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From the Qur'an to Al-Khwarizmi: Traces of Mathematics in Islamic Intellectual Heritage

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Abstract
The traces of mathematics in the Islamic intellectual heritage highlight Al-Khwarizmi's fundamental contributions and the mathematical implications of the Qur'an. This study analyzes the central role of Islamic civilization in preserving and developing mathematics, driven by both religious and practical motivations. A literature review method is used to synthesize data from various academic sources. The results show that Al-Khwarizmi revolutionized algebra and disseminated the Hindu-Arabic number system, forming the basis of modern algorithms. Furthermore, the Qur'an implicitly and explicitly contains mathematical concepts that inspire an understanding of divine order and its application in Islamic law. The conclusion affirms the symbiotic relationship between faith and reason in advancing mathematics in the Islamic world, providing a balanced perspective on global scientific progress.

Keywords: Al-Khwarizmi; Islamic Mathematics; Algebra; Qur'an; Intellectual Heritage

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1. INTRODUCTION

The Golden Age of Islam, which spanned approximately the 7th to the 13th centuries AD, was a very fertile period for the development of science and intellectual life. During this period, Islamic civilization not only preserved but also significantly expanded the wealth of knowledge inherited from previous traditions. Mathematics, in particular, underwent a profound transformation, with an innovative synthesis of Greek, Indian, and Babylonian concepts forming the foundation for modern disciplines (Jaloliddin &

Kholmurodov, 2025). The role of Islamic civilization in this process went beyond mere passive transmission; it was a dynamic intellectual process involving critical absorption, analysis, and original creation. This role highlights the transformative intellectual activity that laid the groundwork for future global scientific progress, rather than merely serving as a conduit.

Among the monumental figures to emerge from this era was Muhammad ibn Musa al-Khwarizmi. He is widely recognized as the "Father of Algebra" and was a key figure in the spread of the Hindu-Arabic numeral system, from which the term "algorithm" derives (Aleeshan et al., 2023). Al-Khwarizmi's work was not only theoretical but also highly practical, aimed at solving concrete problems in commerce, land measurement, and inheritance law (Elamin, 2025). This pragmatic approach ensured the relevance and widespread adoption of his innovations.

The intellectual heritage of Islam provides a holistic framework in which science and religion are not viewed as separate entities, but instead as integrated. The study of mathematics in Islamic civilization was uniquely driven by religious and practical motivations, reflecting the symbiotic relationship between faith and reason (Nasaruddin, 2018). The relationship between mathematics and religion in the Islamic context is not a process of "Islamizing" mathematics itself, in the sense of creating a theologically defined mathematical system. Instead, the main goal is to deepen religious understanding and practice through the lens of mathematics (Nasaruddin, 2018). This makes mathematics a means for humans to understand divine order and fulfil their purpose in creation, which, in turn, fosters a deeper spiritual connection through scientific understanding (Kurniawan & Hidayati, 2020). This understanding prevents misinterpretation and establishes a nuanced theoretical framework for this discussion.

Although the contributions of Islamic mathematics have been recognized, there is often a lack of a comprehensive understanding of how various elements from Al-Khwarizmi's fundamental innovations to the mathematical implications in the Qur'an are interrelated and collectively form this rich intellectual heritage. Therefore, the research question is: How do Al-Khwarizmi's revolutionary contributions to algebra and algorithms, as well as the numerical and conceptual implications found in the Qur'an, collectively shape and enrich the intellectual heritage of mathematics in Islamic civilization? Based on the identified issues, the objectives of this study are (1) To analyze Al-Khwarizmi's fundamental contributions to the development of algebra, algorithms, and the spread of the Hindu-Arabic number system; (2) To explore the broad role of Islamic intellectual heritage in the development of the discipline of mathematics as a whole; (3) To identify and discuss the relationship between mathematics and the Qur'an, including numerical patterns, manifestations of divine order, and their application in Islamic law. (4) To explain the religious and practical motivations that drove the study and advancement of mathematics in Islamic civilization.

2. RESEARCH METHOD

This study adopts a literature review approach as its primary methodology, in accordance with journal template requirements (Sulianto et al., 2019; Syakur et al., 2020). This approach allows for an in-depth analysis of relevant scientific works to construct a comprehensive and evidence-based argument. This method was chosen due to the historical and conceptual nature of the topic, which requires the synthesis of information from various academic sources.

Data were collected from various authoritative academic sources, including leading scientific journals, reference books, monographs, and other academic publications relevant to the history of mathematics, Islamic civilization, and Qur'anic studies. Priority was given to recent publications, ideally those published within the last five years, to ensure the relevance and novelty of the scientific perspective (Sulianto et al., 2019; Syakur et al., 2020) Sources used include works by (Al-Daffa', 1977; Berggren, 1986; Rashed, 2001), as well as articles from ResearchGate and historical archives such as the MacTutor History of Mathematics Archive (O'Connor & Robertson, 1999).

The data collection process involved systematic searching, critical reading, and synthesis of information from the identified sources. This included analysis of key arguments, historical facts, conceptual frameworks, and interconnections between various aspects of mathematics and Islamic thought. Information was extracted and categorized based on its relevance to subtopics within the discussion framework, ensuring comprehensive and focused coverage.

The collected data is analyzed descriptively to present historical facts and conceptual relationships in a clear and structured manner. A critical-analytical approach is applied to interpret findings, identify trends, cause-and-effect relationships, hidden patterns, and broader implications. The conceptual analysis focuses on understanding how mathematical principles were understood and applied within the Islamic intellectual and religious framework.

This analysis reveals a sophisticated intellectual ecosystem within Islamic civilization, characterized by the interaction between preservation, innovation, and application. Sources point to three distinct but interconnected activities: first, the translation and preservation of ancient texts; second, original research and innovation; and third, the practical and religious application of mathematical knowledge (Al-Daffa', 1977; Berggren, 1986; Rashed, 2001). Preservation ensured the continuity of knowledge, while innovation built upon this foundation, resulting in new disciplines such as algebra and refined methods such as the decimal system. Crucially, the motivation behind many of these

innovations stemmed from practical and religious needs, which in turn spurred further theoretical development. For example, the development of the astrolabe to determine the direction of the Qibla or the need for calculations in inheritance law directly influenced the advancement of algebra. This created a cyclical relationship in which practical needs drove theoretical advances, which in turn enabled more sophisticated applications, demonstrating the unique characteristics of Islamic mathematics compared to, for example, purely theoretical Greek mathematics (Nasaruddin, 2018). The dynamics of this interaction are a core theme that will be elaborated throughout the "Results and Discussion" section.

3. RESULTS AND DISCUSSION

3.1 RESULTS

A. Mathematical Intellectual Heritage in Islamic Civilisation

Baitul Hikmah in Baghdad, founded during the reign of Caliph Harun al-Rashid and developed under Caliph al-Ma'mun, served as an intellectual centre and main library (Gutas, 1998). This institution became a catalyst for a massive translation movement, translating important works from Greek, Indian, Persian, and Syrian into Arabic, including texts by Euclid, Ptolemy, Aryabhata, and Brahmagupta (Al-Daffa', 1977; Berggren, 1986). Islamic mathematics developed through a synthesis of Greek (geometry), Indian (decimal system and zero), and Babylonian (algebraic problem solving) traditions (Al-Daffa', 1977; Berggren, 1986). Algebra became an independent discipline, the decimal number system included fractions, and trigonometry developed independently of astronomy with the six trigonometric functions (Katz, 1998). Advances also occurred in geometry, Diophantine equations, and number theory (Al-Daffa', 1977; Berggren, 1986).

B. Contributions of Al-Khwarizmi

Al-Khwarizmi is recognised as the "Father of Algebra" through his Kitab al-jabr wa al-muqabala (c. 820 AD), which systematised the solution of linear and quadratic equations in six standard forms (O'Connor & Robertson, 1999). This book discusses practical problems such as trade, land measurement, and inheritance (O'Connor & Robertson, 1999). Through Algoritmi de numero indorum (c. 825 AD), he introduced the Hindu-Arabic number system and the concept of zero to the Western world, with the term "algorithm" derived from his name (Madjid, 2017; O'Connor & Robertson, 1999). His astronomical work, Zij as-Sindhind, provides tables for the movement of celestial bodies and prayer times (O'Connor & Robertson, 1999). His work was translated into Latin and used as a textbook in Europe until the 16th century, influencing mathematicians such as Abu Kamil, Al-Karaji, and Fibonacci (O'Connor & Robertson, 1999; Rashed, 2001)

Table 1. Al-Khwarizmi's Major Contributions and Their Impact

Name of Work	Year (Estimated)	Main Contribution Areas	Description of Specific Contributions	Impact/Influence
Kitab al-jabr wa al-muqabala	c. 820 M	Algebra	Systematization of solutions of linear and quadratic equations; Introduction of the operations "al-jabr" and "al-muqabala" (O'Connor & Robertson, 1999)	Became a separate discipline; Foundation of modern algebra; Used as a primary textbook in Europe until the 16th century (O'Connor & Robertson, 1999)
Algorithms for the number of indicia	c. 825 M	Numerical Systems & Algorithms	The introduction and spread of the Hindu-Arabic number system (including the concept of zero and decimal notation) to the Western world; The origin of the term "algorithm" (Madjid, 2017; O'Connor & Robertson, 1999).	Revolution of numerical computation; Foundation for modern computing, AI, and computer science; Influenced European mathematicians such as Fibonacci (Cai, 2023).
She as-Sindhind	c. 820 M	Astronomy	Compilation of astronomical tables that are important for understanding the movements of celestial bodies and determining prayer times (O'Connor & Robertson, 1999)	Widely used in the Islamic world; Influenced European astronomy (Rashed, 2001)

C. Traces of Mathematics in the Qur'an

The Qur'an contains mathematical concepts such as numbers, arithmetic, geometry, and measurement, for example in Surah al-Baqarah, an-Nisa', and al-Maidah

(Abdusysyakir, 2006). Verses such as Surah Yasin verse 40 show divine order through the movement of celestial bodies, and Surah An-Nisa verses 11, 12, 176 regulate the distribution of inheritance with numerical patterns (Abdusysyakir, 2006). Mathematical applications are seen in Islamic law such as faraidl (inheritance), zakat, determining the direction of the Qibla, prayer times, and the Islamic calendar (Abdusysyakir, 2006). Islamic geometric patterns in art and architecture reflect divine order, with the Golden Ratio used for visual harmony (Critchlow, 1976).

Table 2. Selected Examples of the Application of Mathematical Concepts in the Qur'an and Fiqh

Mathematical Domain	**Specific Concepts**	**Verse Al-Qur'an / Fiqh Law**	**Application Description**
Numbers & Arithmetic	Rational Numbers, Fractions	An-Nisa 4:11-12, 176 (Faraidl)	Fair and appropriate distribution of inheritance according to the specified proportions (Abdusysyakir, 2006)
Arithmetic	Addition, Subtraction, Multiplication	Al-Baqarah 2:196 (Fasting for Hajj/Umrah); Al-Ankabut 29:14 (Story of Prophet Noah); Al-Baqarah 2:261 (Reward for Good Deeds)	Calculation of the number of days of fasting; Duration of the life of Prophet Noah; Multiplication of rewards for good deeds (Abdusysyakir, 2006)
Geometry	Angle / Direction	Al-Baqarah 2:144 (Qibla)	Determining the direction of the Kaaba in Mecca for accurate prayer (Nasaruddin, 2018)
Measurement	Distance / Length	Sa'ie Ritual (Hajj/Umrah)	Calculation of the total distance of seven rounds between Safa and

			Marwah (Abdusysyakir, 2006)
Measurement	Time	Al-Hajj 22:47; Yunus 10:5 (Calendar, Prayer Times)	Determining daily prayer times; Differences between the Shamsiah and Qamariyah calendars (Abdusysyakir, 2006).
Arithmetic	Proportion	Zakat	Determination of the value of zakat that must be paid from assets (Abdusysyakir, 2006)

Tabel 2 menyajikan beberapa contoh penerapan konsep matematika dalam Al-Qur'an dan Fiqh. Setiap contoh menunjukkan bagaimana prinsip-prinsip matematika, seperti bilangan, aritmetika, geometri, dan ukuran, diterapkan dalam konteks ayat atau hukum Islam, misalnya perhitungan warisan, waktu ibadah, arah qibla, atau zakat. Tabel ini bersifat illustrative dan tidak mencakup seluruh temuan penelitian, melainkan hanya menampilkan beberapa aplikasi yang relevan untuk memberikan gambaran tentang keterkaitan matematika dengan praktik keagamaan.

D. Motivation for Studying Islamic Mathematics

The study of mathematics was driven by religious needs such as determining the direction of the Qibla, prayer times, inheritance laws, and zakat (Abdusysyakir, 2006; Nasaruddin, 2018). Practical needs include astronomy for navigation, trade, land measurement, architecture, and tax administration (Al-Daffa', 1977; Berggren, 1986; Rashed, 2001)

3.2 DISCUSSION

A. The Mathematical Intellectual Heritage of Islamic Civilisation

Baitul Hikmah was not merely a passive library but a centre of scholars and translators that involved careful revision of texts and demonstrated critical engagement with sources (Gutas, 1998). This translation movement was a deliberate intellectual project to synthesise and advance global knowledge, driven by curiosity and intellectual supremacy (Rashed, 2001). The synthesis of Greek, Indian, and Babylonian traditions overcame their

respective limitations; for example, the weakness of Greek algebraic symbolism was complemented by the Indian decimal system (Katz, 1998; O'Connor & Robertson, 1999). The development of algebra, trigonometry, and number theory marked a paradigm shift toward abstraction, freeing mathematics from the constraints of Greek geometry and enabling general solutions and the handling of irrational numbers (Al-Daffa', 1977; Berggren, 1986)

B. Al-Khwarizmi: Foundations of Modern Algebra and Algorithms

Kitab al-jabr wa al-muqabala introduced algebra as a systematic discipline, with the operations "al-jabr" and "al-muqabala" solving equations narratively due to the absence of modern notation (Katz, 1998). This work was practical, solving inheritance and trade problems, ensuring its widespread adoption (O'Connor & Robertson, 1999). Algoritmi de numero indorum revolutionised calculation with the Hindu-Arabic numeral system, and the term "algorithm" reflects its procedural approach that underpins modern computing, including AI and cryptography (Cai, 2023). Al-Khwarizmi's influence spread to Europe through Latin translations, becoming a textbook until the 16th century and influencing mathematicians such as Fibonacci (O'Connor & Robertson, 1999) . His contributions were so fundamental that they were naturalised into the mathematical canon without explicit attribution, demonstrating the successful integration of his ideas (O'Connor & Robertson, 1999).

C. Traces of Mathematics in the Qur'an and Its Applications

The Qur'an inspires a mathematical worldview through its emphasis on divine order, as in Surah Yasin, verse 40, which encourages the investigation of numerical patterns (Abdusysyakir, 2006). Mathematical applications in faraidl, zakat, Qibla, and prayer times demonstrate a unique integration between religious practice and mathematical theory, with the astrolabe as an example of an improved Greek tool for religious purposes (Nasaruddin, 2018) Islamic geometric patterns, using the Golden Ratio, express theological concepts such as Tawhid through art, combining mathematics, aesthetics, and spirituality (Critchlow, 1976). This makes Islamic geometry a visual language of divine order, connecting Muslims with the order of creation.

D. Religious and Practical Motivations

Religious needs such as faraidl and Qibla spurred the advancement of algebra and geometry, while mathematics reinforced religious practices with precision tools (Abdusysyakir, 2006; Nasaruddin, 2018). This cycle integrated faith and reason, in contrast to theoretical Greek mathematics (Nasaruddin, 2018). Practical needs in trade, architecture, and administration involved collaboration between theorists and practitioners, spreading mathematical knowledge to various levels of society (Rashed,

2001). This integration of theory and practice made Islamic mathematics socially and intellectually relevant.

4. CONCLUSION

The intellectual heritage of mathematics in Islam is a dynamic synthesis of various traditions, reinforced by institutions such as Baitul Hikmah. Muhammad ibn Musa al-Khwarizmi revolutionised algebra and introduced the Hindu-Arabic numeral system, forming the foundation of modern algorithms. The Qur'an contains mathematical concepts that inspire divine order and applications in Islamic law, such as faraidl and zakat. The study of Islamic mathematics was driven by religious and practical motivations, fostering a reciprocal relationship between faith and reason that led to significant progress.

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6. RECOMMENDATIONS

Understanding the history of Islamic mathematics is essential for an inclusive perspective on global scientific progress. Further research could explore:

1. Other mathematical domains in the Qur'an, such as logic or set theory
2. Al-Khwarizmi's methodological principles for modern AI ethics
3.The role of mathematics in other sciences in Islamic civilisation, such as physics or optics

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