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IBN MĀJID'S *KITĀB AL-FAWĀ'ID* AND THE CONCEPTS OF 'TRIAL AND ERROR' AND 'METHODOLOGICAL DOUBT' II: ANALYSIS

Andreas Eckart* and Mesut Idriz**

Abstract: The concepts of 'trial and error' and 'methodological doubt' are given in the context of the book of navigation *Kitāb al-Fawā'id* by the great Arabian navigator and writer Aḥmad Ibn Mājid. In a preceding paper (I) we summarised and commented on the text sections in his book that are essential for the analysis. While these concepts were developed in the 19th century by Conwy Lloyd Morgan and in the 17th century by René Descartes, respectively, we show that comparable concepts were also developed and applied more than 200 years earlier by Ibn Mājid. We highlight the emergence of these concepts in recent history as they are closely linked to the development of evolutionary theory and epistemology. We also place our findings into the scientific and philosophical context of Ibn Mājid's time. Finally, we discuss our results in the framework of the transfer of knowledge from Arabic sources.

Keywords: *Ibn Mājid*, *Ibn al-Haytham*, *René Descartes*, *Conwy Morgan*, *Arabic astronomy, time keeping and navigation*, *trial and error*, *methodological doubt*

1. INTRODUCTION

In addition to fascinating observational results[1] and innovative instrumentation,[2] the observer's psychological and physical properties played a crucial part in shaping the scientific process, influencing the accuracy and reliability of measurements of stellar

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1 George Saliba, *A History of Arabic Astronomy: Planetary Theories During the Golden Age of Islam* (New York University Press, 1994), 143.

2 Tofigh Heidarzadeh, "Islamic Astronomical Instruments and Observatories," in *Handbook of Archaeoastronomy and Ethnoastronomy*, ed. J. McKim Malville and Clive L. N. Ruggles (University of New Mexico Press, 2015), https://doi.org/10.1007/978-1-4614-6141-8_203.

positions and calculations of geographical coordinates. In particular, the transfer of knowledge might have adhered to protocols, which warrant further exploration. In the previous paper,[3] we gave textual evidence from the work of the famous Arabic navigator Ibn Mājid (ca. 1432–1500) for the process of information transfer and use of the concept of "trial and error"[4] in a philosophical environment of methodological doubt developed more than 200 years earlier by René Descartes[5] (1596–1650). Our approach maintains high systematic rigour. Paper I provides a complete catalogue and analysis of the sections within the *Kitāb al-Fawā'id* where Ibn Mājid details his protocols for data collection, evaluation of inherited knowledge, and professional interactions with fellow navigators and mariners. In the present contribution, we compare the concept of "trial and repetition," which is an early version of "trial and error," as well as the concept of methodological scepticism put forward by Ibn Mājid to the more modern well-established concept of trial and repetition.

This method of trial and error was developed in behavioural research and psychology (see discussion in section 2.4) but has found its way into scientific or technical fields, especially when the problem cases become complex and the application of inductive or deductive methods to solve the problem become confusing. The trial and error approach is usually associated with more recent methodological developments. In this article, however, we demonstrate that it entered scientific practice much earlier. This primarily concerns the achievements of the navigator Ibn Mājid.

Cartesian doubt, a concept developed by René Descartes,[6] is a form of methodological scepticism. This approach is also referred to as Cartesian scepticism or methodical doubt. Cartesian doubt is a deliberate and structured process of questioning one's beliefs to establish a foundation for knowledge. Descartes' method has been seen as a precursor to the modern scientific method, which involves starting with minimal assumptions and deducing higher-order information. In the case of Descartes, his famous statement, "Cogito, ergo sum" (I think, therefore I am), is a foundational statement for his philosophical enquiry. In this article, we will examine, based on the textual legacy of Ibn Majid, to what extent a form of this methodological doubt has found its way into Arabic scholarship during the Islamic Golden Age.

For our work, we had access to the 1925 copy of the Damascus version of Ibn Mājid's *Kitāb al-Fawā'id*. It is now available in digital form as SM-53[7] at the Library of Congress in Washington (see Paper I, section 2). It is described and analysed in detail in a paper by

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3 Andreas Eckart and Mesut Idriz, "Ibn Mājid's Kitāb al-Fawā'id and the Concepts of 'Trial and Error' and 'Methodological Doubt' I: The Data," *Australian Journal of Islamic Studies* 11, no. 4 (2026).

4 Robert Jackson et al., "Trial-and-Error Solving of a Confinement Problem by a Jumping Spider, Portia fimbriata," *Behaviour* 138, no. 10 (2001), https://doi.org/10.1163/15685390152822184.

5 René Descartes is a French philosopher, scientist and mathematician. He is widely considered an essential figure in the emergence of modern science and philosophy.

6 René Descartes, *Discourse on the Method*, trans. Donald A. Cress (Hackett Publishing Company, 2009).

7 Aḥmad ibn Mājid, *Kitāb al-Fawā'id fī uṣūl 'ilm al-baḥr wa-al-qawā'id* [The Book of Benefits on the Principles of Navigation and Nautical Rule], 1925 (copy of Damascus version), SM-53, Near East Section, Library of Congress, Washington, DC.

Marina Tolmacheva.[8] A complete commented translation of the MS2292 version of Ibn Mājid's *Kitāb al-Fawā'id* was then published by G. R. Tibbetts in 1971. Here, we refer to and quote from Tibbetts' 1981 reprint.[9]

In the transliterations we use *j* and *īy*, instead of *ǧ* and *iyy*, as well as *sh*, instead of š. All translations were made or revised by the author.

The paper is organised in the following way: We present a detailed discussion of the information as extracted from Ibn Mājid's *Kitāb al-Fawā'id*. This includes a discussion on the navigator's role in his social environment, the sociological expectations in the application of his methodological doubt, in section 2.1. The virtue of a proper sitting position (while taking measurements) and its influence on the mental focus is elaborated in section 2.2. We discuss the sitting position as it is essential to ensure repeatability of astronomical nautical measurements. Hence, it falls in line with Ibn Mājid's application of the concepts of "trial and repetition" and the methodological doubt. In 2.3, we examine why the skill of navigation is a science and Ibn Mājid's statements can therefore be considered as scientific and valuable from a philosophical standpoint. The analysis results obtained in the previous sections are essential in motivating the concepts that are the focus of our contribution to Ibn Mājid's work. In 2.4, we look at the concept of "trial and error" and what Ibn Mājid says about it in his *Kitāb al-Fawā'id*. In section 2.5, we discuss the role of methodological doubt in his remarks on how to obtain nautical measurements and transferring or using the corresponding result. Finally, in section 2.6, we see Ibn Mājid's position in the philosophical environment of his time. As a last point, in section 2.7, we investigate the phenomenon of transfer of knowledge from Arabic sources and what we can extrapolate about Ibn Mājid's case. Summary and conclusions are given in section 3.

2. DISCUSSION

2.1 Role of the Navigator in his Social Environment

It is beneficial to acquire knowledge from others, including our ancestors, but it is crucial that this knowledge withstands scrutiny. True understanding and mastering situations come from gaining experience through a repeated process of trial and verification. This principle applies to inherited knowledge (of astronomical and nautical facts) and the introduction of new procedures (to apply that knowledge, improve on it, and transfer the information about this to forthcoming generations). Interaction within a guild or community, i.e., comrades and practitioners in their field, is vital, as it allows for sharing of new, verified knowledge and collective problem-solving.

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8 Marina Tolmacheva, "An Unknown Manuscript of the Kitāb al-Fawāʾid," *Journal of the American Oriental Society* 114, no. 2 (1994), https://doi.org/10.2307/605131.

9 Gerald R. Tibbetts, *Arab Navigation in the Indian Ocean Before the Coming of the Portuguese*, Oriental Translation Fund, vol. 42 (Royal Asiatic Society of Great Britain and Ireland, 1971. Reprint, 1981).

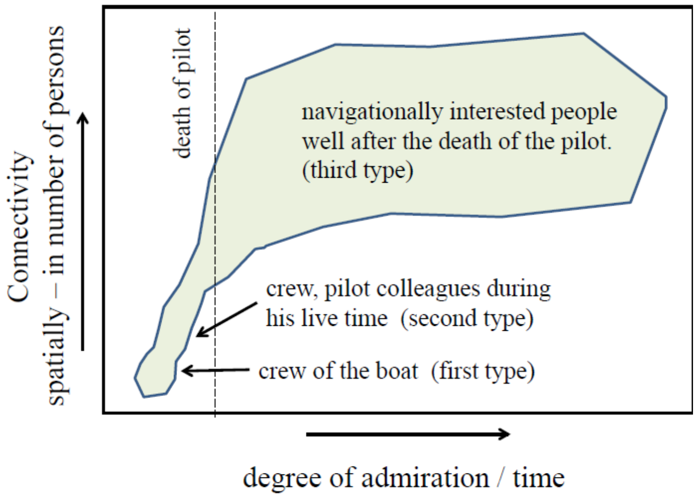

Figure 1: In this heuristic diagram, we present the number of people to whom the pilot is known, i.e., with whom he has contact (this may include people at a greater distance who are neither part of the crew nor connected, for example, with the boat), as a function of the degree of admiration over time. As information spreads, the level of admiration usually increases with time. Through numerous publications and orally transmitted fame, the third type of navigator is still known even after his death (indicated by the dashed line).

Ibn Mājid is fully aware of the navigator's role as the person responsible for the preservation and transfer of knowledge (see Paper I, section 3.1). This is demonstrated by his classification of navigators into three groups of different qualities. These range from the simple survival of a pilot to the educated, book-writing ideal of a famous and responsible navigator. In Figure 1, we depict this situation heuristically to understand the overall systematics that Ibn Mājid presents in his classification of different types of navigators.

In the context of maritime navigation, guilds played a significant role in disseminating information, addressing challenges, and improving the ability to use the newly acquired information (i.e. the knowledge). These organisations presumably were well informed about new developments and relied on the collective experience of their members to overcome problems. Ibn Mājid, a renowned navigator, often references groups of around 20 people when discussing decision-making or mediation. This seems to be a convenient quorum for effective discussion and problem-solving, although the exact reason for the number remains unclear.

The choice of about 20 individuals may reflect the average size of a guild or the number of interested and capable navigators in a harbor at any given time. Ibn Mājid does not provide explicit justification for this number, leaving room for interpretation. According to Tibbetts,[10] pilots were organised into guilds and fraternities, with close relationships among members. By using the term 'pilot,' Tibbetts highlights the capabilities of people like Ibn Mājid, since they have the astronomical, geographical, and mathematical knowledge to 'pilot' the ship through dangerous or simply unknown waters. A 'captain' commands the ship (i.e. the crew on board) and uses the information obtained from the pilot. Hence, in this case, using the

[10] Ibid.

term ‘pilot’ is a matter of technical accuracy versus general authority. Also, a pilot is not a ‘simple’ navigator, as he has the scientific capabilities of using inherited data, obtaining new data, and transferring that new information to forthcoming generations. The demands of their profession were so rigorous that they were, in a sense, enslaved by their duties. The group size of 20 people was probably ideal to manage the pressure of high responsibility. A smaller number would not provide helpful compensation of pressure or sufficient support, and too large a number might mean excessive anonymity, which is also not conducive to overcoming a problem.

The pilot’s role requires a high level of expertise, dedication, and responsibility. Pilots had to navigate complex waters, make critical decisions, and ensure the safety of their crew and cargo. The close relationships among pilots and their organisation into guilds likely helped them cope with the demands of their profession and share knowledge and best practices.

The life of a pilot encompasses a range of psychological, physiological, and sociological aspects that are crucial for success. According to Ibn Mājid, an ideal pilot must possess a unique combination of qualities, including calmness, determination, knowledge, respect, cleverness, and experience. These attributes enable the pilot to maintain focus and concentration during critical astronomical/nautical measurements.

To ensure peak performance, Ibn Mājid recommends that, before each astronomical measurement/observation, pilots prepare themselves by washing their face with cold water to stay fresh and alert (see section 2.2). Additionally, a comfortable sitting position is essential for taking accurate astronomical measurements. Given the high stakes of navigation in the Indian Ocean (and other maritime regions in which Arabic boats navigated), where the lives of the crew and success of the mission depend on precise calculations, reproducibility and correctness are paramount (see Paper I, sections 3.4 and 3.7.1). To achieve reliable results, pilots must adhere to standardised procedures for astronomical and nautical measurements. This includes following consistent preparation protocols to guarantee high-quality outcomes of these observations. The gravity of navigational measurements underscores the need for meticulous attention to detail and a commitment to excellence.

Beyond technical skills, effective communication is vital for a pilot. Through conversations and written records, pilots must impart new and relevant knowledge to others. Regular, critical contact with the ship’s crew, passengers, and fellow pilots facilitates the exchange of ideas and fosters a collaborative environment. All these sociological aspects of piloting highlight the importance of interpersonal skills in ensuring successful voyages and advancing navigational knowledge.

2.2 Sitting Position and Mental Focus

The question of whether a lying or upright sitting position is more conducive to concentration has been scientifically investigated. Here, we summarise the results of these investigations to judge the validity of Ibn Mājid’s statement on the sitting position (Paper I, sections 3.2 and 3.4). In an experiment, students were asked to consecutively subtract seven from a given number and 56% of the students tested said it was easier to do the problems when they were sitting up.[11] The articles highlight that using an empowered position may optimise one's focus, i.e., enhance concentration, improve mood, and allow one to breathe easier.[12] In the experiment, the alertness scale of participants was measured through a questionnaire.[13] The graph and column diagrams in Figure 2 are an analytical representation of the results of these investigations. Alertness steadily decreased over time, but there was only a tendency but no mathematically significant difference between the results for the two postures.

However, doing sensitive nautical measurements while sitting is preferred anyway, since standing is unpractical on a boat, in particular if it is in motion. Hence, Ibn Mājid was probably guided by this experience when laying out his instructions on how to properly conduct nautical measurement (presumably in the morning or right after sleep).

That sensitive measurements were regularly made by ancient astronomers and navigators is also clear from Ibn Al Haytham's work. For example, measuring star distances to the Milky Way's faint edges requires adaptability in night sky vision.[14] This implies psychological and physical conditions that needed to be fulfilled by the observer to conduct these tasks.

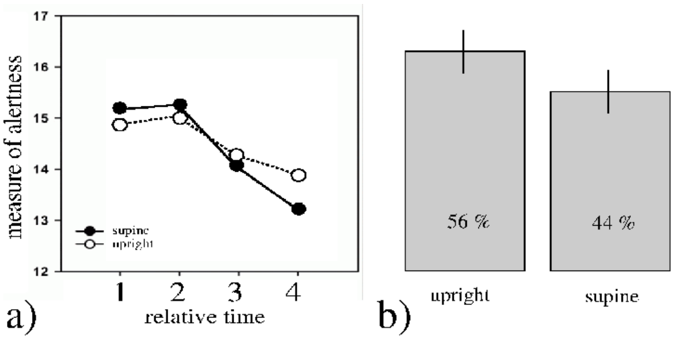

Figure 2: Left: Level of alertness as a function of time. Alertness decreases in the supine and upright positions. As can be seen on the right, the difference is not significant. No uncertainties were reported in the publication. Here, we assume the square root of the measured quantity as a reliable approximation for the uncertainty.

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11 Brenda Kim, "Sitting Up Straight can Improve Mental Focus," August 21, 2018, Labroots, https://www.labroots.com/trending/neuroscience/12469/sitting-straight-improve-mental-focus; Markus Muehlhan, "The Effect of Body Posture on Cognitive Performance: A Question of Sleep Quality," *Frontiers in Human Neuroscience* 8, no. 171 (2014), https://doi.org/10.3389/fnhum.2014.00171.

12 "Why we should make an Effort to Sit up Straight," Spectrum Health, September 30, 2024, https://www.spectrumhealth.ie/blog/why-we-should-make-effort-to-sit-up-straight.

13 For use of a multi-dimensional mood questionnaire, see Rolf Steyer et al., "Testtheoretische Analysen des Mehrdimensionalen Befindlichkeitsfragebogens (MDBF)" [Test-Theoretical Analyses of the Multidimensional Well-Being Questionnaire], *Diagnostica* 40 (1994).

14 Andreas Eckart, "Ibn Raḥīq's Text on the Milky Way: Perception of the Milky Way in the Early Islamic Society," *Arabic Sciences and Philosophy* 29, no. 2 (2019), https://doi.org/10.1017/S0957423919000055.

2.3 Science of Navigation

One could argue that Ibn Mājid was primarily a practitioner rather than a formal scientist, and therefore his navigational concepts should not be viewed as precursors to modern scientific methodology. However, this perspective overlooks the fact that navigation is – and has always been – a rigorous science. From a contemporary standpoint, navigation is defined by its reliance on empirical observation, complex mathematics, and iterative technology to solve the fundamental problem of positioning and guidance. It requires a sophisticated understanding of physical phenomena, ranging from celestial mechanics and spherical trigonometry to meteorology and oceanography. By synthesising these disciplines through the use of precise instruments, bathymetric charts (systematic depth measurements, especially in coastal regions), and dead reckoning (calculation distance from speed and travel time, see Paper I, section 3.7.3), navigation transforms raw environmental data into a systematic framework for safe and efficient travel.

Consequently, the methodology developed by Ibn Mājid within this maritime, intellectual environment is not merely "practical knowledge," but a structured application of the scientific method. His work exemplifies the transition from anecdotal traditions to systematised, reproducible data, which is the hallmark of science. As noted by Tibbetts in his definitive study of Arab navigation, Ibn Mājid's work represents a "scientific" approach to the sea, where traditional oral knowledge was codified into a written, analytical system that demanded constant verification against physical reality.[15]

Moving beyond technicality, it is valuable to examine Ibn Mājid through the lens of philosophical reflection. While he was not a theoretical philosopher in the Hellenistic or scholastic tradition, his approach aligns with that of a practical philosopher (i.e. someone who treats philosophy not as a library of abstract theories but as an operating system for life). His 'philosophy' was one of radical pragmatism, firmly rooted in the high-stakes reality of naval command. This nautical epistemology prioritised empirical truth and ethical responsibility, suggesting that for Ibn Mājid, the pursuit of navigational accuracy was inseparable from a broader intellectual commitment to understanding the natural world order.

In that framework he was following the tradition of *tajriba* (experiment) and *ikhtibār* (testing) as well as a heuristic illustration of *adab al-ʿālim* (scholar's etiquette) to establish empirical proof. Ibn Mājid's transition from a regional navigator to a globally recognised scientist and philosopher is evidenced by the Portuguese and Ottoman reliance on his work. Their reception of his texts confirms the universal value of his empirical methodology and its role in defining early modern intellectual enquiry.

Ibn Mājid occupies a unique position in history because he represents the transition from theory to application. While the earlier Islamic Golden Age (8th to 11th centuries) laid the mathematical and astronomical foundations, Ibn Mājid (late 15th century) was the 'practical philosopher' who turned those abstracts into a global navigational system.

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15 Tibbetts, *Arab Navigation in the Indian Ocean*.

2.4 Trial and Error – Trial and Repetition

The expression "trial and error" now has a firm place in science and is even frequently used in everyday life. The recent history of this expression (see references below) is closely linked to the development of evolutionary theory and epistemology. Before giving analysis, we summarise the origin of the more recent European and the older Arabic occurrence of a similar term (see Paper I, section 3.3).

Recent European sources: William Homan Thorpe[16] (1902–1986) is said to have introduced the term 'trial and error.' A further initiator of the theory of trial and error learning was Edward Lee Thorndike[17] (1874–1949). He based his findings on behavioural trial-and-error experiments with animals in the laboratory. The term was first used in biology by Herbert Spencer Jennings[18] and W. Holmes (1904/1905). Later, it was adopted and generalised in cybernetics by William Ross Ashby[19] (1903–1972).

According to W. H. Thorpe, the term was devised by Conwy Lloyd Morgan (1852–1936) in his "An Introduction to Comparative Psychology."[20] In this 1894 publication, the phrase "trial and error" occurs in several chapters (11, 12, 14 and 15). In chapter 14, the term "repeated trial and error" can be found. In fact, W. H. Thorpe reports in his "The Origins and Rise of Ethology" that C. Lloyd Morgan initially tried similar expressions like "trial and failure" and "trial and practice." Under the fundamental principle "Morgan's Canon," animal behaviour should be explained in a clear and straightforward way. He proposed simple learning through "trial and error" as an alternative to higher mental processes.

Arabic sources: Coinciding with the emergence of the expression "trial and error," interest in Arabian navigation and seafaring in the Indian Ocean increased. The Turkish Admiral Sidi 'Ali Çelebi wrote a book on navigation – largely based on Ibn Mājid's work. This was highlighted by the Italian orientalist Luigi Bonelli (1865–1947) in two publications.[21] Bonelli comments on the work of Sidi 'Ali Çelebi and quotes the Ottoman Turkish text extensively. In 1912, M. Gaudefroy-Demombynes (1862–1957) wrote a publication[22] in which he reported on two manuscripts (one of which is the MS2292) listed in the de Slane's Catalogue in the Bibliothèque Nationale in France. These contained the works of Ibn Mājid. At this

16 William Thorpe, *The Origins and Rise of Ethology* (Hutchinson, 1979), 26.

17 Edward Thorndike, *Animal Intelligence: An Experimental Study of the Associative Processes in Animals* (Columbia University Press, 1898).

18 Herbert Jennings, *Behavior of the Lower Organisms*, reprint (Indiana University Press, 1976). See also Herbert Jennings, *The Early Development of Asplanchna Herrickii de Guerne: A Contribution to Developmental Mechanics*, reprint (Nabu Press, 2011).

19 William Ashby, "The Physical Origin of Adaptation by Trial and Error," *Journal of General Psychology* 32 (1945).

20 Conwy Morgan. *An Introduction to Comparative Psychology* (The Walter Scott Publishing Co., 1894); George Mead, "Review of an Introduction to Comparative Psychology by C. Lloyd Morgan," *Psychological Review* 2 (1895).

21 Luigi Bonelli, "Del Muhit o o descrizione dei mari delle Indie" [Of the Ocean or the Description of the Seas of India], *Rendiconti d.R. Acc. d. Lincei* (1984); Luigi Bonelli, "Ancora del Muhit o descrizione dei mari delle Indie" [Once More of the Ocean or the Description of the Seas of India], *Rendiconti d.R. Acc. d. Lincei* (1895).

22 Maurice Gaudefroy-Demombynes, "Les sources arabes du Muhît" [The Arabic Sources of the Ocean], *Journal Asiatique* t.clxv. (1912).

point, the MS2292 manuscript had been in the Bibliothèque Nationale de France since 1860, i.e., for more than half a century. Unfortunately, it is not possible to know when and how many times this manuscript has been requested by readers at the Bibliothèque Nationale.[23] The Arabic text was then published by the orientalist Gabriel Ferrand (1864–1935) starting 1921,[24] also giving a translation and commentaries. Many other publications followed. A complete commented translation of the MS2292 version of Ibn Mājid's *Kitāb al-Fawā'id* was then given by G. R. Tibbetts in 1971/1981.

Analysis: The more recent concept of "trial and error" was developed in the context of ethological and psychological research (see references above); that is, the scientific observation of behaviour in animals and humans.

As our detailed study of *Kitāb al-Fawā'id* shows, already in the 15th century, Ibn Mājid developed his idea of the "trial and repetition" concept from observation of his fellow navigators, sailor comrades and maybe close inspection of the passengers. Instead of the more negative, fatalistic "trial and error" or "trial and failure" popularised by Conwy Lloyd Morgan, Ibn Mājid employs a more positive – albeit less dramatic – alternative: "trial and repetition." This mirrors Morgan's term "trial and practice." These latter two expressions align more closely with a practice-based validation of knowledge than the modern methodological label of "trial and error."

Hence, Ibn Mājid's concept of "trial and repetition" can be taken as a *direct equivalence* to the statement "trial and practice," as the two concepts carry the same meaning and can be swapped without losing information or meaning. However, with respect to the statement "trial and error," it could be seen as a *proto-concept*, i.e., early-stage, precursor of a way of thinking about how to solve a problem, particularly in navigation and seafaring.

As a sailor and navigator, he knew only too well that errors and failures in the application or acquisition of knowledge could be fatal. A maritime accident or even actual suffering could result in death and the loss of all transported goods. Sea voyages in Ibn Mājid's time were just as dangerous as space travel is today, and in both cases, "failure is not an option." It is interesting to note that the German word for ship accident is "havarie." This word derives from the Arabic عوار, *ʿawār*, "fault, damage" or even *ʿawārīyya*, "goods damaged by seawater."

To avoid damage, Ibn Mājid had to rely on perseverance and practice as a navigator. Therefore, every attempt and trial was based on prior knowledge or reasonable expectation to make sure the results did not necessarily lead to total failure. Therefore, he used the terms 'trial and repetition,' where the latter word can also be interpreted as 'practice.'

23 Personal communication, September 15, 2025, with M. Khalid Chakor Alami, Chargé des manuscrits arabes et persans, Bibliothèque nationale de France (BnF), Département des Manuscrits, 58, rue de Richelieu 75084 Paris Cedex 02.

24 Gabriel Ferrand, *Instructions Nautiques et Routiers Arabes et Portugais des XVe et XVIe Siècle: Reproduits, Traduits et Annotés* [Arab and Portuguese Nautical and Route Instructions of the 15th and 16th Centuries: Reproduced, Translated, and Annotated] (Libraire Orientaliste Paul Guenther, 1928).

This rigorous application of “trial and repetition” mirrors the ethical standards of *adab al-ʿālim* (scholar’s etiquette), in which intellectual precision was considered a moral imperative. Such an iterative approach proved essential for achieving the precision and exactness (i.e. correctness and reliability) required to solve complex problems. This concept is famously represented by the work of Badr al-Dīn ibn Jamāʿah (1241–1333).[25] Ibn Mājid’s work can clearly be labelled as part of the *tajriba*/*ikhtibār* tradition (experiment/testing) as represented by, e.g., Ibn al-Haytham[26] (Alhazen, c. 965–1040) in the field of optics and astronomy, Jābir ibn Ḥayyān[27] (Geber, c. 721–815) in the field of alchemy/chemistry, and Abū Bakr al-Rāzī[28] (Rhazes, c. 865–925) in the field of medicine.

Hence, Ibn Mājid and his predecessors during the Islamic Golden Age were united by a paradigm of empirical rigour. This ‘spirit’ was the transition from speculative philosophy to systematic observation, where truth was not just found in ancient texts, but validated through practical trial and error.

2.5 Methodological Doubt

One source of this prior knowledge was the knowledge passed down from ancestors (Paper I, section 3.7.1). This knowledge, however, could not be accepted uncritically but had to be carefully examined first.

Ibn Mājid’s fundamentally cautious and sometimes suspicious attitude towards his comrades, his ancestors, and even himself is entirely in line with the methodological doubt (also called Cartesian doubt) formulated two centuries later by René Descartes in his “Discours de la méthode” and first published anonymously in French in 1637. Descartes developed this method as a way to achieve absolute certainty in knowledge by systematically doubting all beliefs that are not completely certain and indubitable, ultimately aiming to establish a secure foundation for knowledge.

While Ibn Mājid only passes on newly developed and traditional knowledge after careful examination, the transmission of knowledge comes with a moral obligation. He will not only refrain from passing on potentially erroneous information (i.e. everything must be verified before passing it on), but he also always safeguards himself with the presence of a few expert comrades.

25 Badr al-Dīn ibn Jamāʿah, *Tadhkirat al-sāmiʿ wa-al-mutakallim fī adab al-ʿālim wa-al-mutaʿallim* [A Memorandum to the Listener and the Speaker on the Etiquette of the Scholar and the Learner], ed. Muḥammad Hāshim al-Nadwī (Al-Maktabah al-Tawfīqiyyah, 2014), 12–15. Badr al-Dīn ibn Jamāʿah was a prominent Islamic scholar, jurist, and educator of the Mamluk Empire. His most famous work, *Tadhkirat al-Sami’ wa-al-Mutakallim* (The Admonition to the Hearer and the Speaker), is a classic of Islamic educational science.

26 Ibn al-Haytham was a medieval mathematician, astronomer and physicist from present-day Iraq. He made significant contributions to the principles of optics and astronomy.

27 Jabir ibn Hayyan, known in the West as Geber, was a prominent Persian scholar who wrote in Arabic. He is considered the “father of chemistry” and influenced numerous disciplines, including alchemy, medicine, astronomy, and philosophy.

28 Abū Bakr al-Rāzī was a prominent Persian scholar, physician, and philosopher who wrote in Arabic. He is considered one of the greatest clinicians of medieval medicine and a pioneer of empirical research.

Descartes used methodical doubt to create a systematic philosophical worldview from the simplest principle. In Ibn Mājid's case, systematic doubt, which he applied to all the information he had acquired from his ancestors and to the newly developed navigation methods, was the reason to examine everything thoroughly, so it was not accepted uncritically or even passed on. Ibn Mājid's form of methodical doubt is also more practice-oriented than that of Descartes. It is even oriented psychologically in his assessment of his comrades. His goal is not to construct a comprehensive philosophical worldview, but to build a comprehensive pool of verified navigational knowledge that will benefit the profession, passengers, and success of trade missions.

In this context, we also must mention Al-Ghazālī's[29] (1058–1111) philosophical doubt, detailed in his work *al-Munqiḏ min aḍ-ḍalāl* (Deliverance from Error). Among other aspects, it originated from questioning the reliability of sensory perception and intellectual reasoning. He famously expressed doubts about sensory perception, arguing that the senses could be deceived and can be deceiving. He cites as an example the seemingly stationary shadow, which later turns out to be moving with the sun's changing position. He then extended his doubt to the intellect. Doubting the reality of dreams, he speculates that one's entire waking experience could be a dream, rendering the primary truths of the intellect unreliable as well. Ibn Mājid does not go that far. As a pragmatic pilot, he doubts the sources of knowledge, but after careful investigation, he preserves a wealth of useful information in a way that it then can be used for hands-on navigation.

While distinction must be drawn between the two concepts, we should avoid equating Ibn Mājid's approach with Cartesian doubt. While Descartes' methodological doubt is a systematic epistemological project aimed at foundational certainty, Ibn Mājid's approach emerges as a form of professional caution and source criticism born from a high-stakes navigational environment. He does not articulate "doubt" as an abstract philosophical end, but as a rigorous verification practice necessitated by the Red Sea and Indian Ocean contexts.

However, Ibn Mājid's practice-based approach also contains a significant degree of generality. As established in Paper I, his doubt extends beyond astronomical and nautical measurements to encompass the entire sociology of knowledge: he critically assesses the transmission of maritime traditions, the classification of pilots into different types, the varying mathematical and astronomical competencies of his peers, and even the "ergonomics" of the navigator's physical posture to ensure the repeatability of results (see Paper I, sections 3.4, 3.5, 3.6 and 3.7).

By integrating these nautical, astronomical, and social variables into a unified system of verification, Ibn Mājid's work functions as a *proto-concept* of the modern version of methodological doubt. It represents the "seed" of intellectual rigour, an ancestor that contains the essentials of modern methodological doubt, while remaining deeply rooted in its

[29] Al-Ghazālī was a Muslim scholar and polymath. He was one of the most prominent and influential philosophers and theologians in Islamic history.

historical and practical contextualisation (see comments on 'naturalisation and locality' in the following section).

2.6 Ibn Mājid in the Philosophical Environment

Arab scholars made significant contributions to knowledge transfer through their translation movement and research. Some of the most well-known scholars who have written about the nature of knowledge transfer or contributed to it through their work need to be mentioned. In comparison to them, Ibn Mājid stands out for his application-oriented analysis of the transfer of knowledge across generations or from a few (sailors or boat crews) to larger groups of people (mostly navigators like himself). Ibn Mājid's methodological approach to test knowledge fits well with classical Arabic philosophy.

Ibn al-Haytham emphasises the importance of experimentation and observation in his work "Kitāb al-Manāzir" (Book of Optics). In *Kitāb al-Manāzir*, Ibn al-Haytham describes his experimental method and emphasises the importance of observation and experimentation in investigating the nature of light and visual perception. He criticises the blind acceptance of authority and conducts numerous experiments to test his theories and gain new insights.

Ibn al-Haytham's work reflects a balance between grateful acceptance and critical assessment of observational data. In his manuscript on the Milky Way's distance,[30] he praises Ptolemy and uses his data on stellar distances from the edge of the Milky Way to estimate their parallaxes and hence the distance to the figure of the Galaxy in the sky. Ibn al-Haytham mentions Ptolemy explicitly as an honourable researcher, noting that if Ptolemy had found a parallax, he would have mentioned it in his work *Almagest*. Later, in his book "The Resolution of Doubts Concerning the Almagest," Ibn al-Haytham critically evaluates Ptolemy's work on lunar motion. Hence, Ibn al-Haytham shows a way of critically dealing with data and observations that is comparable to Ibn Mājid.

Al-Fārābī[31] (c. 872–950) identifies two approaches to the comprehension of faith.[32] The first is for "enlightened, wise men or philosophers" based on reason, proof, and logic. The second approach is for the common people, containing only vague representations of the information. Wise men or the elite pass the acquired knowledge on to those who follow and trust them. The followers of the wise receive the most authentic knowledge. The rest are left behind and far from understanding the essence. In the case of Ibn Mājid, one can argue that the chosen ones are represented by the community of colleagues and navigators in front of which he discusses knowledge or proclaims new information.

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30 See Andreas Eckart, "The Early Great Debate: A Comment on Ibn Al-Haytham's Work on the Location of the Milky Way with Respect to the Earth," *Arabic Sciences and Philosophy* 28, no. 1 (2018), https://doi.org/10.1017/S0957423917000078; Andreas Eckart and Mesut Idriz, "Knowledge of the Milky Way in the Arabic Cultural Region between the 8th and the 15th Centuries," *Australian Journal of Islamic Studies* 8, no. 3 (2023), https://doi.org/10.55831/ajis.v8i3.637.

31 Al-Fārābī was an outstanding philosopher from present day Iraq, who combined Greek philosophy with Islamic theology. His works contributed to the interpretation and development of philosophical and scientific works.

32 Peeter Müürsepp et al., "The Being of Science in Al-Farabi's Philosophy", *Acta Baltica Historiae et Philosophiae Scientiarum* 12, no. 2 (2024), https://doi.org/10.11590/abhps.2024.2.06.

Ibn Sīnā[33] (980–22 June 1037) discusses the transfer of science in general terms.[34] He is interested, for example, in how information from one science may be put forward to another science, described as *naql al-burhān* (نقل البرهان) or transfer of proof (evidence). He mainly discusses how these pieces of evidence from different research fields can interact with each other. In "Al-Shifā'" (The Healing), Ibn Sīnā takes a systematic approach to scientific research,[35] based on observation, experiment, and induction. This approach is also largely followed by Ibn Mājid.

In *Tahāfut at-Tahāfut* (The Incoherence of the Incoherence), Ibn Rushd[36] (1126–1198) strongly attacked al-Ghazālī's *Tahāfut al-Falasifa* (The Incoherence of the Philosophers), a work in which the 12th century theologian al-Ghazālī sought a strengthening of piety by attacking philosophers. Ibn Rushd, point by point, discusses the "alleged" errors in al-Ghazālī's views and methodology. He affirms that the evidence brought by al-Ghazālī's attack on philosophers arises when isolated components of philosophy are taken out of context, appearing to contradict the remainder. As in the case of Ibn Mājid, this debate is dominated by doubts about the statements of a group of individuals (here, philosophers rather than navigators or sailors), and only detailed, repeated analysis promises to bring clarification.

These comparisons show that Ibn Mājid's methodological approach to examining the acquisition and transmission of knowledge is embedded in the approach of leading philosophers from the Arab world.

Addressing the process of "naturalisation,"[37] it is evident that Ibn Mājid's work is deeply embedded within the Islamic culture. Islamic culture during the Golden Age was characterised by a dynamic synthesis of faith and reason, rooted in the pursuit of *ʿilm* (knowledge). Hence, Ibn Mājid and his predecessors were united by a paradigm of empirical rigour. This 'spirit' represented a cultural transition from speculative philosophy to systematic observation, where truth was not just found in ancient texts, but validated through practical trial and error. This atmosphere turned the Islamic world into a 'testing ground' where the classical heritage of the past was not merely preserved, but actively interrogated and refined through a lens of utility and precision. In his introduction to "Arab Navigation in the Indian Ocean before the Coming of the Portuguese," G. R. Tibbetts provides a list of 14

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33 Ibn Sīnā (aka Avincenna) was a versatile scholar who wrote works on medicine, philosophy, and natural sciences. His works, such as the "Canon of Medicine," were later translated into Latin and influenced the European Renaissance.

34 Jules Janssens and Ku Leuven, "A New Encompassing Theory of Science in Ibn Sīnā," *International Journal on the Transfer of Knowledge* 9 (2024), https://doi.org/10.21071/mijtk.v9i.16899.

35 Ibn Sīnā, "al-Shifā', al-Burhān," II [The Healing, The Proof], 8, 169, 4–15. English translation and explanation in Riccardo Strobino, *Avicenna's Theory of Science: Logic, Metaphysics, Epistemology* (University of California Press, 2021), 259–60, Texts 10.6–10.7.

36 Ibn Rushd (Averroes), from Cordoba in Al Andalus, was an important commentator on the works of Aristotle. He attempted to harmonise Aristotelian philosophy with Islam and emphasised the importance of reason and logical analysis.

37 For example, Abdelhamid Sabra, "The Appropriation and Subsequent Naturalization of Greek Science in Medieval Islam: A Preliminary Statement," *History of Science* 25, no. 3 (1987), https://doi.org/10.1177/007327298702500302.

references quoted and used in *al-Fawa'id*.[38] With the exception of Ptolemy's *Almagest*, all are sourced from the Arabic-Islamic cultural domain, including works by Naṣīr al-Dīn al-Ṭūsī[39] (1201–1274), Abū al-Ḥasan al-Ṣūfī[40] (903–986), and Abū Ḥanīfa al-Dīnawarī[41] (c. 815–895).

Following Sabra's emphasis on contextualisation and locality,[42] one can argue that Ibn Mājid's navigational science, his concept of "trial and repetition" and the methodological doubt were an inherently local development. Rather than passive inheritance of past developments or Greek sources, his work in *al-Fawā'id* represents active appropriation of knowledge, specifically forged by the unique sociological and physical demands of navigating the Indian Ocean and Red Sea. In this light, his text is not a mere transmission of data but a creative response to his historical and local geographic contexts.

By situating Ibn Mājid within the *tajriba*/*ikhtibār* tradition, this paper contributes to the investigation into what sparked the Islamic Golden Age – an era defined by a paradigm of empirical rigour. This commitment to verification over mere tradition fuelled advancements in science and navigation, demonstrating how Muslim scholars forged an intellectual sovereignty that contributed to the foundations of modernity.

2.7 Transfer of Knowledge from Arabic Sources

There are multiple examples of potential transfer of knowledge and ideas from Arabic sources into Western science and philosophy. Some are solid and others are based on speculation.

Based on evidence, there is substantial overlap between elements of the work of Copernicus and those from Arabic sources three centuries earlier. This concerns the Ṭūsī Couple, the phonetically identical labelling of points in one of Copernicus' diagrams, and the so called *'Urdi Lemma* that he used.

The Ṭūsī Couple is a geometrical construct that takes its name from the famous astronomer and polymath Naṣīr al-Dīn al-Ṭūsī, who first proposed it in 1247.[43] He later formalised and proved it in 1259. This construct involves two nested circles that help to describe the elliptical figure shape of planetary orbits.

In the early seventies of the 20th century, the German historian of science Willy Hartner drew attention to the fact that even the naming of geometric points employed in a diagram

38 Tibbetts, *Arab Navigation in the Indian Ocean*, 39–41.
39 Naṣīr al-Dīn al-Ṭūsī was a Persian scholar, among other skills, experienced in astronomy and mathematics.
40 Abū al-Ḥasan al-Ṣūfī was a leading Persian astronomer and mathematician famous for his "The Book of Fixed Stars (Kitāb ṣuwar al-kawākib)."
41 Abū Ḥanīfa al-Dīnawarī was a famous astronomer, geographer and historian.
42 Sabra, "The Appropriation and Subsequent Naturalization of Greek Science."
43 George Saliba, "The Role of the Almagest Commentaries in Mediæval Arabic Astronomy: A Preliminary Survey of Tusi's Redaction of Ptolemy's Almagest," *Archives Internationales d'Histoire des Sciences* 37 (1987).

preserved in the Copernican works were phonetically identical to the same geometric points used in the diagram employed by al-Ṭūsī three centuries earlier.

The second theorem concerns the *'Urdi Lemma*, called after Mu'ayyad al-Din al-'Urdi (d. 1266) who first proposed it before 1250,[44] about three centuries earlier than Copernicus. The only difference is that in the work of 'Urdi, the theorem is introduced with full formal mathematical proof, while in Copernicus' works it was taken for granted and left without any such proof.[45]

Another famous example for the information flow from Arabic sources is the speculation on transfer of ideas from al-Ghazālī to René Descartes' proof. There is fundamental similarity between the two philosophies in the sense that they both use a radical form of scepticism, or doubt, in order to arrive at a foundational certainty. Both philosophers question all previous knowledge, yet they emerge from this doubt with a foundational certainty of their existence: Al-Ghazālī bases his existence on that of God and Descartes bases it on his thinking self. Descartes had close relationships to some of the Orientalists in or around Paris at that time (e.g. Jakob Golius, 1596–1667) who either owned copies of al-Ghazālī's work *al-Munqiḏ min aḍ-ḍalāl* (Deliverance from Error)[46] or had direct access to it. Part of al-Ghazālī's work was also already available through other sources. So, it is conceivable that Descartes directly or indirectly heard about al-Ghazālī's thoughts.

In the case of establishing the concept of "trial and error," the indication for information transfer from Arabic sources is much less clear or can even be excluded. Although in 1894, when Conwy Lloyd Morgan published his results, Ibn Mājid's *Kitāb al-Fawā'id* had been in the repositories of the Bibliothèque Nationale de France for over 30 years, the information on Ibn Mājid's work only slowly percolated into the scientific community of the late 19th century (initially through Ottoman sources). However, it cannot be fully excluded that some of Ibn Mājid's thoughts were discussed in the faculties and clubs of that time.

Ibn Mājid's *al-Fawā'id* was widely recognised and highly influential within the Arab-Islamic seafaring community. Born around 1432, the productive author Ibn Mājid still represents the classical phase of Islamic science (The "Golden Age" starting about 750 and ending with the sack of Baghdad by the Mongols in 1258). This period predates the post-classical era (approx. 1200–1800), which is characterised by Ahmed El-Shamsy as a time of intellectual decline and the "disappearance of books" – long before the subsequent revival of the Islamic written tradition.[47]

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44 George Saliba, *The Astronomical Work of Mu'ayyad al-Din al-'Urdi: A Thirteenth-Century Reform of Ptolemaic Astronomy* (Center for Arab Unity Studies, 1990), 31–36.

45 Anthony Grafton, "Michael Maestlin's Account of Copernican Planetary Theory," *Proceedings of the American Philosophical Society* 117 (1973).

46 Abū Ḥāmid al-Ġazālī, *Deliverance from Error*, trans. W. Montgomery Watt, ed. Richard J. McCarthy (Westminster Press, 1990).

47 Ahmed El-Shamsy, "The Social Life of Books: For Shifts in Islamic Intellectual History and Scholarly Culture," in *The Book in the Islamic World: The Written Word and Communication in Middle Eastern Societies*, ed. George N. Atiyeh (State University of New York Press, 1995); Ahmed El-Shamsy,

What is most striking here is the similarity between the earlier version of the term "trial and practice" used by Conwy Lloyd Morgan in 1894 (see references above), or his later use of the phrase "repeated trial and error" with Ibn Mājid's words: "trial and repetition." However, the observation is so fundamental and straightforward that the concept may have been developed independently. In Morgan's case, it stems from the observation of the behaviour of animals; in Ibn Mājid's case it originated from the observation of fellow navigators and sailors.

Even following the traditional "Golden Age" of Islamic science, Ibn Mājid's work exemplifies the continued flourishing of scientific production into the 15th and 16th centuries. As George Saliba argues,[48] this period was not one of decline but of sophisticated original work. Ibn Mājid's legacy had a tangible impact on the European Renaissance and beyond, as his maritime expertise was well known to the Portuguese explorers who navigated the Indian Ocean during this era.

Hence, our study underscores how the global transformation triggered by Muslim scholarly achievements laid the essential foundations for modernity, which is a historical reality frequently overlooked in Eurocentric narratives of "modernity." By positioning Ibn Mājid within the *tajriba* tradition, this section aligns with the AJIS Special Issue's focus on the Islamic Golden Age. Our work supports that the transition to systematic, empirical observation was not merely a regional success but a catalyst for the scientific and navigational shifts that eventually reshaped the world, asserting that the roots of modern progress are deeply embedded in this – without doubt – timeless Islamic intellectual heritage.

The biggest difference between Arabic and more recent Western sources, however, is the possibility of publication in print. This enabled the rapid and worldwide spread dissemination of information.

3. SUMMARY AND CONCLUSIONS

In this study we have demonstrated that the concepts comparable to those of "trial and error" and "methodological doubt," often attributed to Conwy Lloyd Morgan in the 19th century and René Descartes in the 17th century, respectively, were also developed and applied by the Arabian navigator Ibn Mājid over 200 years earlier in his seminal work *Kitāb al-Fawā'id*. We studied essential passages from this book and have shown how Ibn Mājid incorporated these concepts into his navigation practices.

"Trial and error" (also known as "trial and practice" or "trial and repetition") is a fundamental method of problem-solving (particularly in the field of natural sciences and

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Rediscovering the Islamic Classics: How Editors and Print Culture Transformed an Intellectual Tradition (Princeton University Press, 2020), 45–60, https://doi.org/10.23943/princeton/9780691174563.001.0001.

48 George Saliba, "The Role of the Astrologer in Medieval Islamic Society," in *The Book in the Islamic World: The Written Word and Communication in Middle Eastern Societies*, ed. George N. Atiyeh (State University of New York Press, 1995); George Saliba, "For the History of Applied Sciences and the 'Golden Age' Debate," *The Fountain* 41 (2003): 24; George Saliba, *Islamic Science and the Making of the European Renaissance* (MIT Press, 2007), 121–30.

technological development – but not exclusively if one sees 'trial and error' as an iterative process of interpretation and refinement, moving from tentative hypothesis to a more nuanced understanding of human culture and thought) where individuals learn through repeated attempts and corrections. While it is not a scientific method in the classical sense, "trial and error" can be a component of scientific enquiry (see above comment on it as an iterative process of treating information and resulting cognition or epistemological insight). Here, it is helpful in fields like hypothesis testing, improvement of experimental design or iteration and refining theories and procedures. This is the way Ibn Mājid uses this concept of "trial and repetition" in his *Kitāb al-Fawā'id* to probe passed down and newly obtained navigational knowledge.

Methodological doubt, also known as Cartesian doubt, is a philosophical approach developed in the Western world by René Descartes. It involves systematically questioning one's beliefs and assumptions to establish a foundation for knowledge. In science, methodological doubt is helpful in promoting critical thinking, questioning assumptions as well as establishing foundations for knowledge. All these concepts converge within the praxis-oriented philosophical framework of Ibn Mājid's navigation and maritime environment. The way he expresses doubts about his ancestors, fellow navigators and sailor comrades is used to generate a well-tested fundus of navigational knowledge that can be passed down to other navigators and interested people.

We have shown how the psychological and physiological properties of the observer/ navigator are integrated into scientific procedures for astronomical and nautical measurements, calculations, and knowledge transfer in general. Although Ibn Mājid is not known as a philosopher, we can situate him and his work within the scientific and philosophical context of this time. Hence, our research highlights the contributions of Arabian scholars to the development of navigation and scientific thought.

Ibn Mājid's work on navigation, his methodological concepts of "trial and repetition" as well as his systematic scepticism in judging people and scientific data definitely contributed to highlighting the golden era of knowledge and discovery across the Muslim world encompassed by the Indian Ocean and Red Sea in the 15th century and beyond. This paper contributes to sociological aspects of the Islamic Golden Age by demonstrating that Ibn Mājid's methodology (in handling information – passed down and newly obtained – and in his systematic scepticism toward the accounts of his seafaring contemporaries) was not an isolated phenomenon, but a product of the sociological conditions of the 15th century Indian Ocean world. His reliance on 'trial and repetition' and 'systematic scepticism' reflects a culture of enquiry where intellectual authority was decentralised and based on empirical performance rather than static tradition. By examining the Red Sea and Indian Ocean as a 'sociological laboratory,' this work illustrates how Muslim scholarly advancements were sustained by a maritime network that was motivated to act with and strive for precision in a framework of evidence-based discovery. Furthermore, we argue that this sociology of knowledge – characterised by the interrogation of data and rejection of unverified testimony

– served as a crucial bridge to modern scientific rigour, thereby situating Ibn Mājid as a key figure in the global transformation that defines the Islamic Golden Age's enduring heritage.

The reception of his work by the Portuguese and, subsequently, the Ottomans demonstrates the far-reaching influence of his empirical investigations as they transitioned toward the early modern era.

The integrity and transparency he displayed in his dealings with contemporary seafarers embody the high moral standards and ethical ideals of the Islamic scholarly tradition and follows the tradition of *tajriba* (experiment) and *ikhtibār* (testing) to establish empirical proof. Ibn Mājid's professional integrity serves as a heuristic illustration of *adab al-ʿālim* (scholar's etiquette) applied to the maritime world, reflecting the high moral standards of the Islamic scholarly tradition. His interactions with colleagues and strictly hierarchical classification of navigators constitute a deep window into the social fabric of the maritime community during and beyond the Islamic Golden Age.

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