure of their audience. Some material features of book production flowed from elite audiences down to less deep-pocketed readers who otherwise might not have afforded books with so many illustrations. Conversely, the attention to applied knowledge brought more practical topics into the book-lined rooms of government officials.

While the earliest printed manuals of nautical science were published in Portugal in the first decades of the 16th century (Sánchez, 2021), the first to enjoy a wide readership were Pedro de Medina's *Arte de*

2 Sacrobosco's *De Sphaera*, written in Paris in the early 13th century, was the most popular academic introduction to astronomy up to the 17th century. It saw ten translations into Spanish and Portuguese between 1510 and 1650, more than in the other European vernaculars combined. See Crowther *et al.* (2015).

Navegar (Valladolid, 1545) and Martín Cortés's *Breve compendio de la sphera y de la arte de navegar* (Seville, 1551). Cortés was a humanist with little navigational experience, while Medina served the crown as a consultant on maritime matters and taught at Cádiz from 1530. These two works were in a class of their own and certainly fit the characterization of luxury goods. Both were dedicated to royalty: Cortés's to Carlos I and Medina's to (then) Prince Felipe. Physically grander than subsequent books in the genre, Cortés's and Medina's volumes were both handsomely printed in quarto format with generous margins to provide room for annotations. Their title pages were augmented with red ink, a common embellishment in the early decades of printing.

At this stage in the history of scientific book production, experts had different notions of how to present technical information, particularly when it came to illustrations. In Medina's book, each of the eight chapters is set off by a full-page woodcut- to introduce readers to the topics: the sun, moon, tides and winds. Medina borrowed from the graphic program of Apianus's cosmographical work, enlarging the woodcuts. He also included several lengthy series of images: fourteen circles represent the vessel's sailing direction or rhumb lines (Medina, 1545, ff. xxxiiv-xxxiiiiv); another sixteen track the stars of the Little Dipper rotating around the Pole Star over the course of twenty-four hours (ff. lxxii-lxxiiiiv). In chapter four, thirteen circles indicate how to measure the sun's declination, depending on the observer's position relative to the Equator (ff. xxxix-xli). Nine larger woodcuts again demonstrate how to observe the sun, and here we see the navigator holding a small mariner's astrolabe in his outstretched arm (ff. xliiv-xlix).

For his part, Cortés chose to illustrate instruments. His detailed illustrations can be taken as a sign that navigational tools like the astrolabe and nocturnal were unfamiliar to most readers. At this date in the mid-16th century, even the nautical plane chart needed to be described and depicted on a full-page spread (Cortés, 1551, f. lxvii). Cortés augmented the woodcuts with spinning disks known as volvelles, to help his readers understand how the tools functioned. Cortés adapted volvelles from Apianus, and also added his own. He devised a volvelle to stand in for the "guard stars" at the front of the Little Dipper's bowl as they rotated around the Pole Star, effectively condensing Medina's sixteen images over five pages into a single, concise representation (f. lxxxiii). This paper disc was designed to help the reader visualize the rotating heavens, as well as to function as a working, if flimsy, scientific tool. By virtue of their motion and interactivity, volvelles can simplify complex relationships (Broecke, 2000, p. 140). The presence of this Little Dipper volvelle in Cortés's book suggests that readers needed a higher level of assistance to successfully comprehend this timekeeping method.

Images in these manuals helped theoreticians transmit unfamiliar concepts to readers, but that was not the only direction that information flowed. Within these texts, it is also possible to find evidence of how practitioners were already viewing the world. For instance, in discussing the Little Dipper in book five, Medina asked readers to look at the North Star and imagine a cross superimposed upon it. They should then label the part above the star, the head, the part below the feet, and each side an arm. They would then see the "guards" rotate around the circle. The stars spend three hours in each of the circle's eight sub-sections, taking six hours to move from head to the left arm, and so on (Medina, 1545, ff. lxxv*v,* lxxvii). In addition to carefully quantifying the motion of the heavens, Medina provided a three-dimensional frame of reference –but it is unlikely that he was the first to use this embodied framework. This type of mental clock keyed to body parts would have originated with European mariners seeking to orient themselves north. Where Medina chose to explain other concepts with extensive suites of woodcut circles, this section on cardinal direction is illustrated only by squares subdivided into quarters. (Fig. 1) These basic squares are ill-suited to depicting the constant motion of the heavens, so after four sequential squares, Medina added a circle to demonstrate how the cardinal directions, or the vertical plane, could also be linked to the stars rotating over 24 hours, through three dimensions. The very simplicity of these diagrams hints that readers likely already understood the point being described. Mariners would have readily been able to envision the stars spinning slowly overhead, a metaphor that long predated Medina's dials or even Sacrobosco's circles. The human body, after all, is a universal unit of measurement.

Instead of being deemed solely elite reading materials, these navigational books should be seen as trial balloons for what would become a robust, diverse market (Gulizia, 2016; Schotte, 2020). In the early decades of the 16th century, *catedráticos* were not yet assured of readership for these publications. After all, the men taking classes at the Casa were only beginning to realize the importance of being literate. Yet it soon became necessary for navigators to pass examinations and pro-

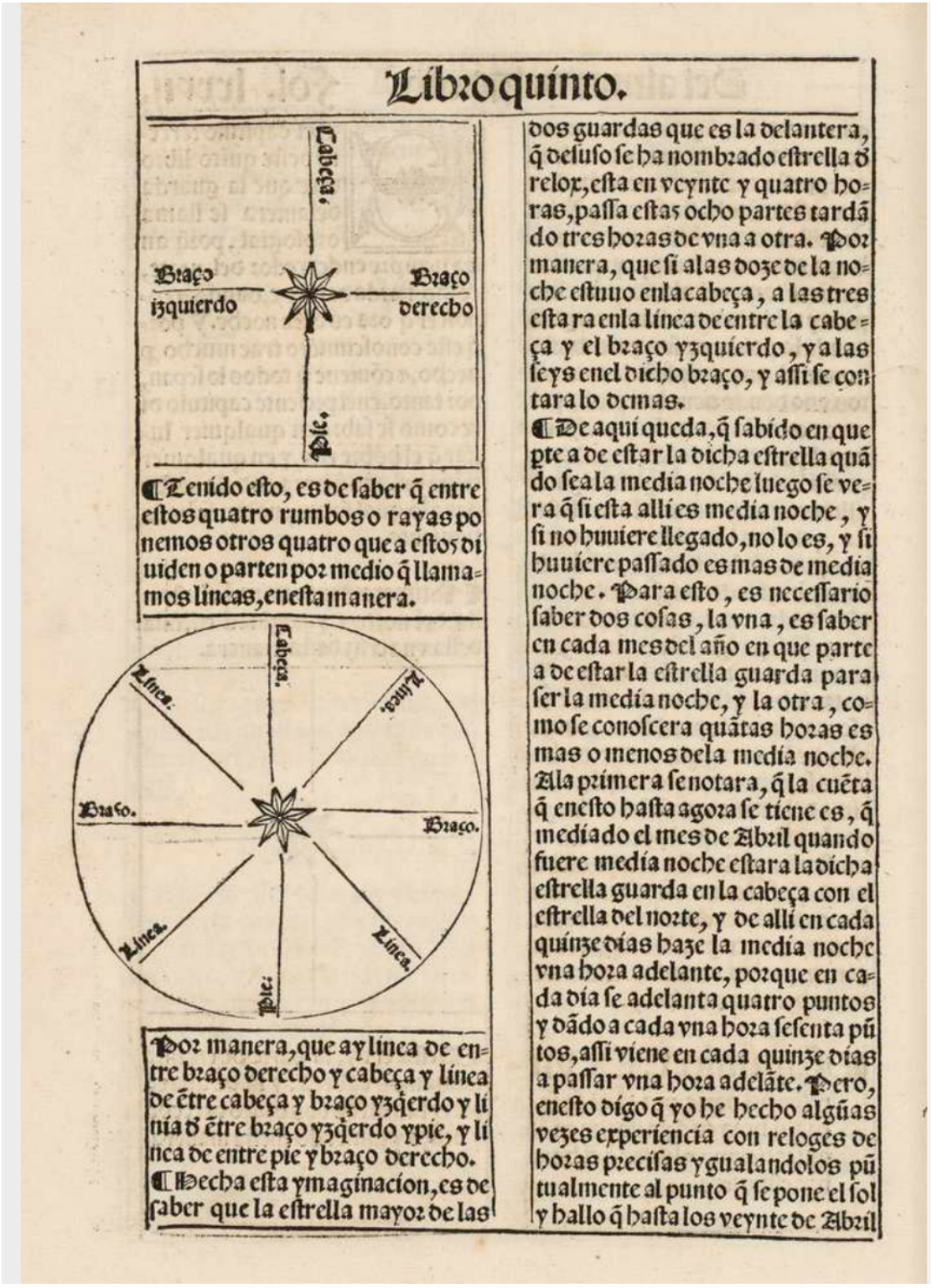

Figura 1. Diagramming how the human body can be used as a guide for both direction, with one's head to the north, and time, as the stars of the Little Dipper rotate overhead. P. de Medina, *Arte de Navegar* (Valladolid, 1545), f. lxxvii*v*. Imagen procedente de los fondos de la Biblioteca Nacional de España

duce textual records of overseas voyages, so within a few generations, literacy (and numeracy) rates among at least that group of mariners climbed dramatically.[3] As the number of literate sailors ballooned, so did the number of printed treatises on the "art of navigation." These followed the pattern established by Cortés and Medina. For instance, Zamorano's 1588 *Compendio* contained the same topics as Medina's *Arte* and featured the all-important astronomical tables –but in a smaller format, with just eight woodcuts. Like so many early modern authors, Zamorano recognized the importance of self-promotion, and included a comparison that aimed to elevate his book above others; the "Tabla del Autor mas precisa" would obviously replace the "Tabla antigua menos cierta" (Zamorano, 1588, f. 47). To reassure his readers that his less elaborate volume was still worth purchasing, Zamorano presented his work as cutting-edge, precise, and certain.

First-generation nautical manuals were clearly directed to a hybrid audience. Cosmographical knowledge could reassure decision makers before they committed to financing new voyages. At the same time, these splendid illustrated volumes codified the information connected to the "science" of navigation. As this material was streamlined, it resonated more easily with men who spent their lives at sea. The cosmographical chapters on the sun, stars, and the motion of the water –initially intended to explain the structure of the Earth and the heavens to university students– now informed mariners who used those natural bodies as signposts. And even alongside the theoretical discussions of poles and zeniths, we find relatable references to the humble human figure.

Manuals had limitations, of course. Navigation lessons at the Casa were not focused entirely on theory. After somewhere from two to twelve months of classes, students were required to pass examinations with a hands-on component. They needed to demonstrate how to use instruments and mark a course on a chart –even though these topics did not appear in any published textbook. Evidently, there were still aspects of navigational training that took place person-to-person (Schotte, 2024, p. 60).

Still, nautical textbooks had another key advantage: they proved to be very effective at transmitting the techniques first articulated by Iberian professors to maritime communities further afield. Volumes dropped in price, reaching an increasingly large audience of working mariners as well as enthusiasts. As these texts were translated and sold in foreign port communities, they offered models to other authors, not just educators but also entrepreneurs who began to pen local adaptations.

TRANSFERS & TRANSLATIONS

As vessels or vectors for transmitting knowledge, books were ideal. Throughout the 16th century, maritime authorities and teachers generally regarded Iberia as the center of expertise. Other states established training programs that shared many features of the school at the Casa de la Contratación, with lectures, textbooks, and examinations. When new generations of authors sought to demonstrate their credentials, they invoked Portuguese and Spanish authorities. The names Cortés, Medina, and Pedro Nuñes (famous for describing loxodromes) appeared as touchstones in many prefaces, as Dutch, French, and English authors sought to link their newer works to established experts.

Cortés and Medina had counterparts in 16th-century France, maritime experts with links to the ruling class, like Pierre Desceliers, Jacques Devaulx and Guillaume Le Vasseur de Beauplan, who prepared nautical guides and maps for elite readers.[4] In the French case, however, instead of printing those texts, the authors prepared hand-drawn, gilt manuscripts on vellum. The content was very similar, with familiar cosmographical chapters and diagrams. Yet due to their format and considerable cost, these texts did not circulate beyond a small elite audience.

In England and the Netherlands, by contrast, maritime communities chose a less expensive means to stay abreast of state-of-the-art navigational knowledge: they published translations of Iberian texts. Although it can be difficult to track the precise moments when bookish knowledge crossed borders, we do know of a few such transfers. An English sea captain, Stephen Borough, visited the Casa de la Contratación in 1558.

3 While the majority of common seamen remained illiterate, Pérez-Mallaína Bueno (1998) estimated that nearly ¾ of Spanish pilots were literate by the late 16th century (pp. 87, 231). On Iberian numeracy, and the connection between navigation and commercial arithmetic, see Vilches (2019), p. 37.

4 See, e.g., Jacques Devaulx (1583, 1584), "Les premieres Œuvres de Jacques Devaulx." BNF-Richelieu Mss. Français 150 and 9175. https://gallica.bnf.fr/ark:/12148/btv1b550024840 and http://gallica.bnf.fr/ark:/12148/btv1b55002476g; Guillaume Le Vasseur de Beauplan (1608), "Traicté de la Géodrographie, ou Art de naviguer." BNF-Richelieu Mss. Français 19112. http://gallica.bnf.fr/ark:/12148/btv1b52506053t; see also Van Duzer (2015).

He returned to London with plans to establish a similar school –and a copy of Martín Cortés's *Breve Compendio de la Sphera y de la Arte de Navegar*. While Queen Elizabeth never agreed to Borough's proposal to become the English equivalent of the *piloto mayor*, her compatriots quickly arranged for Richard Eden to translate Cortés's volume into English as *Arte of Navigation* (London, 1561).

Medina's *Arte de Navegar*, for its part, made its way north to the Spanish Netherlands. French and Dutch translations were made in Antwerp in 1581. This version, with an appendix by instrument-maker Michiel Coignet, saw three subsequent Dutch editions. The important maritime publisher, Claes Claesz. of Amsterdam, seized an opportunity, selling not only the Medina/Coignet work but numerous related manuals. In addition to producing a less expensive edition of Lucas Waghenaer's nautical atlas, Claesz. sold translations of Rodrigo Zamorano's and William Bourne's popular works (Selm, 1987, pp. 176-79).

Compared to Medina's original tall quarto, these Dutch imprints were decidedly more modest. They were printed without large margins, colour, or full-page illustrations for each chapter. As a publisher, Claesz. was more interested in quantity of sales than quality of production. He clearly welcomed a range of customers, from deep-pocketed merchants to working sailors.[5]

At the close of the 16th century, Amsterdam was the "bookshop of the world" (Pettegree and der Weduwen, 2019). Here we can see the beginnings of a substantive market for nautical books. Claesz and other nautical booksellers sold all of the paper paraphernalia that a mariner might need –textbooks, charts, logbooks– and the merchant companies began to outfit each vessel with copies of popular manuals. The nautical book market then took off in other urban centres and smaller port towns. In addition to London and, somewhat later, Paris, there were successful maritime publishers in ports such as Hoorn, Le Havre, and Dieppe, the latter of which saw a number of titles translated from English and Portuguese into French in the 1630s and 1640s (Schotte, 2019, p. 69).

Entrepreneurial authors were quick to step in. For instance, at the turn of the 17th century, Willem Jansz. Blaeu published an influential Dutch nautical manual as an appendix to his new nautical atlas, *Licht der Zeevaert* (1608). Blaeu, who established his family's influential cartographic publishing house and served as an examiner for the Dutch East India Company (Netten, 2014), was interested in astronomy as well as cartography. His 51-page introduction to the art of navigation hewed remarkably close to the Iberian cosmographical works: it was one of only a few Dutch-language texts that began with cosmographical definitions. Like Cortés, Blaeu also included several volvelles. Aware of the visual potential of maps, Blaeu crafted sophisticated illustrations. In the section on the Sun's declination, he provided useful updates to the circles representing the observer's position relative to the Equator. Where the navigators in Medina's *Arte* simply held their astrolabes in front of them, Blaeu depicted an elegant man in a ruff and hose kneeling on the horizon, in the act of using an oversized mariner's astrolabe. Aware that the cross-staff was the mariners' preferred instrument, Blaeu depicted it in a second circle. (Fig. 2) There he did away with the observer's body, leaving just a head and a cross-staff positioned at eye level. For readers just learning the techniques of observation, these images gave far clearer instructions.

Readers eagerly sought out publications like Blaeu's and Coignet's. By the final decades of the 17th century, many maritime administrators in northwestern Europe viewed textbook authorship as a nearly mandatory marker of expertise. It became increasingly expected to produce such a work prior to taking up a post as an instructor or examiner. As a result, 17th-century nautical authors were more diverse than those in the early days of the genre, and their numbers surged. They were less likely than the catedráticos to be university educated, but first-hand sailing experience was still not a criterion. A few men found second careers in the classroom after sustaining injuries at sea, but more were land-based entrepreneurs. No matter the teachers' background, they filled their books with marketing promises. One confident instructor claimed his book could "teach Navigators what serves for Navigation around the whole World, which can be learned (with God's help) in one month or less" (Broucke, 1609, f. 62*v*).

Authors and publishers debated whether textbooks should be comprehensive or offer a more curated selection of topics that would be easier to master in a short period. Could mariners handle challenging math and dense theory, or did they need everything to be simplified? The pendulum swung back and forth

5 For instance, Claesz. promised to pay mariners who offered corrections to the charts in his atlases. He sold Waghenaer's atlas as a set or as individual volumes for customers with different budgets. Schilder and Egmond (2007, p. 1395).

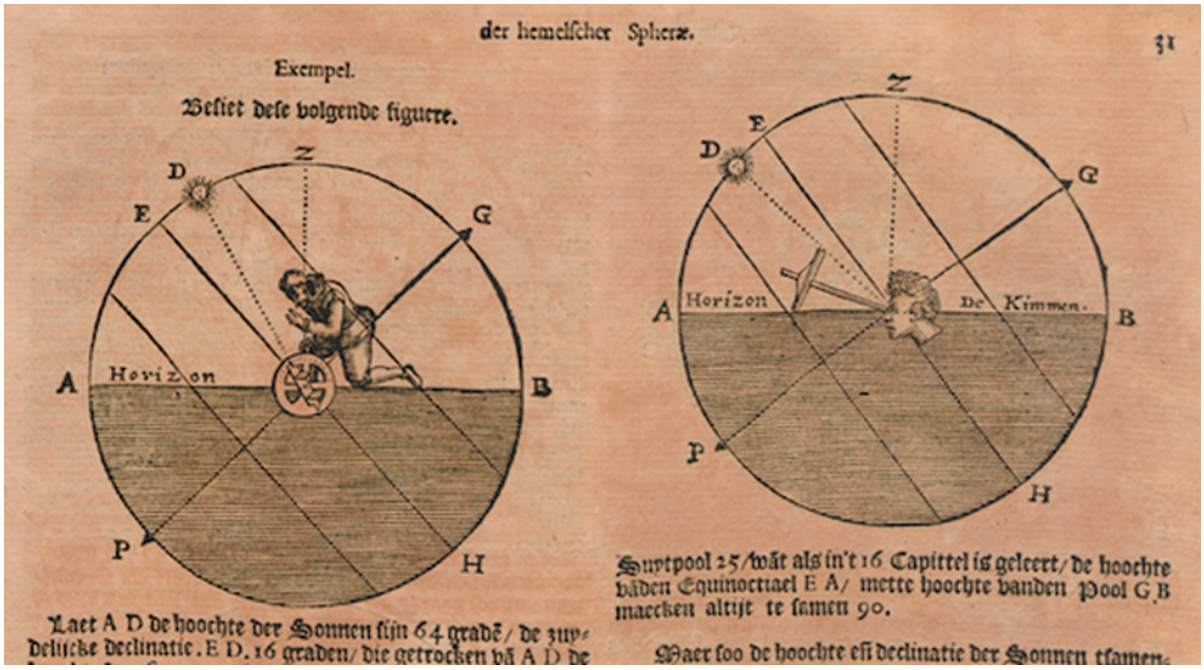

Figura 2. The observer, with the mariner's astrolabe (left) and cross-staff (right), carefully positioned on the horizon. W. Blaeu, *Licht der Zee-vaert* (Amsterdam, 1608), p. 31. Imagen: Universitätsbibliothek Marburg

between theoretical and practical books (Albuquerque, 1986, p. 275). Just as at the Casa school, instructors expected their students to follow along with the lectures and classroom texts, but outside of Iberia they were increasingly likely to have their students review mathematical problems rather than cosmographical definitions.[6] In English manuals, authors introduced students to mathematical rudiments in the first chapters: addition, subtraction, and multiplication seemed more crucial to celestial navigation than the definition of the azimuth or zenith angle. By contrast, in the Netherlands, where youths had in many cases already learned the basics of arithmetic in primary school, nautical manuals jumped right to trigonometry and logarithms.

By the late 17th century, navigation textbooks were diverse in content and approach. The opening chapters can offer insights about what the authors viewed as foundational. For instance, since the Dutch expected their audience to already know multiplication and were unconcerned with cosmographical definitions, their first chapters focused on a different primary concern: computing the time of high tide. To do this, mariners needed to know the date as well as whether the current year was a leap year. After that, they used their fingers and thumbs to quickly calculate where in the lunar cycle they were, which would allow them to determine high and low tide. To keep track of the many steps of this process, mariners once again relied on their bodies. For this reason, Dutch textbooks included woodcuts of hands and disembodied digits, a visual means of teaching the "rule of thumb."

Dutch mariners had a compelling reason for disregarding the cosmographical definitions that typified the first generation of manuals. Given the North Sea's shallow coast and strong tides, tracking the daily tide cycles was crucial for ships leaving from Dutch ports. Miscalculating by an hour could mean that a fleet would be trapped in port or, worse, stranded on a sandbar. By contrast, the Iberians dealt with relatively trivial tides, especially in the predictable Mediterranean. Thus, their nautical experts were less concerned with the calendar; no thumbs appeared in Spanish manuals. (Medina did include a theoretical chapter on "pull of the moon," but not until Book Seven of the *Arte de Navegar*.)

6 On the substantial material record of late-17th- and 18th-century classroom practices (from English and French curricula and especially Dutch student workbooks), as well as evidence of working mariners taking manuals to sea, see Schotte, 2019, ch. 2, 3, 4.

A nautical manual's place of publication led to other differences. Instrument recommendations almost always had a patriotic angle. The English were partial to the backstaff, which they called the Davis quadrant after its English inventor; French writers labeled it the "quartier Anglois." Certain tools and books also became popular because the large companies provided them for free to their navigators. Mariners might learn about foreign instruments from other sailors in multinational crews, but printed books helped disseminate technical details of these innovations.

Instrument use also varied with time and place. French mariners preferred to plot their courses on graphical instruments such as universal quadrants, while Dutch mariners turned to books of tables to compute routes using trigonometry. When it came to the challenging task of estimating a vessel's speed, highly skilled Dutch navigators could tell how fast a vessel was sailing from a passing fleck of sea foam. However, developing the ability to read this foamy "Dutchman's log" took many years. Sailors with less ocean-going experience, unable to conjure up an "average day's sail" from memory, opted instead to throw a log-and-line off the stern to get a reasonable estimate of their speed (Waters, 1958, pp. 427-29).

Even within the Dutch corpus, we note changes over the decades. Early 17th-century texts only briefly mentioned the technique of estimating speed simply by observing the surface of the water. C. J. Lastman was concise: "Thus someone that sees daily how far the ship travels through the water and makes himself an image of that, and remembers that when a ship makes similar progress it will sail so many miles in a day... so can he, with time, come to good estimates" (Lastman, 1629, p. 54). Later in the century, Dutch authors went into far greater detail about how to assess the rate of the passing foam. In 1662, Joost van Breen described how a sailor should calibrate his internal metronome using a sandglass, gave tips for retraining if his counting inadvertently sped up, and advised on the best position to stand on deck (Breen, 1662, pp. 113-14).

Van Breen's thick description signals that his readers were unaware of these technical details. Where Lastman's audience had likely already spent years at sea and were turning to his book for spherical trigonometry lessons, forty years later van Breen's readers needed basic pointers on where to position themselves and how to count. As the pool of sailors expanded to keep up with the thousands of long-distance commercial voyages, Dutch authors could no longer assume that their readership possessed an elevated degree of experience. For people ignorant of the skills their fathers had used daily, teachers needed to be more explicit. Meanwhile, authors outside the Netherlands did not even attempt to teach these complex tacit skills. By the 18th century, few if any European mariners knew how to calculate speed with the "Dutchman's log," and all relied instead on the log and line. Although it might seem tempting to read this shift as part of an exorable trend towards instrumentalized modernity, these texts in fact demonstrate the value of resisting that teleological narrative. "Traditional" methods were often more accurate than later instrumental solutions. However, as transoceanic commerce increased, older, nuanced methods fell out of favor because they took considerable time to master.

SHIFTING AUTHORITY, SHIFTING PRACTICE

Throughout the 16th century and into the 17th, Iberia was regarded as the font of European navigational knowledge. A deep respect for Spanish authors permeated educational texts and institutions as early Dutch and English authorities looked southward for best practices. Samuel Pepys, Secretary to the Admiralty in the 1670s, actively sought out reference works about the Casa de la Contratación and kept a wishlist of Spanish books pertaining to the "Discipline of their Navy or Fleets; Books of voyages; [and the] Art of Navigac[i] on."[7] However, even in Pepys's day, authors outside of Iberia began to regard themselves as equal authorities. For instance, the anonymous English author of the *Accomplish'd Sea-man* (1686) admitted that Spanish authors like Medina had, "by God's Providence," written impressive works on navigation –but, he continued, "the Art it self hath been happily practised by the Portugals, the Spaniards, the Hollanders, and our own Nation" (*The Accomplish'd Sea-Mans Delight*, 1686, p. 43). His "Country-men" were at least as capable as their rivals.

By the final years of the 17th century, navigation students and other interested readers were looking less frequently to Spain. With the explosion of printed nautical works elsewhere, especially England and the Netherlands, Spanish experts themselves felt the need to consult texts written in other languages. In his *Theatro Naval Hydrographico* (1688), Spanish navy officer and privateer Francisco Seixas (Seyxas) y Lovera rec-

7 Oxford, Bodleian Library, Rawlinson MS. C 859. "List of Spanish books desired by Pepys for himself (chiefly in navigation)", (1683), ff. 155-7, 165-8.

ognised that the centre of expertise had shifted north. He noted that "que por no entender varias lenguas estrañas los Pilotos, y Navegantes Españoles, carecen de las noticias que mas han menester, para destinguir lo bueno de lo malo, y escoger lo mejor, que anda escrito en diversas lenguas, sobre las navegaciones de los Mares" (Seixas y Lovera, 1688, Prologo al Lector). Seixas y Lovera presented himself as a practitioner with abilities in multiple languages, able to present the latest advances in the field to an avid, but monoglot, audience. His bid for patronage worked, and the Marquis of Los Vélez, the president of the Council of the Indies, granted Seixas y Lovera a position in New Spain (Supiot, 2022).

Seixas y Lovera continued to regard print as an avenue to career advancement, with mixed success. While in Mexico his second publication failed to charm a prickly official, and he was forced to return to Spain. At that point Seixas y Lovera produced a French translation of his previous book, the *Theatre Naval Hydrographique*, and dedicated it to Louis XIV's illegitimate son, the Comte de Toulouse, Grand Admiral de France (Seixas y Lovera, 1704). At a moment when France was in an ascendant position during the War of Spanish Succession, the captain hoped to use his language skills and nautical knowledge to secure a new patron. However, he died the following year, and there is no evidence that his book earned him favour from the Comte.

The efforts that Seixas y Lovera put into his literary career are illuminating. In the late 17th century, nautical books were a viable means to obtain patronage. At the same time, the Spaniard's claim in 1704 to have digested 200 foreign-language texts for his compatriots indicates that the centre of maritime print had definitively moved away from Iberia (Seixas y Lovera, 1704, p. 4). Rather than continuing to set the standard for other nations, maritime Iberians recognised that others were making progress elsewhere, pushing ahead with new instruments, institutions, and manuals.

Within the nautical titles that made up this tidal wave of print, we find evidence not only of the differing technical concerns in various regions but also divergent notions of what sailors were capable of and required to do. Dutch books were shaped by shallow coastal waters but also reflected an expectation that sailors could handle mathematics at an advanced level. For instance, later editions of Claas Gietermaker's influential manual, *'t Vergulde Licht der Zeevaert* (1710), included sophisticated practice problems involving cube roots; while these would have had limited application at sea, they indicate a diverse, educated readership. In France, by contrast, not all navigation students were literate or numerate, and first needed to be taught the basics of arithmetic. Therefore, instructors offered instrumental workarounds rather than expecting common mariners to do lengthy calculations. In England, the expectations were somewhere in the middle: youth at the Royal Mathematical School had studied arithmetic and Latin before beginning navigation lessons, but other maritime men needed to be introduced to mathematical fundamentals.

A small number of nautical authors incorporated cutting-edge scientific theories into their manuals, with varying degrees of credibility. Robert Heath, a British mathematician and author of almanacs for "gentlemen and ladies" as well as "seamen," wrote dismissively of recent fringe astronomical theories in his *Astronomia Accurata* (1760), but in the same volume introduced his readers to valuable astronomical data produced by the French Académie des Sciences. Soon after, in the *Palladium-Supplement* (1764), Heath mocked John Harrison's ultimately revolutionary longitude timekeeper. Then, as now, it could be difficult to discern which authors were true experts in their fields, but emphasising innovation remained a key to selling books.

As authorities grew more demanding about tracking a ship's geographic position, we do find more mathematics in nautical textbooks. Dutch volumes almost always contained logarithmic and trigonometric tables in their latter pages. Well into the 18th century, Dutch manuals followed the model set by Abraham de Graaf, who published his nautical manual bound with Adrian Vlacq's comprehensive tables in 1658.[8] In England, sailors could find tables issued as part of their nautical manuals or buy separately published trigonometric tables.[9] Spanish manuals, by contrast, did not begin to regularly incorporate trigonometry or logarithms until several decades into the 1700s (Navarro-Loidi and Llombart, 2008, p. 90). However, as we see in texts like the *Trigonometria* (1718) of Pedro Manuel Cedillo and the *Tratado de trigonometria* (1739) of Juan Sánchez Reciente, author-educators began to expect their students to be familiar with arithmetic, pushing them

8 See Peters (1989), pp. 615, 642, for a list of Dutch, English, and Latin-language nautical works that include Henry Briggs's and Vlacq's logarithmic tables. Gietermaker's preeminent manual, *'t Vergulde Licht der Zee-vaert* (1660), also included complete tables.

9 e.g. Norwood (1631), Gellibrand (1635). For tables, see Gunter (1620) and Oughtred (1657).

quickly to trigonometry. Nearly two centuries after Cortés and Medina published their works, cosmographical definitions dropped out of the first chapter of Spanish textbooks.[10]

CONCLUSIONS

The 18th century progressed with its share of military conflicts, mercantilism, and other factors, and authors of nautical textbooks in northwestern Europe began to critique the Spaniard maritime experts who had inspired them. The third edition of John Robertson's *Elements of Navigation* (1796) contains pointed comments about Spanish authors, especially Medina. James Wilson, who contributed the volume's lengthy bibliographic preface, acknowledged the pioneering roles of Medina and Cortés. However, he then asserted that "idle speculations (…) abound in Medina and Cortes" and that "Medina gave ridiculous directions" (Robertson *et al.*, 1796, pp. iv-v). In his opinion, "[t]hough the Spaniards were the earliest writers on navigation, yet they were very backward to adopt its improvements" (p. xxvii). Of course, due to the competitive rhetorical style of the period, the French come off nearly as inadequately, and the Dutch only slightly better: he deemed them "very skilled mariners," but "negligent when it came to observations and record keeping" (p. xxviii). Wilson was committed to burnishing the reputation of English authors. It was not Medina or Cortés but "Wright, Norwood, and Bond" who "settled (…) the true principles of navigation" (p. xxiii).

Other authors echo this same patriotic argument. French and Dutch writers also claimed that their compatriots received the kernel of navigational wisdom from the Spanish and then single-handedly brought it to its current acme. Such teleological claims obscure two underrecognized facts: first, the development of the science of navigation was a shared enterprise. Inventors, authors, and practitioners passed information across national, linguistic, and class barriers, ultimately inventing new techniques while simultaneously preserving older ones. This leads to the second underappreciated fact: printed books play an invaluable role in capturing, codifying, and fostering the transmission of tacit knowledge (Schotte, 2019; Leitão and Sánchez 2022; Smith, 2022).

By the 18th century, the nautical book market was firmly established. Mariners and merchants knew where to go to purchase their paper tools, and myriad volumes were produced to meet the demand. While the maritime publishing centre may have moved north out of Spain by the close of the 17th century, much of the framework established in the early 1500s was still visible in the nautical publications devoted to training sailors. European maritime communities continued to emulate the Iberian system –where a *piloto mayor* or similar examiner oversaw lessons and examinations, and the manuals published as teaching tools also informed a broader public. Questions that examiners considered vital featured prominently in the textbooks they authored, and as a result, even students who never presented themselves for an exam would have learnt those key concepts in the classroom (Schotte, 2024, pp. 71-73). But change was coming to this stable pedagogical environment; after more than a century of stasis, the content of nautical manuals had evolved from their very uniform beginnings.

Significantly, late-18th century nautical manuals no longer held the same cachet that they had in the century following the opulent beginnings of Cortés and Medina. In the Netherlands, wealthy merchants continued to read nautical texts, intrigued by mathematical problems therein. Elsewhere, however, the readership was no longer diverse. Maritime communities and educational models had shifted, leaving students as the primary audience for nautical manuals. As the standards for daily record keeping and mathematical precision rose, elegant title pages and generous margins disappeared, replaced by countless practice questions on flimsy paper.

Many of these modest books survive and now serve as rich sources for modern scholars. They offer windows into the worldview of working mariners who studied them, annotated the margins, and took them on voyages. Alongside the more theoretical aspects of open-water sailing, authors have left us clues about how mariners used their bodies as guides to geographic positioning and time-telling and how they trained themselves as metronomes for estimating speed. In addition to wooden and brass instruments, they relied on their hands, their bodies, and their imagination. Authors described new inventions that they planned to market to readers, but in the process of itemising innovative techniques, we find that they also captured evidence of elusive older practices.

In 1588, Rodrigo Zamorano reassured his readers that his "pequeno trabajo yo entendiere que os agrada

10 Naiera (1628) is an early example of a Portuguese nautical manual that incorporated trigonometry, cited by Albuquerque (1986, p. 274). Most 17th-century Spanish manuals avoided it.

dare presto a luz la Hydrografia." However, by the close of the 18th century, the science of navigation had diversified so much that no single "little work" could illuminate the entire field. Instead, numerous "little works" were carried to sea by men who were able to read definitions, interpret images, decipher columns of numbers, and blend the wisdom contained in the pages with their own lived experience.

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The author of this article declares that she has no financial, professional or personal conflicts of interest that could have inappropriately influenced this work.

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Margaret Schotte: Conceptualization, Formal analysis, Funding acquisition, Writing – original draft, Writing – review & editing.

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