

# Cultivating Mathematical Thought: A Comparative Analysis of Islamic Scholars and Their Educational Networks, Past and Present

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## Abstract

This paper explores the educational trajectories and intellectual development of eight influential Muslim mathematicians, four from the Islamic Golden Age and four from the modern era, through a comparative qualitative analysis. It examines how diverse educational networks, mentorship structures, and institutional environments shaped mathematical thought across time. By analyzing both the continuities and divergences in how knowledge was transmitted, the study highlights a shift from manuscript-based, interdisciplinary learning to specialized, globally connected academic systems. The findings offer insight into how classical Islamic approaches to mentorship, holistic inquiry, and communal knowledge-sharing can inform contemporary educational and scientific practices.

## Keywords

Educational Networks, Historical Comparison, Islamic Mathematics, Mathematicians

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## 1. Introduction

The intellectual flourishing of medieval Islamic civilization saw the cultivation of mathematical genius through vibrant educational networks, institutional patronage, and an epistemological worldview deeply grounded in unity, symbolism, and rational inquiry. Mathematics strongly appealed to Muslim thinkers because its abstract nature offered a way to connect the diversity of the physical world with

the concept of divine unity, serving as a symbolic language to understand the structure of the universe. Within Islamic tradition, two main types of mathematics developed: one focused on algebra and its close relationship with geometry and trigonometry, and the other, rooted in Pythagorean thought, viewed numbers not only as quantitative tools but also as symbols reflecting deeper metaphysical truths that ultimately point back to a unified source (Nasr, 2003).

Muslims pursued mathematics and astronomy initially to fulfil religious needs; using geometry to determine the direction of Mecca, arithmetic and algebra for inheritance calculations, and astronomy to identify key religious dates like Ramadan, but their engagement with these sciences also led to significant developments in areas such as trigonometry, advanced geometry, and the symbolic interpretation of numbers, contributing to broader intellectual and cultural progress (Al-Daffa', 2016). Educational systems shaped by regional traditions, supported by waqf endowments and scholarly networks, gently fostered the continuity and sharing of mathematical knowledge across generations and changing dynasties (El Hour, 2025).

This study examines the educational trajectories of eight influential Muslim mathematicians across two historical periods. The classical figures; Al-Khwarizmi, Al-Battani, Ibn Khaldun, and As-Samaw'al al-Maghribi, represent the intellectual vibrancy of the Islamic Golden Age, while the modern scholars; Maryam Mirzakhani, Yahya Ould Hamidoune, Nader Masmoudi, and Chehrzad Shakiban, reflect contemporary mathematical achievement within global academic systems. By focusing on their intellectual formation and the educational environments that shaped their development, this study seeks to compare the pedagogical structures, mentorship traditions, and scholarly networks that fostered mathematical innovation across centuries. In doing so, it highlights the evolving role of educational ecosystems in cultivating mathematical thought within Islamic contexts, both past and present.

## 2. Literature Review

Previously, Islamic mathematicians advanced in key fields such as algebra, geometry, and trigonometry, applying mathematics to practical needs in religion, navigation, map-making, art, trade, and governance. Their work supported religious observance by calculating prayer times and contributed to economic systems through measurement and taxation. Beyond practical use, mathematics became a foundation for philosophical inquiry, and Muslim scholars also played a key role in preserving and transmitting global mathematical knowledge, including adapting Indian numerals into the system used today (Lewis, 2020). In contrast, modern Muslim mathematicians often pursue mathematics within formal academic institutions driven by intellectual curiosity, global research challenges, and the pursuit of innovation (Dramanu & Asamoah-Gyimah, 2023) in fields such as theoretical physics, computer science, and applied mathematics, excelling due to increased access to international education, research funding, and collaborative

networks.

## 2.1. Classical Muslim Mathematician Scholars

### 2.1.1. Al-Khwarizmi

Al-Khwarizmi is recognized as a foundational figure in the history of mathematics and computation due to his formalization of algebra and early development of algorithmic thinking (Elamin, 2024). His work, particularly in *The Compendious Book on Calculation by Completion and Balancing*, introduced a structured method for solving equations that laid the groundwork for modern algebra and computational procedures (Saputra, 2022). At the House of Wisdom in Baghdad, he helped systematize the use of Hindu-Arabic numerals, including the concept of zero, which revolutionized arithmetic across cultures (Muhtar, 2014). The Latin translation of his works introduced terms like “algorismus” into Europe, directly influencing the development of algorithms and number systems used today (Saputra, 2022). His interdisciplinary approach, spanning mathematics, astronomy, geography, and calendar studies, reflects a holistic educational environment rooted in rational inquiry and religious integration (Muhtar, 2014). Scholars note that his logical reasoning and openness to abstract mathematical concepts, like zero and negative numbers, were tied to theological principles and philosophical depth (Elamin, 2024). Al-Khwarizmi’s legacy continues to be relevant in modern computational fields, particularly in artificial intelligence and algorithmic design.

### 2.1.2. Al-Battani

Al-Battānī (Albategnius) made significant contributions to astronomy and mathematics, particularly through his seminal work *Zīj al-Sābit*, which offered refined models of the solar year, planetary motions, and eclipses (Abdul Latif, 2011). His calculations corrected several of Ptolemy’s errors and demonstrated a high level of observational precision across decades. He pioneered the use of trigonometric functions; sine, cosine, tangent, and cotangent in astronomy, replacing older chord-based systems and laying the foundation for modern trigonometry (Abdul Latif, 2011). His innovations in spherical trigonometry, including the sine law, were essential for astronomical calculations such as predicting solar and lunar eclipses. Al-Battānī’s works were later translated into Latin and became influential among European astronomers, including Copernicus and Kepler. Al-Battānī served as a crucial bridge between classical Greek astronomy and the scientific advancements of the Renaissance, distinguished by his methodological accuracy and reliance on empirical observation. His legacy exemplifies the intellectual sophistication and scholarly infrastructure that defined scientific pursuits in the Islamic Golden Age, where rigorous study was supported by institutions that fostered the transmission and development of knowledge (Mollah, 2024).

### 2.1.3. Ibn Khaldun

Ibn Khaldun’s exposure to mathematics was deeply interwoven with his broader

study of rational disciplines, notably through his teacher al Abili, that not only grounded Ibn Khaldun in fiqh and kalam but also instructed him in the philosophic and mathematical sciences, discoveries that shaped his early intellectual formation (Irwin, 2018). Ibn Khaldūn lays out seven rational sciences, placing logic (Mantīq) at the summit, followed by the mathematical sciences, namely arithmetic, geometry, cosmography (astronomy), and music, before proceeding to natural sciences and theology (Çetinkaya, 2017). Particularly notable is how music is recognized as a mathematical science: it is defined through its analysis of numerical relationships, especially in tuning and melody, and involves methods of measurement, emphasizing correlation between sounds and structured mathematical ratios (Dajani, 2015). The discipline's utility, as Ibn Khaldūn views it, lies in facilitating proper control and understanding of musical range and melody.

#### **2.1.4. As-Samaw'al Al-Maghribī**

As Samaw'al al Maghribī made significant contributions to algebra by proving important algebraic identities for specific cases and systematically expanding binomial expressions. He also developed an early version of Pascal's triangle, using diagrams and an early form of mathematical induction to understand patterns in binomial coefficients (Bajri, 2011). Ibn Khaldūn emphasized the importance of mathematics, particularly geometry, in cultivating clear and disciplined thinking. He regarded mathematical sciences as essential for intellectual development and moral character, highlighting their role in fostering precise reasoning and ethical conduct (Baga, 2017). He established foundational rules for understanding positive and negative numbers, introducing the concepts of excess and deficiency (Rogers, 2008). Additionally, he provided systematic methods for manipulating powers and developed instructional charts to guide readers through multiplication and division of both simple and complex algebraic expressions. Notably, his work on dividing complex polynomials marked a significant advancement in algebra, employing a step-by-step procedure with organized charts to facilitate the calculation process.

## **2.2. Modern Contemporary Muslim Mathematician Scholars**

### **2.2.1. Maryam Mirzakhani**

Maryam Mirzakhani's work in mathematics, particularly in the study of Riemann surfaces and moduli spaces, led to groundbreaking insights into the geometry and dynamics of these structures (Clay Mathematics Institute, 2008). Her research bridged multiple disciplines, including hyperbolic geometry, complex analysis, topology, and dynamical systems, providing a deeper understanding of the symmetry of curved surfaces such as spheres and hyperbolic objects (Agarwal, Shah, & Venkataraman, 2018). Her work exemplified curiosity-driven pure mathematics, motivated by a deep desire to understand fundamental structures in research that, while rooted in theoretical exploration, holds potential implications for physics, engineering, cryptography, and beyond (Carey, 2014). In 2014, Maryam Mirzakhani became the first woman and the first Iranian to be awarded the Fields

Medal, the most prestigious honour in mathematics, for her significant contributions to the dynamics and geometry of Riemann surfaces and their moduli spaces (Rezgui, 2023). Her groundbreaking work has been widely recognized as a milestone not only in mathematical research but also in challenging gender barriers within the field, inspiring broader inclusion in the mathematical sciences.

### **2.2.2. Yahya Ould Hamidoune**

Yahya's deep engagement with strategic games, including national-level Mauritanian draughts (Srand or Dhamet), chess, bridge, and backgammon, not only sparked his interest in abstract game theory but also laid the groundwork for his early research in graph connectivity and combinatorial structures. This playful foundation eventually evolved into his pioneering use of the isoperimetric method in additive combinatorics, where he reframed classical results in additive number theory through the lens of graph connectivity, bridging his passion for games with groundbreaking mathematical innovation (Plagne, Serra, & Zémor, 2013). Yahya Ould Hamidoune authored approximately one hundred research papers, with major contributions spanning additive number theory, graph theory, and combinatorics, including landmark results such as the proof of the Erdős-Heilbronn conjecture and a Freiman-Kneser-type theorem for nonabelian groups. His work not only advanced understanding in areas like Cayley graph topology, zero-sum problems, and the Waring problem over finite fields but also earned him the Prix Chinguitt for his impact on additive number theory (Diagana, 2012).

### **2.2.3. Chehrzad (Cheri) Shakiban**

Chehrzad "Cheri" Shakiban, who arrived in the United States as a refugee from Iran, went on to earn a PhD in mathematics from Brown University in 1979, becoming the first Iranian woman to achieve this distinction. She later became the first Iranian woman appointed as a full Professor of Mathematics, and in recognition of her academic contributions, was awarded an honorary Doctor of Science degree by Heriot-Watt University in 2024 (Philip, 2024). She has contributed to applied mathematics through her work in calculus of variations, fractal geometry, and computer vision, particularly in developing differential invariant signature curves for object recognition (Riddle, n.d.). She is also co-author of Applied Linear Algebra, a widely used textbook that integrates theoretical concepts with real-world applications in numerical methods and dynamical systems.

### **2.2.4. Nader Masmoudi**

Professor Nader Masmoudi, a leading mathematician affiliated with NYU Abu Dhabi, has authored over 160 research papers spanning fluid dynamics, dispersive equations, and homogenization of elliptic problems, with more than 80 of these appearing since 2012 in premier mathematics journals. He was awarded the 2022 King Faisal Prize in Science for his groundbreaking contributions to mathematical stability theory and dynamical systems, particularly his insights into the validity and long-term behaviour of Euler's fluid dynamics equations (Khaleej Times,

2022). He received the Fermat Prize in 2017 in recognition of his profound and innovative contributions to the analysis of nonlinear partial differential equations, particularly for providing a rigorous and comprehensive resolution to longstanding hydrodynamic stability problems originally posed in the late 19th century by the pioneers of modern fluid mechanics (Tunisian Monitor Online, 2021).

### 3. Methodology

This study adopts a comparative qualitative research design to examine the mathematical contributions of four prominent classical Muslim mathematicians (from the Islamic Golden Age) alongside four influential Muslim mathematicians from the 20th and 21st centuries. The objective is to identify the different educational networks they encounter.

#### 3.1. Selection Criteria

The selection of mathematicians for this study was guided by three main criteria: recognized influence within their respective historical or contemporary contexts; documented contributions to mathematics as evidenced in peer-reviewed literature or historical mathematical treatises; and cultural or religious self-identification as Muslim, or acknowledgment of their work within established Muslim scholarly traditions. Priority was given to individuals whose mathematical work had a discernible impact on subsequent generations, either through direct scholarly transmission or integration into educational systems. Care was also taken to ensure a balance of geographic and disciplinary diversity, representing various branches of mathematics and regions within the broader Islamic world. This approach supports the broader aim of the study, to trace not only mathematical innovations, but also the educational and intellectual networks that sustained them across different periods and contexts.

The classical mathematicians include Al-Khwarizmi, Al-Battani, Ibn Khaldun and As-Samaw'al al-Maghribi. The modern figures include Maryam Mirzakhani, Yahya Ould Hamidoune, Nader Masmoudi, and Chehrzad Shakiban. These individuals were chosen not only for the significance of their mathematical contributions but also for the extent to which their work reflects the broader intellectual, cultural, and institutional contexts of their time. Their inclusion allows for a cross-temporal analysis of how mathematical thought was cultivated, transmitted, and evolved within Islamic scholarly traditions across different eras.

#### 3.2. Data Collection

Primary data for the historical figures were obtained from translated mathematical manuscripts, historical commentaries, and scholarly analyses that contextualize their contributions within the Islamic Golden Age. For contemporary mathematicians, information was collected from peer-reviewed journal articles, biographical and bibliometric databases, as well as institutional websites, interviews, academic profiles, and records from prize-awarding organizations. These diverse

sources ensured a comprehensive understanding of each mathematician's work, influence, and the educational or institutional environments in which they operated. This multi-source approach allowed for both depth and accuracy in documenting their mathematical legacies.

### 3.3. Analytical Framework

This study employs a comparative thematic analysis to explore how mathematical knowledge was acquired, nurtured, and transmitted by Islamic scholars across two distinct periods: the classical era and the modern era. The analysis focuses on educational pathways, mentorship networks, and institutional contexts that influenced each mathematician's intellectual development. Central themes include methods of knowledge transmission—such as oral teaching, manuscript study, and formal academic training, alongside the role of scholarly communities and socio-political factors shaping learning environments (Saliba, 2011).

For classical mathematicians, the focus is on traditional educational structures including madrasas, libraries, and scientific academies (e.g., Bayt al-Hikma), as well as the systems of patronage and intercultural exchange that supported scholarly endeavours (Saliba, 2011). These institutions facilitated knowledge transfer through close teacher-student relationships and manuscript circulation, crucial for the preservation and expansion of mathematical ideas (El-Rouayheb, 2010).

In contrast, contemporary mathematicians are analyzed within the framework of modern academic institutions, global research collaborations, and formalized graduate education systems that often transcend national boundaries (Phillips & Schweisfurth, 2014). This shift reflects the professionalization and internationalization of mathematical research, where institutional affiliations, peer-reviewed publications, and international conferences play key roles in knowledge dissemination.

By comparing these two groups, the study identifies both continuities and transformations in the cultivation of mathematical thought within Islamic scholarly traditions, highlighting a movement from manuscript-based, localized mentorship toward structured, globalized academic networks. This comparative perspective builds on recent scholarship emphasizing the evolving nature of scientific education and intellectual exchange in Muslim contexts.

### 3.4. Limitations

This study is limited to eight mathematicians and does not aim for statistical generalization. Rather, it provides a narrative-based analytical comparison to highlight individual and contextual influences on mathematical innovation across time. Due to the selective nature of the sample, the findings may not capture the full diversity of Muslim mathematicians or the wide spectrum of educational practices across different regions and periods (Creswell & Poth, 2017). Additionally, the reliance on secondary sources, especially for historical figures,

poses challenges related to the availability and accuracy of documentation, which may affect the completeness of the analysis (Howell & Prevenier, 2001). Despite these limitations, the study offers valuable insights into the evolving educational networks that have shaped mathematical thought within Islamic scholarly traditions.

#### 4. Comparison of Educational Journeys

The educational journeys of classical and modern Muslim mathematicians reveal both striking contrasts and thematic continuities shaped by the broader intellectual and institutional frameworks of their respective eras. Classical mathematicians such as Al-Khwarizmi, Al-Battani, Ibn Khaldun, and As-Samaw'al al-Maghribi were educated primarily through informal, yet rigorous scholarly networks centered around madrasas, private tutors, and centers of learning such as the Bayt al-Hikma in Baghdad. Their learning was deeply embedded within interdisciplinary traditions that blended mathematics with philosophy, astronomy, and theology (Nasr, 2003). Knowledge was transmitted orally or through hand-copied manuscripts, with intellectual advancement often depending on one's access to manuscripts, scholars, and court patronage. Mentorship was highly personalized, and success often hinged on reputation within scholarly circles rather than formal degrees (Lewis, 2020).

In contrast, modern mathematicians such as Maryam Mirzakhani, Yahya Ould Hamidoune, Nader Masmoudi, and Chehrzad Shakiban progressed through structured and credentialed educational systems, often involving international mobility. Their academic development typically began in national or elite science-focused secondary schools, followed by university-level studies at globally recognized institutions. Graduate education played a crucial role, with emphasis on research publications, doctoral supervision, and peer-reviewed evaluation (Phillips & Schweisfurth, 2014). Institutional affiliations and access to global academic networks were critical to their success, supported by fellowships, conferences, and advanced computational resources. While mentorship remains important, the process has become more formalized and externally validated through metrics such as citations, grants, and academic ranking.

**Table 1** and **Table 2**, presenting Classical and Modern Muslim Mathematicians respectively.

**Table 1.** Classical Muslim mathematicians.

Name	Period	Key Contributions	Educational Journey
Al-Khwarizmi	c. 780-850	Founder of algebra; introduced Hindu-Arabic numerals and algorithms	Studied at the House of Wisdom (Bayt al-Hikma) in Baghdad; learned from translations of Greek and Indian texts
Al-Battani	c. 858-929	Improved trigonometric methods; precise astronomical observations	Likely educated in Harran and Syria; studied Ptolemaic astronomy and developed independent observations

## Continued

<b>Ibn Khaldun</b>	1332-1406	Founder of sociology and historiography; contributed to logic and mathematics	Trained in traditional Islamic education in Tunisia; learned from scholars in Fez and Cairo
<b>As-Samaw'al al-Maghribi</b>	c. 1130-1180	Advanced algebraic notation and decimal fractions; supported Al-Karaji's algebraic methods	Educated in Baghdad; trained in mathematics and astronomy under scholars influenced by earlier Islamic works

**Table 2.** Modern Muslim mathematicians (20<sup>th</sup>-21st Century).

Name	Period	Key Contributions	Educational Journey
<b>Maryam Mirzakhani</b>	1977-2017	Work on Riemann surfaces, moduli spaces, and dynamics; first woman to win the Fields Medal (2014)	Early education in Tehran; attended National Organization for Development of Exceptional Talents; PhD at Harvard University
<b>Yahya Ould Hamidoune</b>	1947-2011	Over 100 papers in additive number theory, graph theory, and combinatorics; solved Erdős-Heilbronn Conjecture	Early schooling in Mauritania and Egypt; PhD at University of Paris VI; Researcher at CNRS, France
<b>Nader Masmoudi</b>	1974-present	Major work in fluid dynamics and nonlinear PDEs; winner of the Fermat Prize (2017) and <b>King Faisal Prize (2022)</b>	Studied in Tunisia; PhD from École Normale Supérieure, France; Professor at NYU Abu Dhabi
<b>Chehrzad Shakiban</b>	1950s-present	Research in calculus of variations, fractal geometry, and image processing; co-author of <i>Applied Linear Algebra</i>	Arrived in U.S. as refugee; Master's from Harvard; PhD from Brown University; Professor at University of St. Thomas, MN

## 5. Summary and Comparison of Classical and Modern Muslim Mathematicians

The selected classical Muslim mathematicians: Al-Khwarizmi, Al-Battani, Ibn Khaldun, and As-Samaw'al al-Maghribi, were foundational figures in the development of algebra, astronomy, logic, and number systems. Their work emerged in an era of flourishing scientific inquiry during the Islamic Golden Age (8th-14th centuries), often supported by state-sponsored institutions such as the Bayt al-Hikma in Baghdad. These scholars were deeply embedded in intellectual networks that prioritized translation, synthesis, and original contributions across disciplines, blending mathematics with philosophy, astronomy, and logic.

In contrast, the modern mathematicians; Maryam Mirzakhani, Yahya Ould Hamidoune, Nader Masmoudi, and Chehrzad Shakiban, operate within globalized academic systems, often engaging with highly specialized fields such as partial differential equations, additive number theory, and mathematical physics. Their education typically involves international mobility, formal graduate programs, and integration into structured research institutions such as Harvard, CNRS

(Centre National de la Recherche Scientifique), or NYU (New York University) Abu Dhabi. Unlike the classical era, where scholars often worked independently or in small circles, modern mathematicians are part of vast, collaborative, and peer-reviewed ecosystems.

For a detailed comparison of the learning approaches between classical and modern mathematicians, please refer to **Table 3**, which outlines the key differences in their educational contexts and trajectories.

**Table 3.** Differences in learning approaches between classical and modern mathematicians.

Learning Aspect	Classical Mathematicians	Modern Mathematicians
<b>Learning Environment</b>	Informal, manuscript-based, and community-driven	Formal, degree-based, and institutionally structured
<b>Scope of Knowledge</b>	Polymathic: philosophy, astronomy, theology, math	Highly specialized within subfields
<b>Institutional Support</b>	Caliphates, royal patronage, scientific academies	Universities, research grants, fellowships
<b>Knowledge Dissemination</b>	Hand-copied manuscripts and oral teaching	Peer-reviewed journals, conferences, digital databases
<b>Mobility</b>	Regional travel within the Islamic world	Global academic migration (e.g., from Iran to U.S. or France)

## 5.1. Lessons from the Classical Tradition for the Modern World

The classical Islamic mathematical tradition emphasizes holistic, interdisciplinary learning, deep mentorship, and knowledge-sharing as central to intellectual development. These principles remain relevant today, offering valuable models for fostering inclusive, ethical, and collaborative academic environments in the modern world.

### 5.1.1. Interdisciplinary Integration

Classical mathematicians often view knowledge holistically. Modern education systems could benefit from fostering broader intellectual foundations across sciences and humanities, reducing excessive compartmentalization in academia.

### 5.1.2. Mentorship and Knowledge Transmission

The classical tradition emphasized close, sustained mentorship, often embedded in scholarly circles. While modern academia uses formal advising, a return to deeper intellectual mentorship—especially for underrepresented scholars—can strengthen innovation.

### 5.1.3. Cultural Responsibility in Science

Classical scholars saw themselves as stewards of civilization. Encouraging cultural pride and ethical responsibility among scientists today can inspire broader participation and commitment to societal advancement.

### 5.1.4. Accessibility and Democratization of Learning

During the Islamic Golden age, the knowledge sharing was promoted through handwritten copying and scholarly commentary. In the modern context, open-access publishing, digital collaboration platforms, and multilingual materials serve a similar purpose by making knowledge more widely accessible and inclusive.

## 6. Conclusion

The comparative analysis of classical and modern Muslim mathematicians underscores the enduring importance of educational networks, mentorship, and intellectual environments in cultivating mathematical excellence. While classical scholars such as Al-Khwarizmi and Al-Battani thrived in manuscript-based, interdisciplinary settings supported by court patronage and scholarly circles, modern figures like Maryam Mirzakhani and Nader Masmoudi advanced within globally networked academic institutions driven by formalized research structures and international collaboration.

Despite the temporal and contextual differences, both groups reflect a shared commitment to rigorous inquiry, mentorship, and the pursuit of knowledge as a societal and ethical responsibility. Lessons from the classical tradition, particularly its emphasis on holistic learning, sustained mentorship, and accessibility, which remain relevant today, offer pathways to enrich contemporary mathematical education and foster inclusive, cross-cultural intellectual growth. By reconnecting with these enduring values, modern systems of learning can better nurture innovation and broaden participation in the mathematical sciences.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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