7. Precious Art or Tried and Tested Science: Early Modern Indian Ocean Navigation in Context

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Abstract: Classical nautical Arabic literature, particularly the works of Aḥmad ibn Mājid and Sulaymān al-Mahrī from the late fifteenth and early sixteenth centuries, serves as a crucial example of early modern technical literature. This *Fachliteratur* was taught discreetly to select initiates. Their writings encompass various terms related to their subject, such as *ʿilm* (knowledge), *tajribah* (experimentation), and *ikhtirāʿ* (invention), which highlight the practical and theoretical aspects of astronavigation. I compare these terms with contemporary early modern European sources, where discussions around *scientia*, *experientia*, and *ars* contributed to the evolution of modern science. This comparative analysis of non-European texts broadens the discourse, enriching it and challenging the Eurocentric perspective on the origins of modern scientific thought.

Keywords: scientific revolution, arabic nautical corpus, history of ideas, craft transmission, cosmology, Indian Ocean.

Introduction

This chapter has to do, fundamentally, with an age-old question of classical philosophical pedigree: the relation between practical and theoretical knowledge. This means it has to do with epistemology, including the classification of knowledge. But I shall treat my subject through topical examples from the history of early modern science, to enrich

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the fundamental discussion from a very specific and tangential field of action. I could say with the same justification that this chapter is about early modern Arabic navigation and about the definition and role of theoretical and practical knowledge in it. The following pages, then, have to do with particular instances of Indian Ocean navigation practices in the sixteenth century. They will be prefaced and concluded with some notes on the fundamental issues mentioned above, which will run through the chapter *sotto voce* as I present my nautical evidence. Additionally, by comparing this with contemporaneous early modern developments in Europe and by highlighting certain commonalities, I suggest ways in which the narratives of the early modern origins of Western science may be further nuanced, allowing for the sophistication of practices like those of the Indian Ocean navigators.

It can be safely said that our age-old question, the theory–practice question, goes back *substantially* to what is portrayed in Plato's *Timaeus* as the indetermination of the demiurge. This divine creative intelligence, who is a mathematician and an architect and who fashions and "implements" the universe, straddling metaphysical principles and physical determinations, gave rise to echoes and elaborations, both in the Platonic and Aristotelian traditions, which would inform and determine countless discussions throughout the Middle Ages.[1] For as long as epistemology was considered in its essential relations to metaphysics, theology, or mythology, depending on the more or less symbolic languages of different cultures, our question had a universal import. It is sufficient to think of the Hindu figure of Vishvakarman, Builder of the Universe, with the associated Vedic exegesis on caste activities and the status of art,[2] or the biblical figures of Bezalel and Solomon, masters of the *logos*, of the crafts and architecture.[3] As a universal and timeless question, then, it is best and most appropriately studied within historiographical frameworks which respect the variety and depth of pre-modern cosmologies; or we could also say, which take into account the relevant cultural contexts. To do justice to basic questions

1 In-depth discussion, historical and bibliographic references are given in Luc Brisson, *Le même et l'autre dans la structure ontologique du Timée de Platon: un commentaire systématique du Timée de Platon*, 3rd ed., International Plato Studies 2 (Sankt Augustin: Academia Verlag, 1998), 27–106, 538.

2 See Stella Kramrisch, "Traditions of the Indian Craftsman," *The Journal of American Folklore* 71, no. 281 (September 1958): 224–225.

3 For these two characters in their relations to cosmogony and cosmology, see Juan Acevedo, *Alphanumeric Cosmology from Greek into Arabic* (Tübingen: Mohr Siebeck, 2020), 105–106, 166–167, https://doi.org/10.1628/978–3-16–159246–1.

in the history of science, it might be ventured, the same kind of shift is needed as that advocated by Aby Warburg and his associates in the field of the history of art: "to see the image as being indissolubly bound up with culture as a whole."[4] We could put it even more succinctly and say that the history of science is called by its own subjects of study to be a history of ideas and a "science of culture," *Begriffsgeschichte* and *Kulturwissenschaft*, to use the established German terms. In particular, the semantic traps of our narrowed-down contemporary words "art" and "science"[5] are to be avoided.

Fortunately, this is the kind of scholarship that has been coming from many directions over the last decades, addressing and redressing previous perspectives, arguing cogently for an understanding of "science" that can do justice to the historical realities of earlier times and other cultures, an "enriched perspective" "reinventing the discipline,"[6] exploring the "situatedness of science."[7]

This chapter aims to offer a contribution in this direction, not only by reaching geographically into Indian Ocean sources written in Arabic, but also by drawing awareness to the religious, or more properly cosmological, aspect which often needs to be fully accounted for in the historiography of science. This latter concern does not derive from any programmatic interest, but is rather borne out again and again by the sources, and is thus a *sine qua non* for a proper understanding of premodern "science." My Arabic sources, in particular, exhibit the cosmological awareness which is common to scientific works produced within the Abrahamic worldview. Let us now turn to them.

4 Michael Diers, Thomas Girst, and Dorothea von Moltke, "Warburg and the Warburgian Tradition of Cultural History," *New German Critique* 65 (1995): 69, https://doi.org/10.2307/488533.

5 Traps masterfully analyzed and illustrated in Anna Wierzbicka, "Defining 'the Humanities'," *Culture & Psychology* 17, no. 1 (March 2011): 40–44, https://doi.org/10.1177/1354067X10388841, and Anna Wierzbicka, *Experience, Evidence, and Sense: The Hidden Cultural Legacy of English* (Oxford: Oxford University Press, 2010) especially 6–34 on empiricism and experience. See also, more recently, Philipp Roelli, *Latin as the Language of Science and Learning* (Berlin: De Gruyter, 2021), 23–26, https://doi.org/10.1515/9783110745832.

6 See in general, Katharine Park and Lorraine Daston, eds., *The Cambridge History of Science*, 1st ed. (Cambridge: Cambridge University Press, 2006), https://doi.org/10.1017/CHOL9780521572446. See also Arun Bala et al., eds., *The Bright Dark Ages: Comparative and Connective Perspectives* (Leiden: Brill, 2016), https://brill.com/view/title/24942.

7 Hugh Richard Slotten, "Introduction," in *The Cambridge History of Science*, Vol. 8: *Modern Science in National, Transnational, and Global Context*, ed. Hugh Richard Slotten, Ronald L. Numbers, and David N. Livingstone, 1st ed. (Cambridge: Cambridge University Press, 2020), 1, https://doi.org/10.1017/9781139044301.002.

7.1. The Corpus and the Pilots

The received extant corpus of Arabic nautical literature—stretching into the nineteenth century, when a new generation of texts begins to appear—consists of the works of Aḥmad ibn Mājid and of Sulaymān al-Mahrī, who hail from the southern Arabian Peninsula and flourished in the late fifteenth and early sixteenth centuries respectively. This corpus, preserved in manuscripts in libraries around the world, and amounting roughly to more than a thousand pages of modern printed editions,[8] has an unparalleled historical importance for both intrinsic and extrinsic reasons. It is of intrinsic value because it contains a wealth of extremely varied historical, literary, scientific, and technical information. It is extrinsically important, first, because it was produced around the time of the first arrivals of the Portuguese expeditionary forces, which would come to alter dramatically the dynamics of the region; and second, because it greatly influenced later nautical works, notably in Turkish[9] and some Indian languages,[10] some later Arabic works, and most likely European languages benefitting from local knowledge.[11]

Most of the works by Ibn Mājid (ca. 1420–end of fifteenth century) are technical instructional poems, with the outstanding exception of his *Fawā'id fī uṣūl 'ilm al-baḥr wa-al-qawā'id* (hereafter *Fawā'id*; "Commentaries on the Principles and Foundations of Maritime Science"), a long, encyclopedic, at times highly specialized and at times disarmingly varied work composed in his old age. The *Fawā'id* is the only complete work of this corpus to have been made widely available in translation in a Western language, through Gerald Tibbetts's 1981 publication.[12] In Ibn Mājid's own view, though, it is the (*Al-*

8 Critical editions of most works were produced by Ibrahim Khoury in Damascus in the early 1970s, as part of a four-volume series, Al-ʿUlūm al-baḥrīya ʿinda al-ʿarab [Maritime Sciences among the Arabs]. These have been supplemented more recently with publications by Ḥasan Ṣāliḥ Shihāb. For comprehensive details, including manuscript sources, see Juan Acevedo, Inês Bénard, and Juliane Müller, *Indian Ocean Arab Navigation Studies Towards a Global Perspective: Annotated Bibliography and Research Roadmap, v. 5.1*, vol. 2, RUTTER Technical Notes (Lisbon: ERC RUTTER Project, 2023).

9 Namely the 1554 *El-Muḥīṭ fi İlm el-eflak ve'l-ebhur* ("Book of the Ocean on the Science of the Spheres and the Seas") of Sidi Ali Reis (Çelebī); for details see the above-cited Technical Note by Acevedo and Bénard.

10 Cf. in Malayalam, Lotika Varadarajan, *The Rahmani of M. P. Kunhikunhi Malmi of Karavatti: A Sailing Manual of Lakshadweep* (New Delhi: Manohar, 2004).

11 See chapter 8 of this volume, where Inês Bénard discusses the relation with Portuguese nautical sources in particular.

12 G. R. Tibbetts, *Arab Navigation in the Indian Ocean before the Coming of the Portuguese* (London: Royal Asiatic Society of Great Britain and Ireland, 1981; Routledge, 2004), enriched with

Ḥāwiyat al-ikhtiṣār fī uṣūl ʿilm al-biḥār (hereafter *Ḥāwiyah*; "Comprehensive Summary on the Principles of the Knowledge of the Seas") which counted as his most important didactic poem.[13]

Sulaymān al-Mahrī (ca. 1480–1550) is a more restrained and strictly technical author, treating topics which mostly overlap with and develop those of Ibn Mājid. His most important work is *Al-ʿUmdah al-mahrīyah fī ḍabṭ al-ʿulūm al-baḥrīyah* (hereafter *ʿUmdah*; "The Reliable Mahrī Treatise on the Exactitude of Maritime Sciences"). Interestingly, al-Mahrī exhibits an astronomical bent which is absent from Ibn Mājid, is unusual for nautical literature, and which brings him remarkably close to the Arabic scholarly astronomical tradition.[14]

These two authors consider themselves to be the heirs of a centuries-old tradition of maritime knowledge, a tradition of which we only have anecdotal traces in travel literature. They give detailed instructions on nautical astronomy and stellar navigation, using the lunar stations in sophisticated chronometric and positional ways. They elaborate on the use of stellar rhumbs to plot routes which cover an area from Jeddah in the Red Sea south to Madagascar, and all along the Yemeni and Persian Gulf coasts, then down the Malabar Coast, beyond this to the Bay of Bengal and east to Malacca and Java; they give seamarks, including topography and depth measures, of many routes, and anchorages on all these regions.[15] Additionally they treat of dangers at sea and on board, and, more significantly for us here, they discuss the virtues and qualities of pilots or navigators (I use these two terms rather interchangeably throughout).

The navigators described in these works are almost without exception called *maʿālimah*, "those who teach," plural of *muʿallim*, which is a common denomination for an instructor of any discipline. Arabic, like other Semitic languages, has great etymological transparency on account of its reliance on lexical triliteral roots. In this case, the *muʿallim* is etymologically a provider of *ʿilm*, meaning "knowledge," from the same root *ʿ-l-m*. Let us look further into this knowledge which characterizes the navigator, and into

valuable notes and appendices. I am currently working on a new critical edition and translation of the *Fawā'id*, taking into account the earliest manuscripts.

13 For detailed information about all the works mentioned in this paragraph, see Acevedo, Bénard and Müller, *Indian Ocean Arab Navigation Studies*.

14 See Eric Staples, Juan Acevedo and Inês Bénard, "Al-Mahrī's *Mir'āt al-salāk li-kurāt al-aflāk*: A 16th-Century Yemeni Navigator's Reflections on Astronomical Knowledge," *Nouvelles chroniques du manuscrit au Yémen* 16 (35) (January 2023): 96–120.

15 An excellent introduction to the details of all these practices is William Facey and Anthony R. Constable, eds., *The Principles of Arab Navigation* (London: Arabian Publishing, 2013).

other associated Arabic terms, and let us compare them with the words used in the European tradition, so as to allow the semantic divergences and coincidences to reveal more fully the concept we are tracking: what was this knowledge of the Arab pilots? Was it a high and lofty and theoretical science, or a mechanical, lowly servile technique? Was it functional or significant, utilitarian or spiritual? Was it monolithic?

7.2. Facets of Knowledge

I shall now present and comment on various occurrences of knowledge-related concepts in the Arabic nautical corpus. They will serve to illustrate the underlying semantic complexity, and thus give us room for elaboration and comparison. Most are taken from the *Fawā'id*, as the representative of the genre par excellence, but I also include examples from other sources.

I must preface the sampling by observing how the very titles of Arabic works pertaining to nautical sciences are already indicative of an established conceptual field: the main works of Ibn Mājid and of al-Mahrī are expressly dedicated to *ʿilm al-baḥr* and *ʿilm al-biḥār*, the "science" or "knowledge" of the sea or the seas. The translation of the word *ʿilm* (pl. *ʿulūm*) alone has been the object of intricate arguments for centuries, and its semantic range has been the object of monographs through the centuries.[16] As pointed out by Akkach, its fundamental importance in Islamic civilization springs from the pages of the Qur'ān, and it is confirmed for the Muslim community by the Prophetic sunnah (the "exemplary way") which determines daily life. A suitable way to explain its range of meanings may be to compare it to the medieval Latin *scientia*, i.e., a term which could equally refer to metaphysical doctrinal knowledge, or to the tenets of "natural philosophy," including concerns that would nowadays belong to engineering, physics, and other disciplines. Similarly, at different stages of development of the Latin language, we would find that the meanings of *ars* aligned with those of Arabic *ʿilm*, as in the important early tradition of the seven *artes liberales*.

So, in the context of navigation, apart from the name of the maritime "science" itself, and as mentioned above, the most common way of

16 Two of the most important recent works on this topic are Franz Rosenthal, *Knowledge Triumphant: The Concept of Knowledge in Medieval Islam*, Brill Classics in Islam 2 (Boston: Brill, 2007); Samer Akkach, ed., *ʿIlm: Science, Religion and Art in Islam* (Adelaide: University of Adelaide Press, 2019).

addressing the Indian Ocean navigators is a cognate of *ʿilm*. In his useful *Muʿjam alfāẓ al-musṭalaḥāt al-milāḥīyah* ("Glossary of Nautical Terminology"), Ibrahim Khoury introduces another common term as he gives the following definition: "*Muʿallim*: the captain (*rubbān*) of a ship; there is no clearcut difference between *muʿallim* and *rubbān*. Each one of them directs the ship, and each one knows about orientation (*hidāyah*) by the stars, landmarks, and by everything else which is necessary for the art (*fann*) of navigation."[17] Before dwelling on this definition, let us look at how this knowledge of the pilots is nuanced and complemented in several passages of our Arabic texts.

Ibn Mājid's two major works, his *Fawāʾid* and his *Ḥāwiyah*, begin with paeans to knowledge in general, and throughout they extol, in very self-aware style, the value of the knowledge they impart and the need for the guidance of a respected master. *Ṭalab al-ʿilm*, the pursuit of knowledge, is the explicit prerequisite of the aspiring navigator, who is often addressed as *ṭālib al-ʿilm*, the seeker of knowledge.[18] In fact, right from the outset, there is a clear continuity between religious and practical knowledge: in the *Fawāʾid* there is mention of the importance of nautical knowledge in its relation to the finding of the *qibla*, the orientation of canonical prayer, whereas in the *Ḥāwiyah* there is mention of the inspiration (*ilhām*) received by the author in order to master and communicate his science in the most worthy manner, followed by the opening lines,

> Oh you who seek after the science of the sea [...], if you are one of those who strive for the sciences (*ʿulūm*), and remembers his teacher every day, you need seamanship books (*rahmānijāt*) [...], with the condition that you do not read them without a teacher, for there are hints in them which the ignorant will consider to be weaknesses.[19]

This kind of introduction makes clear the dependence on a dual transmission of knowledge: one vertical, as the navigators receive their inspiration from above, requesting from God the same orientation (*hidāyah*) that they provide

17 Ibrahim Khoury, *Al-ʿUlūm al-Baḥrīyah ʿinda al-ʿarab 1.3* (Damascus: Arab Academy of Damascus, 1972), 690–884.

18 On the central role of this concept in the Islamic worldview and its codification in the sacred law, see Mohammad Hashim Kamali, *Citizenship and Accountability of Government: An Islamic Perspective*, Fundamental Rights and Liberties in Islam (Cambridge: Islamic Texts Society, 2011), 48–51.

19 Aḥmad Ibn Mājid, "La Hawiya: abregé versifié des principes de nautique," ed. Ibrahim Khoury, *Bulletin d'études orientales* 24 (1971): 249–386, verses 6–11.

Figure 7.1. In this celestial compass rose from a later manuscript in the same nautical tradition, we can see the Kaaba at the center of the thirty-two rhumbs associated with asterisms. It is the image of the qibla as central to orientation in space (Biblioteca nacional de Portugal, Or. 2, fol.1r)

through their work. And one horizontal, as they receive texts and cultivate reverence for their lineage, a relation that practically "unlocks" the texts for them, texts which might otherwise remain poorly understood, or simply impracticable. This regard for the predecessors is actually stressed repeatedly by Ibn Mājid in several works, when he mentions three famous pilots by name, and calls himself, both proudly and humbly, "the fourth of three."[20]

The characterization is expanded a little in the *Fawā'id*, and new key terms are introduced:

20 See especially Shihāb al-Dīn Aḥmad Ibn Mājid, *Kitāb al-fawā'id fī uṣūl 'ilm al-baḥr wa-al-qawā'id*, ed. Ibrahim Khoury and 'Izzat Ḥasan, Al-'ulūm al-baḥrīyah 'inda al-'arab, 2,1 (Damascus, 1971), 14–15.

> A man may decide to act without the practical knowledge (*maʿrifah*) and the understanding (*ḥisāb*) of the sea, but whenever he lacks the *qibla* directions of towns and islands which are in the Encircling Ocean, then he must use this knowledge (*ʿilm*) of ours. So let him strive so, for it is a precious knowledge (*ʿilm nafīs*) whose perfectioning takes a lifetime.[21]

Apart from the reminder about the relation with the *qibla* direction, there is the reference to prolonged practice: this is not a knowledge that can be gained overnight, but the fruit of a life-long effort.

Another term, *maʿrifah*, is crucial in *Fachliteratur* in general, for though often conflated in translation with *ʿilm*, and though broad in philosophical and even mystical connotations, in our context it means the actual acquaintance with a situation, a procedure, a set of parameters; chapter sections in al-Mahrī are often dedicated to the *maʿrifah* of this or that particular point of experience,[22] to a particular know-how. This is why I have chosen to translate it here as "practical knowledge." In this particular case, the word *ḥisāb* is given as the theoretical complement of *maʿrifah*, for it has to do with calculation and reckoning ("arithmetic" is in fact one of its usual meanings), and it always includes the idea of mental activity.

The opening lines of al-Mahrī's *ʿUmdah* give fascinating insights into the theory–practice relation. The author explains how his book intends to be

> concise (*ḍābiṭ*) about its questions on principles and applications […], based on constantly repeated experience (*tajribah al-mutawātirah*) which is either my own or has been received from veracious trusted sources; with a concern for accuracy (*ṣiḥḥah*) which links the principle to the accepted way of measuring (*qānūn al-tadrīj*) in the practical applications.[23]

"Constantly repeated" attempts to convey the strong meaning of *mutawātir*, which has to do with continuity in time and thus following on the idea of

21 Ibn Mājid, *Kitāb al-fawāʾid*, 5. Page numbers refer to Khoury's critical edition; when a folio number is given, it refers to the Bodleian MS Selden Superius 46, which I am currently studying. Translations are mine unless otherwise stated.

22 See Inês Bénard and Juan Acevedo, *Conspectus of Works of Sulayman al-Mahri* (*Muḥtawiyāt muʾallafāt Sulaymān al-Mahrī*). Vol. 13. RUTTER Technical Notes. Lisbon: ERC RUTTER Project, 2024.

23 Sulaymān al-Mahrī, *al-ʿUmdah al-mahrīyah fī ḍabṭ al-ʿulūm al-baḥrīyah*, ed. Ibrahim Khoury, Al-ʿulūm al-baḥrīyah ʿinda al-ʿarab, 1,1 (Damascus, 1971), 3–4.

a lifetime practice, and also with the controlled repetition expressed, for example, in Galileo as *esperienze ben cento volte replicate*, "trials repeated a full hundred times."[24] Here al-Mahrī specifies that it is not just one lifetime, but that it can include the experiences of reliable authorities. We will see more about *tajribah*, "experience," below. The overall impression seems very closely to echo Vitruvius's characterization of *fabrica*, "craft" (the empirical complement of *ratiocinatio*, "reasoning") as *continuata ac trita usus meditatio*, "the uninterrupted and stubborn concern over a specific practice."[25]

As for the last sentence in the citation, which is not easy to parse, my interpretation is the following: there are in this maritime technoscience, as in every other similar discipline, theoretical principles and practical applications. The latter require and depend on established sets, the "accepted ways" or "canons," of conventional "measures" or other analytical systems. And what ensures that there is a connection with the abstract principles is a keen attention to accuracy, the painstaking concern for detail, or to put it in contemporary terms, the fastidious implementation of rules and standard procedures. These fundamental concerns and attention to a basic existing "principle" bring to mind early modern European reflections on the relation between *scientia*, *ars*, and *experientia*, by artisans who "believed they possessed a species of knowledge, based on nature and extracted through bodily work, which was as certain as any demonstrative proof."[26]

Ibn Mājid chimes in as follows, combining the two notions of accuracy and experience:

> In our own times, nothing has been added which is as sound as our teachings (*ʿulūm*), our experiences (*tajārib*), and our discoveries (*ikhtirāʿāt*), as recorded in this book. For everything here has been confirmed by experience (*muṣaḥḥaḥah mujarrabah*), and there is nothing superior to experience (*tajrīb*). 'The end point of the precursors is the starting point of the successors';[27] therefore we have expanded their knowledge and

24 See Peter Dear, "The Meanings of Experience," in *The Cambridge History of Science*, Vol. 3: *Early Modern Science*, ed. Katharine Park and Lorraine Daston (Cambridge: Cambridge University Press, 2006), 123, https://doi.org/10.1017/CHOL9780521572446.005.

25 Vitruvius, *Zehn Bücher Über Architektur / De Architectura*, ed. Curt Fensterbusch, Bibliothek Klassischer Texte (Darmstadt: Wissenschaftliche Buchgesellschaft, 1991), 1,1, 22.

26 Pamela H. Smith, *The Body of the Artisan: Art and Experience in the Scientific Revolution* (Chicago: University of Chicago Press, 2004), 87–93, gives and analyzes examples taken from Leonardo, Dürer, and Paracelsus.

27 *Nihāyat al-mutaqaddim bidāyat al-muta'akhir*; this was a well-known principle in jurisprudence literature (*fiqh*).

> their works, and have paid tribute to them [...] and perhaps occasionally, among the knowledge of the sea which we have discovered, one of the pages of our works might improve on them as regards wording, usefulness, guidance, and orientation.[28]

The root of *ṣiḥḥah* above is the same as that of *muṣaḥḥaḥah* here, and it carries notions of detailed verification, hence controlled accuracy and confirmation. But what is more remarkable in this excerpt is how the primacy of the value of experience is smoothly integrated within the tribute to the forebears. The phrase "nothing superior to experience" echoes almost verbatim the words employed by the very near contemporaneous Leonardo da Vinci, "l'esperientia, madre d'ogni certezza."[29] Later on, along similar lines:

> Take for yourself what has been subject to correction (*muhadhdhab*) and experience, and act upon it, for experience (*tajribah*) means everything in this art (*fann*).[30]

Once again we find the word *fann*, "art," which is used interchangeably with *ʿilm* because it is also used in the sense of Latin *ars*, as in the seven *artes liberales*, comprising a "scientific" dimension which does not quite resonate with our contemporary notion of art. I have little doubt that the most appropriate English translation available nowadays would be "technoscience."[31] In the same tenor, here is another little addition to the mix:

> I have not mentioned anything so ambiguous that its biggest and lowest values vary by approximately two *zām*.[32] Out of this arises its validity (*ṣiḥḥah*), for this knowledge is rational-experiential (*ʿaqlī tajrībī*), not based on convention (*naqlī*).[33]

28 Ibn Mājid, *Kitāb al-fawāʾid*, 16–17.

29 Leonardo's "Paragone," cited in Monica Azzolini, "In Praise of Art: Text and Context of Leonardo's 'Paragone' and Its Critique of the Arts and Sciences," *Renaissance Studies* 19, no. 4 (2005): 502.

30 Ibn Mājid, *Kitāb al-fawāʾid*, 203.

31 See Pamela H Smith, "Science on the Move: Recent Trends in the History of Early Modern Science," *Renaissance Quarterly* 62, no. 2 (2009): 358, https://doi.org/10.1086/599864.

32 In this literature, a *zām* is the customary unit of time, and therefore of distance sailed, approximately 12 nautical miles. For this and other technical terms, see Eric Staples and Abdulrahman Al Salimi, *A Maritime Lexicon: Arabic Nautical Terminology in the Indian Ocean* (Hildesheim: Georg Olms, 2019), 418.

33 Ibn Mājid, *Kitāb al-fawāʾid*, 22.

There is an apparent disagreement here with the respect for the predecessors, while recognizing the primacy of verification by experience, something further developed later:

> We have mentioned in this book the sum of useful matters which are of interest to reflective experts (*al-ʿārifūn al-mutaʾammilūn*) [...] And since 'tested sound knowledge (*ḥikmah*) is the stray property of the believer,'[34] seek your lost property! Even if it be among impious people, for this craft (*ṣanʿah*) is by reason, not by convention.[35]

The famous prophetic tradition cited is often tritely rendered as "wisdom is the stray property of the believer," but in this context, and in general in the corpus at hand, words related to the root of *ḥikmah* have to do with tested, *pondered* knowledge. In this usage of "wisdom", as in the "reflective experts" and the "rational-experiential" label, we can hear echoes, yet again, of the Vitruvian *usus meditatio* mentioned above, the "concern over a specific practice," the proper and artisanal earnest "minding one's business." To suggest a contemporaneous European parallel once again, we seem to be very close, and not just in time, to the *nova scientia* (preferably translated as "New Knowledge") of Niccolò Tartaglia (1499–1557), published in 1537, which "prioritized practical experience, measurement, instrumentation, geometrical theorics, and predictable outcomes."[36]

The use of *ṣanʿah*, "art," introduced as a synonym of *fann*, has in addition the connotation of a technique, of a set of skills and of the making of something, and it carries an implicit question: if navigation is an art in this "productive," "poietic" sense, what is its product? If a sculptor makes sculptures and a pizzaiolo makes pizza, what does a navigator make? Our tentative answer is: the routes, the established paths like highways across the ocean, which allow for regular travel back and forth.[37]

34 Part of a well-known hadith, *Jāmiʿ al-Tirmidhī*, 2687.

35 Ibn Mājid, *Kitāb al-fawāʾid*, 338, fol. 110r–110v.

36 Jim Bennett, "The Mechanical Arts," in *The Cambridge History of Science*, Vol. 3: *Early Modern Science*, ed. Katharine Park and Lorraine Daston (Cambridge: Cambridge University Press, 2006), 692, https://doi.org/10.1017/CHOL9780521572446.028.

37 Cf. in this volume, José María Moreno Madrid's chapter 3, "Monitoring the Paths of the Sea: Rutters, Laws, and Long-Distance Control in Sixteenth-Century Iberian Empires."

7.3. Social Context

This last remark brings me to an observation from outside the text of the Arabic corpus which will allow me to start wrapping up my argument, and which has to do with the social context of navigation. It has to do more generally, with the *political* context of technoscientific developments, with the European early modern "empirical revolution in the world of knowledge," seen as "intimately linked to the construction of global empires,"[38] and with Brendecke's "politics of knowledge" or rather "functions of knowledge."[39] My observation, constantly made over the course of recent research into the sources, is the difference in context between these early modern Arab pilots and their Iberian counterparts. There is never in the Arabic corpus the slightest mention of an official institution, not of even a royal authority, that has any direct relation with the production of the works—it is all, as it were, knowledge for knowledge's sake, pure *Fachliteratur*, unencumbered by patronage, officialdom, or any regulations.

As we consider the narrative that modern science, that vaunted "revolution," may have been driven and shaped by an imperial framework, it will be of profit to ponder on these Arab pilots. The reader will have observed by now what a "modern" scientific approach theirs was, how they combined a respect for their heritage with an uncompromising attachment to verifiable, repeated experience. I have already tried to bring out this kinship in my mentions of European parallels while introducing my Arabic nautical evidence. Observing the differences between these two parallel lines of maritime technoscientific knowledge—especially because they were so fatefully tied after the 1498 arrival of Da Gama in Asian waters—may now help us refine and complete the picture being drawn by scholars such as Harris[40] and Brendecke. When Harris speaks of the crucial role of "the activities of long-distance corporations," like Seville's Casa de la Contratación or Lisbon's Armazéns de Guiné, and when Brendecke says that "some

38 See Antonio Sánchez, "Practical Knowledge and Empire in the Early Modern Iberian World: Towards an Artisanal Turn," *Centaurus* 61, no. 3 (2019): 278, https://doi.org/10.1111/1600–0498.12217.

39 I find the first expression slightly too narrow in scope, while the second is actually a more direct rendering of the original German and is used in the revised Spanish edition, Arndt Brendecke, *Imperio e información. Funciones del saber en el dominio colonial español*, trans. Griselda Mársico, 2nd, rev. and expanded ed. Tiempo emulado. Historia de América y España 25 (Madrid: Iberoamericana, 2016).

40 Particularly Steven Harris, "Networks of Travel, Correspondence, and Exchange," in *The Cambridge History of Science*, Vol. 3: *Early Modern Science*, ed. Katharine Park and Lorraine Daston (Cambridge: Cambridge University Press, 2006), 341–62, https://doi.org/10.1017/CHOL9780521572446.017.

significant elements of the culture of modern empirical knowledge can only be understood when put in relation to the practices of dominion and administration,"[41] perhaps we should indeed let the emphasis strongly be on this administrative, bureaucratic, aspect of empire, in its regulating impact. It is precisely this "managerial" aspect which is so clearly revealed, almost innocently, by Linnaean taxonomy, "a form of biopolitics, what we might call 'imperial biopower,' devoted to turning diversity, local variation, and qualia into data";[42] in its ledger-like organization, it functioned as "a technoscope that depends on empire and at the same time underpins it."[43]

Ibn Mājid and al-Mahrī were to some extent itinerant craftsmen, quite in the spirit of the medieval European guilds; they enjoyed their "academic" freedom, and were devoted to teaching. Their Iberian counterparts, navigators of renown like Bartolomeu Dias (ca. 1450–1500), who first rounded the Cape of Good Hope, or Pedro Alonso Niño (1468–1505), who piloted the *Santa María* for Columbus, were office-holders, functionaries, often hoping for rewards alien to their science. Their knowledge was to a great extent instrumentalized: this was its weakness and also its power—the intellectual weakness of servility, and the pragmatic power of an immense imperial machinery recording, organizing, systematizing. The Arabic nautical corpus is witness to the refinement of empirical observations by generations of scholars, of the tense interplay between theoretical principles and technical know-how advancing knowledge, of the primacy given to evidence—all these elements were there already, and yet no scientific revolution came of it.

Conclusion

The accounts of the rounded knowledge and character of the Arab pilots, and their dual ability in mind-work and hand-work, *raciotinatio* and *fabrica*, are not alien at all to contemporary Renaissance craftsmen who were propelling the "new science." Their appraisal of experience, as seen above, is quite in tune with Leonardo's mention of "bona sperientia," as the "commune madre di tutte le scientie e arti."[44]

41 Brendecke, *Imperio e información*, 19.

42 Nuria Valverde and Antonio Lafuente, "Linnaean Botany and Spanish Imperial Biopolitics," in *Colonial Botany: Science, Commerce, and Politics in the Early Modern World*, ed. Londa Schiebinger and Claudia Swan (Philadelphia: University of Pennsylvania Press, 2007), 293.

43 Valverde and Lafuente, "Linnaean Botany and Spanish Imperial Biopolitics," 279.

44 Leonardo da Vinci, *The Notebooks of Leonardo da Vinci*, ed. Jean Paul Richter, 2 vols (New York: Dover Books, 2012), I:18.

Coming back to what I have called the horizontal transmission of knowledge, the traceable lineages of teachings, with their more or less untraceable kinship and suggestive parallels, we may consider the centuries-long persistence of fundamental notions about craft and theoretical knowledge, weaving their ways through cultures and languages. The influence of the *Timaeus* and of Vitruvius on the Italian Renaissance is well attested to say the least, as in the cases of Filarete and Francesco di Giorgio in the late fifteenth century,[45] or Dürer in the early 1500s, speaking of his artisanal experience as a synthesis of *Kunst* ("art," informed by "intellectual understanding") and *Brauch* (custom, involving practical skill).[46] Only a little later in the sixteenth century, the publication of Pedro Nunes's *De arte atque ratione navigandi* (Coimbra, 1573) brings these several issues completely within our nautical ken. When Nunes affirms that the Portuguese mariners were not just going around the ocean on hit-and-miss expeditions (*indo a acertar*), but that they were "very instructed and armed with instruments and rules of astronomy and geometry" (*mui ensinados e providos de estormentos e regras de astrologia e geometria*),[47] this is once again in tune with the Arab pilots' views. There is unquestionably a degree of sophistication in Nunes's work which has to do with his mathematical genius and unique contributions, but there is something in his relationship with pilots that stands out as different from what transpired in the Indian Ocean a hundred years earlier. It is not just the mutual awareness between navigators and mathematicians, for Ibn Mājid was conversant with the medieval astronomical literature, and al-Mahrī even contributed to it, but the fact that there was a state-sponsored and state-regulated relationship between them. Nunes had been appointed by the Portuguese crown as an officer in charge of instructing the pilots. Thus, as the crown co-opted and instrumentalized both their and Nunes's knowledge and experience, a new breed of navigators and a new nautical science came into being.[48]

Nothing even remotely close to such an institutionalized relationship existed for Indian Ocean pilots, and yet, unexpectedly, what appears to sum up the relationship between this new science and nautical knowledge—token words like "exactitude," "rigor," and the seventeenth-century

45 See Pamela O. Long, *Artisan/Practitioners and the Rise of the New Sciences, 1400–1600* (Corvallis: Oregon State University Press, 2011), 77–78, 80.

46 See Smith, *The Body of the Artisan*, 69–72.

47 Henrique Leitão, "Ars e ratio: A náutica e a constituição da ciência moderna," in *La ciencia y el mar*, ed. María Isabel Vicente Maroto and Mariano Esteban Piñeiro (Valladolid: Universidad de Valladolid, 2006), 190.

48 For valuable insights and references regarding this interplay between "universal detached bureaucracy" and "contingent sailor practice," see Lobo-Guerrero's chapter in this volume.

consolidation of a dual methodology based on 1) rules of mathematical certainty, and 2) experience- and observation-based know-how[49]—appears most familiar within the context of the Indian Ocean navigation of the fifteenth century. I do not mean to establish blanket identifications and to overlook particularities, but to draw attention to this unexpected common ground, from which research into particulars can be better articulated.

Writing still on the horizontal transmission and on the views on ancient authority, Nunes refers to the innovative character of his relationship to navigators explaining that while he differed occasionally from the method of Menelaus, Ptolemy, and Jābir (Geber), he was not at all diverging from Euclid or Theodosius.[50] Similarly, the more one examines the Arabic nautical sources—without losing sight of classical and late antique sources—the more unlikely it appears that there ever was a clear break with ancient cosmology.[51] This is not the place to address the variations of the continuity thesis, but as suggested in the previous pages, there is much in the domain of science that remains unchanged beyond all the talk and fanfare of revolutions. Perhaps what could be seen as a real innovation or the key difference in the European sphere is, to use Spengler's terminology, the Faustian "technical Will-to-Power," and the basic "idea of immediately exploiting in practice any knowledge."[52]

To turn now to the vertical transmission I have mentioned, we can see how, even within the imperial drive and as if between the menacing strides of the European juggernaut, remnants persisted of the cosmological awareness common to *Timaeus* and the Abrahamic cosmogonies. They manifest above all as the vivid and perpetually renewed awareness of a cosmological order, as belonging with and having duties towards an intelligible and also merciful creation: "Because the artisan imitated the processes of nature in his creation of works of art from the material of nature, he had a better understanding of nature, and because he was in contact with God's Creation, he also possessed a better knowledge of God's revelation."[53] These remnants, however diminished and meek, reenact, often through art and ritual, a very

49 Leitão, "Ars e ratio," 206–207.

50 Leitão, "Ars e ratio," 193.

51 For a full metaphysical comparative treatment of one case study, see Acevedo, *Alphanumeric Cosmology from Greek into Arabic*.

52 Oswald Spengler, *The Decline of the West* (New York: A. A. Knopf, 1939), 300–301.

53 Pamela Smith, "Laboratories," in *The Cambridge History of Science*, Vol. 3: *Early Modern Science*, ed. Katharine Park and Lorraine Daston (Cambridge: Cambridge University Press, 2006), 298, https://doi.org/10.1017/CHOL9780521572446.014.

Figure 7.2. Top of the façade of the church of Our Lady of Needs (Nossa Senhora das Necessidades) in Lisbon. The baroque budded cross at the top, with the diagonal rays, seems to visually replicate the sixteen rhumbs of the wind rose below. This church was the home of the Lisbon Oratorian Fathers, who in later times, for about a century, taught mathematics, astronomy, and other disciplines to the Portuguese navigators.[54] The harmony between the cross, representing metaphysical and theological doctrines, and the technoscientific division of space, represented by the wind rose, is in perfect agreement with the "vertical" vision of world-crafting laid out in Timaeus and verified at every turn throughout the Middle Ages. For a detailed study of this question, down to the thirteenth century, see Acevedo, *Alphanumeric Cosmology from Greek into Arabic*.

European drama between its own tendencies to pure science and politicized science. Our efforts at further understanding their dynamics, and the crucial role of these dynamics in the advent of a new global scientistic order, are all the better oriented if they take into account such gentle voices.[54]

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54 See Kenneth Maxwell, *Pombal, Paradox of the Enlightenment* (Cambridge: Cambridge University Press, 1995), 13–14.

(PIDDAC). UIDB/00286/2020; UIDP/00286/2020. https://doi.org/10.54499/UIDB/00286/2020. "Merging Times and Techniques of European and Asian Science Through the Indian Ocean (15th–19th centuries)". DOI https://doi.org/10.54499/2023.06889.CEECIND/CP2831/CT0015.

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