Prologue

The history of science is often traced back to Classical Greece or the European Renaissance; however, its roots extend much deeper into the past. In this inaugural issue of Curiosita, we are pleased to present an essay that highlights one of the earliest and most significant cradles of scientific and technological advancement: the Indus Valley Civilization.

In this contribution, Partha Ghose provides a detailed and thoughtful examination of the scientific knowledge, engineering achievements, and mathematical innovations of the Indus world. Through a careful analysis of archaeological and historical evidence, the essay challenges prevailing narratives and highlights the sophistication of ancient urban societies whose contributions have often been overshadowed in the global history of science.

As Curiosita embarks on its mission to explore the essence of curiosity that has driven human inquiry across cultures and centuries, we invite readers to engage with this work as both a scholarly account and a reminder of the enduring legacy of ancient knowledge.

1 Introduction

The First Urbanization Period (c. 3100–1500 BCE) marks a turning point in human history, when societies began to form complex urban centers with structured governments, social hierarchies, and specialized economies. Among the standout civilizations of this era were Egypt, Mesopotamia, and the Indus Valley—each unique in geography and culture, yet united by their remarkable advancements in architecture, agriculture, and knowledge systems.

What drove this transformation? Primarily, agricultural surpluses enabled population growth, economic specialization, and the rise of new social structures. As Gordon Childe insightfully observed:

The worst contradictions in the neolithic economy were transcended when the farmers were persuaded or compelled to wring from the soil a surplus above their own domestic requirements, and when this surplus was made available to support new economic classes not directly engaged in producing their own food. The possibility of producing the requisite surplus was inherent in the very nature of the neolithic economy. Its realization, however, required additions to the stock of applied science at the disposal of all barbarians, as well as a modification in social and economic relations. The thousand years or so immediately preceding 3000 B. C. were perhaps more fertile in fruitful inventions and discoveries than any period in human history before the sixteenth century A. D. Its achievements made possible that economic reorganization of society that I term the urban revolution.

Each civilization responded to its environment in distinctive ways. Egypt, shielded by deserts and enriched by the Nile's reliable floods, focused on grand religious monuments. Mesopotamia, lacking such natural defenses, became a hub of resilience and adaptation amid frequent environmental challenges. The Indus Valley, cradled by the Indus River and nourished by monsoons, excelled in urban planning, sanitation, and architectural uniformity

Among the most intriguing sites is Rakhigarhi in present-day Haryana, whose scale and sophistication rival that of the more famous Harappa and Mohenjo-Daro. Its excavation has revealed not only advanced city planning but also evidence of early writing and genetic continuity with modern South Asian populations.

Figure 1: The Great Sphinx of Giza. Source: iStock.

2 Key Sectors of the Indus Valley Economy

Agriculture

The backbone of the Indus economy was agriculture. Fertile plains fed by the Indus and its tributaries supported abundant crops: wheat, barley, millet, legumes, cotton, and even spices like turmeric and mustard. Innovations such as wooden plows and well-based irrigation enabled efficient farming. Domesticated animals, from cattle to camels, powered transport and labor, while cotton cultivation laid the groundwork for a thriving textile trade.

Figure 2: A selection of unicorn stamp seals and other seals recovered from Mohenjo-daro. Source: iStock.

Industry and Craft Production

Artisans of the Indus Valley displayed exceptional skill. Cities like Chanhudaro specialized in bead-making and metallurgy; Lothal boasted dockyards and jewelry workshops; and Mohenjo-Daro and Harappa were industrial centers for pottery and bricks. Goods crafted with remarkable precision and uniformity traveled far and wide, hinting at trade networks stretching to Mesopotamia and beyond. The level of standardization suggests not just artistry but organized production and economic planning.

3 The Origins of Geometry and Astronomy in the First Urbanization Period

Geometry

Across early civilizations, geometry emerged from practical needs: measuring land, designing buildings, and planning cities. The

Figure 3: The Great Bath at Mohenjo-daro, Pakistan. Source: iStock.

Sumerians developed a base-60 system that influenced later mathematical traditions. Egyptians applied geometry to survey lands and build monumental structures. In the Indus Valley, geometry took a distinctive form in the grid-like layouts of cities, uniform brick sizes, and proportional constructions—a silent testimony to mathematical precision.

Astronomy

Astronomy intertwined with agriculture and ritual. The Mesopotamians mapped the skies and tracked planetary movements; the Egyptians aligned their monuments with stars like Sirius; and in the Indus Valley, evidence of solstice-aligned structures and seal symbols suggests celestial observation. Lothal's tidal dockyard may have synchronized with lunar cycles, while the recurring horned figures on seals hint at early astrological or ritualistic significance. Later Vedic texts, drawing on these traditions, describe lunar mansions (Nakshatras) that may trace their origins to this period.

Interestingly, the Satapatha Brahmana (a commentary on the Sukla Yajurveda) mentions several times that, unlike other aster-

isms, Krittika (the star cluster Pleiades) rises exactly in the East and does not move away from the eastern quadrant. Was this based on observations made at that time? Astronomical calculations suggest otherwise—Krittika did not rise due east in Vedic times.

Modern astronomical calculations confirm that Krittika would have risen almost exactly due East around 2850 BCE to 3000 BCE, coinciding precisely with the peak of the Indus Valley Civilization. Therefore, the Vedic references almost certainly refer to observations made at earlier times. The Satapatha Brahmana does not explicitly mention precession, but it does refer to different pole stars (Dhruva), which could indicate an awareness of the slow movement of the celestial north over long periods. This hints at an early awareness of celestial precession, the slow shift in the Earth's axis.

Mathematics

Figure 4: Harappa seal. Source: iStock.

Mathematics in the Indus Valley was not just theoretical — it was deeply embedded in everyday life. Standardized weights and measures, such as cubical chert stones in binary and decimal ratios, enabled consistent trade and taxation. A finely calibrated ruler from Lothal reveals a remarkable grasp of units and proportionality, possibly anticipating later Vedic standards. Urban planning followed precise mathematical principles, with right-angled street grids and brick ratios (4:2:1) used across regions.

These achievements highlight not only the technical prowess of the Indus people but also a culture that valued order, measurement, and scientific consistency. Their work in civil engineering

— like sloped underground drainage and uniform house blocks — foreshadowed developments centuries later in Roman and medieval infrastructure.

4 Cultural Influence of the Indus Valley Civilization (IVC)

Though the Indus script remains undeciphered, cultural continuities abound. The city's planning principles echo in Hindu architectural texts. The grid system in Indus cities resembles the Vaastu Purusha Mandala, which serves as the architectural framework for Hindu temples and cities.

Geometrical knowledge in the Śulbasūtras aligns with Indus layouts. The Pythagorean-like precision of Indus structures predates Greek formulations, suggesting cross-cultural exchanges.

Mesopotamian records mention trade with a land called Meluhha — believed to be the Indus Valley Civilization. Trade links with Mesopotamia are affirmed by Indus seals in Ur and Sumer.

Artifacts from Oman and Bahrain, Indus-style pottery, and copper ingots with Indus markings point to maritime trade routes.

The presence of African ivory further confirms that the IVC was not isolated but embedded in a vibrant network of ancient exchange.

5 Decline and Continuity

The IVC's decline around 1900 BCE remains a subject of debate. Climate change, river shifts, and weakening monsoons likely played roles. Unlike Egypt or Mesopotamia, the IVC lacked evidence of centralized rulers or military dominance—a decen-

tralized governance that may have been less resilient in times of crisis. Disruptions in Mesopotamia may also have further weakened the Indus economy.

Some historians once suggested that Indo-Aryans invaded the Indus cities, leading to their collapse (based on the Rigveda's references to battles). However, this theory has been disputed because there is no evidence of large-scale warfare or destruction in the Indus cities, and the decline appears to have been gradual rather than sudden.

Yet decline did not mean disappearance. Rural communities persisted, and cultural threads survived. Some scholars believe that Indo-Aryans may have migrated into a weakened Indus region and gradually assimilated. Harappan weights reappear in later Indian contexts; city planning techniques inform Mauryan and Gupta architecture. Vedic rituals and iconography show traces of Indus heritage.

Rakhigarhi reinforces this narrative of continuity. Its DNA studies, town layouts, and motifs show unmistakable links to later South Asian traditions. Even today, echoes of Indus life survive in nearby village customs, pottery styles, and agricultural practices.

Appendix A The Śulbasūtras

The Śulbasūtras are a collection of ancient Indian texts, written between 800 BCE and 200 CE, that primarily deal with geometric principles used in Vedic rituals. These texts are part of the larger corpus of the Kalpa Sūtras, which provide instructions for constructing altars and fire pits with precise measurements to ensure their alignment with religious and cosmic principles. The most prominent among the Śulbasūtras were composed by sages

such as Baudhāyana, Āpastamba, Mānava, and Kātyāyana.

One of the key mathematical contributions of the Śulbasūtras is their approximation of the square root of 2. The Baudhāyana Śulbasūtra provides the value 1.414215.

These texts also contain early instances of the Pythagorean theorem, centuries before it was formally stated in Greek mathematics. The Baudhāyana Śulbasūtra, for instance, states that in a right-angled triangle, “the diagonal of a rectangle produces the combined areas of both squares on its two sides," which is a direct formulation of the theorem. This principle was crucial in constructing perpendicular lines for altars.

They also encompass a wealth of geometrical constructions that were primarily developed for the precise layout of Vedic ritual altars (yajña-vedis). These constructions demonstrate an advanced understanding of geometry, especially regarding accurate proportions and alignment with cosmological principles.

The Śulbasūtras also provide instructions for transforming one shape into another while preserving the area. For example:

- Converting a square into a rectangle or vice versa.
- Converting a square into a circle with approximately equal area, leading to an early approximation of π.
- Doubling the area of a square (dvisuvarna), an exercise that resembles the classical Greek problem of “doubling the cube."

The texts detail the construction of increasingly complex altar shapes, such as falcon-shaped and circular altars, which required intricate geometric calculations. The precision involved indicates a strong mathematical tradition, likely developed through both theoretical reasoning and practical applications. All of this demonstrates the applied nature of mathematics in ancient India, where geometry was designed not only for abstract reasoning but also

for practical and ritualistic purposes. These texts stand as a testament to early mathematical ingenuity, influencing later developments in both Indian and global mathematical traditions.

The Vedic Period (1500–500 BCE) marks the transition between the decline of the Indus Valley Civilization and the beginning of the Iron Age. This era is named after the Vedas, the oldest sacred texts of Hinduism, which were composed during this time. Early Vedic society was primarily pastoral, gradually evolving into an agrarian culture. Unlike the urbanized Indus Valley Civilization, the Vedic period left no archaeological evidence of large cities or constructed ritualistic altars. As a result, it is unlikely that practical geometry was developed during this era. Instead, it is more plausible that the mathematical knowledge found in the Śulbasūtras, a part of the Vedas, was inherited from the earlier Indus Valley Civilization and preserved through oral tradition by successive generations of sages.

A significant parallel to the mathematical traditions found in the Śulbasūtras appears in the Bakhshali Manuscript, an ancient Indian mathematical text discovered in present-day Pakistan. This manuscript is housed at the Bodleian Library of the University of Oxford in England. Written on birch bark, it is notable for containing the earliest known use of a symbol for zero.

Dating back to a period between the 3rd and 10th centuries CE, the manuscript features numerical calculations, including decimal place value notation and an early concept of zero. Although the Bakhshali Manuscript emphasizes arithmetic and algebra over geometry, it showcases the ongoing evolution of mathematical thought in India. Together, these texts illustrate the rich mathematical traditions of ancient India and their lasting impact on the development of mathematics worldwide.

Appendix B The Rigveda

The Rigveda, widely regarded as the oldest of the four Vedas, is a foundational text of early Indian civilization and religious thought. Scholars generally date its composition between 1500 BCE and 1200 BCE, although some propose earlier or later estimates based on linguistic and archaeological evidence. While the Rigveda is primarily a collection of hymns dedicated to various deities, it also provides insights into the material culture, social organization, and proto-scientific knowledge of its composers. References to measurement, order, and cosmic regularity suggest a familiarity with standardization, which aligns with archaeological findings from the Indus Valley Civilization — most notably their use of standardized weights and the decimal system. For example, in Rigveda 10.85.1, the term “samam” (equal) implies notions of balance and equivalence, possibly reflecting early ideas of standard measurement. Similarly, in Rigveda 1.164.48, the hymn refers to “seven horses drawing the chariot of the sun," which has been interpreted as a symbolic representation of calendrical or astronomical regularity. While direct references to decimal systems are not explicit, the emphasis on order, precision, and structured cosmology supports the argument that Vedic culture inherited or paralleled the mathematical sensibilities of the Indus Valley, possibly through cultural continuity or transmission.

6 Further Reading

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