Indian Knowledge Systems and the Development of Modern Science

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Abstract

It is widely acknowledged that Europe was the epicentre of the modern scientific revolution during the 15th–16th centuries. However, during the same period, much of the Indian subcontinent was reeling under foreign invasions, colonial subjugation, and systemic exploitation, which gradually obscured its once-flourishing and established knowledge tradition. Centuries of colonisation and repeated invasions resulted in cultural erasure that in turn led to a collective amnesia regarding India's vast and sophisticated contributions to philosophy, science, mathematics, astronomy, and medicine, among other fields. Contrary to the popular Eurocentric narrative, modern scholarship has clearly acknowledged that many foundational concepts attributed to Europeans had precedents in ancient Indian texts and practices. The decimal system, the concept of zero, early formulations of algebra and trigonometry, detailed astronomical observations, calendar and time reckoning, metallurgical innovations like rust-resistant iron, and even surgical procedures such as cataract removal originated in India long before their reappearance in the modern world. These concepts and advancements formed the foundation of the modern scientific edifice, which was often deprived of its due recognition. In this work, we present the Indian Knowledge Systems (IKS) as a framework that prefigured and, in some cases, directly contributed to the foundational development of modern scientific thought. Special focus is given to the contributions in natural philosophy, mathematics, astronomy, cosmology, metallurgy, and medicine.

Keywords: IKS, Ancient Indian Science, Ganita Jyotish, Vedic Cosmology

Introduction

Historians confirm that the modern scientific revolution occurred in Europe during the 15th and 16th centuries. This intellectual turbulence marked an important shift in human understanding of the natural world. Scientists and scholars began to challenge the dogmatic authority of the Church. However, the Eurocentric narrative often fails to acknowledge the significant contributions of the Indian subcontinent, which centuries ago established highly developed knowledge systems that formed the basis of many modern scientific disciplines. The Indian Knowledge Systems (IKS), encompassing philosophy, mathematics, astronomy, cosmology, metallurgy, and medicine, represent a holistic intellectual culture that flourished in ancient India. Institutions like Takshashila and Nalanda served as global epicentres of knowledge creation and dissemination, attracting thousands of students from across the world to learn diverse subjects (Basham, 1999).

Unfortunately, this scientific legacy of India was obscured by cultural amnesia brought on by colonial exploitation, repeated foreign invasions, and the deliberate destruction of knowledge repositories, including the burning of Nalanda and Takshashila universities. Modern scholarship increasingly acknowledges that many concepts credited to European scientists, such as the decimal system, the concept of zero, and early astronomical models, had precedents in ancient Indian texts and practices. For instance, Grant Duff (Chauhan, 2024) noted that many scientific advances attributed to Europe were made in India centuries earlier. These concepts, brought to Europe frequently through Persia and the Arab world, shaped the foundations of modern science. The National Education Policy (NEP) 2020 has placed a strong emphasis on the revival of IKS to preserve and promote India's rich intellectual legacy.

This work explores the notable contributions of IKS across various disciplines and their transmission across cultures, particularly through the Arab world into Europe. We aim to reclaim India's rightful place in the global scientific narrative by revisiting ancient sources and integrating them with secondary works of contemporary research.

Philosophy and Logic (The Darshanas): Research Methodology

The Indian philosophical systems (schools), collectively known as 'Darshana', provided a robust framework for inquiry that prefigured modern scientific research methodologies. The six orthodox schools—Nyaya, Vaisheshika, Samkhya, Yoga, Mimamsa, and Vedanta—alongside heterodox traditions like Charvaka, Jainism, and Buddhism offered systematic approaches to understanding natural phenomena. The Nyaya school, with its emphasis on logic and epistemology, developed pramanas (means of knowledge) such as perception (pratyaksha), inference (anumana), analogy (upamana), and verbal testimony (shabda), which parallel modern scientific methods of observation, hypothesis testing, similarity, and literature review, respectively. Basham (1999) notes that Nyaya's detailed analysis of syllogistic reasoning significantly influenced later logical traditions. Similarly, Vaisheshika's atomistic theories, which describe material interactions, proposed that matter is made up of indivisible particles (anu), a notion that predates contemporary atomic theory (Matilal, 1977). Steering concepts have been offered by other schools of thought, such as Samkhya, Yoga, Purva-Mimamsa, and Vedanta.

These philosophical traditions influenced intellectual traditions in the West by encouraging rigorous discussion and empirical validation. The Indian logic tradition, transmitted through Persia to the Arab world and Greece, shaped Aristotelian logic and medieval scholasticism. For instance, the Buddhist logician Dignaga's work on inference influenced Islamic philosophers like Al-Farabi (Frawley, 1991). However, centuries of invasions and the destruction of knowledge centres like Nalanda University and Takshashila University led to the loss of many philosophical texts, obscuring these contributions into oblivion. By revisiting Darshanas, we recognise their role as a foundational research methodology that contributes to the development of modern science.

Mathematics (Ganita): The Language of Science

Indian mathematics, known as 'Ganita', provided the foundational language for modern science. The invention of the decimal system and the concept of zero, documented in texts like the *Brihadaranyaka Upanishad* and formalised by Aryabhatta and others, revolutionised numerical computation (Chauhan, 2024). Brahmagupta's *Brahmasphuta Siddhanta* (628 CE) introduced solutions to quadratic equations and the use of negative numbers, predating European developments by centuries (Thibaut, 1889). The Kerala School of Mathematics, mainly during the 14th and 16th centuries, developed infinite series and early calculus forms, notably in Madhava's work on trigonometric functions, which anticipated Newton and Leibniz (Raju, 2007).

These concepts were transmitted to Europe via Arabic translations, particularly through the works of Al-Khwarizmi, whose *Al-Jabr* (algebra) drew heavily on Indian texts like *Beej Ganita* (Chauhan, 2024). Albert Einstein (Chauhan, 2024) noted that no worthwhile scientific discovery would have been possible without the Indian numeral system. However, colonial historiography frequently marginalised Indian contributions by attributing these developments to Europeans. The *Sulba Sutras*, written around 800 BCE, contain descriptions of the Pythagorean theorem, which is attributed to Pythagoras (Chauhan, 2024). Ganita demonstrates India's lasting influence on the mathematical underpinnings of contemporary engineering.

The Concept of Zero: Shunya

The concept of zero, or 'shunya', and its place value have their roots in the most ancient text, the *Rigveda*, and subsequent literature of India (Chauhan, 2023). In these texts, numbers were generally expressed as combinations of powers of ten. This representation played a crucial role in developing the decimal-place value system in India. The great Sanskrit scholars like Panini (c. 600–300 BCE) and Pingala (c. 450–200 BCE) included the concept of zero in their prosody work. Pingala used binary numbers and was the first to use the Sanskrit word 'shunya' for zero, considered the earliest text to use binary numbers, which were later borrowed for the machine language of computers (Chauhan, 2023). Zero's transmission to Europe occurred through Arabic mathematicians like Al-Khwarizmi, who incorporated Indian numerals into his works, leading to their adoption in Europe by the 12th century (Chauhan, 2024). In contrast, Babylonian mathematics used a placeholder in their base-60 system but lacked a formal zero, while Chinese counting rods relied on positional context without a distinct symbol (Pingree, 1981). The Indian zero's algebraic and symbolic clarity laid the foundation for modern mathematics, underscoring IKS's global impact.

Table: Comparative Development of Zero

Civilisation	Contribution	Period	Impact

Indian	Concept of 'shunya' in the *Rigveda*, used by Panini and Pingala	600–200 BCE	Enabled decimal-place value system, binary numbers, and algebraic operations; foundational for modern mathematics (prosody, binary numbers by Pingala, decimal system) (Chauhan, 2023)
Indian	Use of a dot as a placeholder in the *Bakhshali Manuscript*, evolving into the zero symbol	3rd–4th century CE	Facilitated the positional decimal system, transforming numerical representation (Hayashi, 1995)
Babylonian	Placeholder symbol in base-60 system	300 BCE	Limited to numerical contexts; lacked the formal concept of zero (Pingree, 1981)
Chinese	Counting rods with positional context; no formal zero	200 BCE	Relied on position; zero had no algebraic or symbolic role (Pingree, 1981)
Greek	No concept of zero	500 BCE–300 CE	The absence of zero hindered the development of algebra (Pingree, 1981)

Astronomy (Ganita Jyotish): Understanding the Sky

A considerable amount of astronomical knowledge is embedded in the literature of ancient India. Astronomy, popularly known as 'Jyotisha' in the *Vedas* and Vedic literature, has been recognised as the eye of the *Vedas*. The history of astronomical knowledge in India goes back to the appearance of the *Vedas*, the *Samhitas*, the *Brahmanas*, and the commentaries thereafter. Apart from the *Vedas*, the oldest available treatise exclusively devoted to astronomy is the *Vedanga Jyotisha* (~1300 BCE), composed by Sage Lagadha (Pingree, 1981).

The Rigvedic sages knew the workings of numerous astronomical phenomena; for example, the sun was the primary source of energy and light to humankind; the moon is lit by sunlight (*Shukla-Yajurveda Samhita* 18.40 and *Krishna-Yajurveda, Taittiriya Samhita* 3.4.7.1), and oceanic tides were caused by the moon. They also discerned that the Earth is spherical and freely floating in the sky.

According to the *Chhandogya Upanishad* (7.1.2.4), the 'nakshatra-vidya' (science of asterisms) was one of the core disciplines in the Vedic era, with dating potentially extending to 6000 BCE. The development of Indian astronomy passed through the golden period of Aryabhatta, Varahamihira, and the Kerala School to the first half of the 18th century CE. The Kerala School, including scholars like Parmeshvara, Neelakantha Somasutvan (Somayaji), Jyeshthadeva, Achyuta Pisharati, Narayana Bhatathiri, and Putumana Somayaji, made significant contributions. Unfortunately, in the 18th and 19th centuries CE, Jyotisha in India was reduced to a subject of pundits and religious rituals, focusing on astrology (*Falit Jyotish*) while undermining astronomy (*Ganita Jyotish*), the pinnacle of scientific achievement.

Aryabhatta's *Aryabhatiya* (499 CE) proposed the rotation of the Earth, described elliptical planetary orbits, explained solar and lunar eclipses, and many astronomical principles predating Europeans by a millennium (Shukla, 1976). His calculation of the Earth's diameter (12,742 km) is remarkably close to modern values (12,742 km) (Shukla, 1976). Bhaskaracharya's *Siddhanta Shiromani* (12th century) calculated the Earth's orbital period as 365.258756484 days, aligning with modern measurements (Chauhan, 2024). The *Surya Siddhanta* provided accurate data on planetary distances and diameters, such as the Earth-Moon distance, which were validated later by modern astronomy (Burgess, 1860).

Indian astronomical knowledge, transmitted through Arabic translations by scholars like Al-Biruni, profoundly influenced Islamic and European astronomy, steering the overhaul of the Renaissance in Europe. For instance, the *Zij*, an Islamic astronomical book that tabulates parameters used for astronomical calculations, was developed by Islamic scholars and incorporated Indian methods (Frawley, 1991). The destruction of institutions like Nalanda and

Takshashila obscured these remarkable contributions, but surviving texts reveal India's advanced understanding of the cosmos. Ganita Jyotish underscores India's foundational role in the global astronomical heritage.

Cosmology (Brahmasphuta Siddhanta): The Beginning and Evolution of the Universe

In Indian texts, such as the *Rigveda*, *Puranas*, and the *Darshanas* (Vedic, Jain, and Buddhist), geometrical models of the universe and the terrestrial Earth are described. The *Siddhanta* texts provide theories of established principles in astronomy and cosmology. The *bhugoladhyaya* of *Surya Siddhanta* discusses the creation of the universe and Earth, and the evolution of *panchamahabhutas* (ether, air, fire, water, earth). Varahamihira, in his *Brihat Samhita,* describes the evolution of the cosmos. These texts also deal with directions in space and parts of time (past, present, and future). The concepts of the genesis of the universe in astronomical texts are similar to those in most Indian philosophical schools.

Vedic cosmology, propounded by rishis of the *Rig Veda* and later articulated in texts like Brahmagupta's *Brahmasphuta Siddhanta*, offers insights into the origin and evolution of the universe. The *Nasadiya Sukta* of *Rig Veda* (10.129) contemplates the cosmos's beginnings, positing a state of neither being nor non-being, a philosophical precursor to modern cosmology theories of the Big Bang (Griffith, 1896). Vedic texts describe cyclical time scales as yugas, spanning billions of years, which resonate with time scales of modern cosmological models (Chauhan, 2024). Brahmagupta's mathematical treatments provided a scientific basis for these ideas, integrating astronomy and cosmology through precise calculations (Thibaut, 1889).

These concepts influenced Persian and Greek thought through cultural exchanges, as seen in the cosmological ideas of Anaximander, who interacted with Indian-influenced regions (Frawley, 1991). Colonial biases ignored these contributions, dismissing Vedic cosmology as mythological. Carl Sagan (Chauhan, 2024) highlighted the significance of Vedic cosmology, stating: "Vedic cosmology is the only one in which the time scales correspond to those of modern scientific cosmology. It is yet another ancient Vedic science that can be confirmed by modern scientific findings. The cosmology of the *Vedas* closely parallels modern scientific findings."

By examining Vedic cosmology, one can uncover a sophisticated framework that anticipates modern cosmological theories, affirming India's contributions to understanding the universe.

Chemistry (Rasa Shastra): Science of Alchemy

In ancient India, chemistry was not as distinct a discipline as it is today, but it emerged as an integral part of Vedic science, particularly during the later development of Ayurveda. This knowledge gained prominence as people began using plant-based and vegetable products to enhance longevity and treat diseases.

According to Vedic literature, ancient Indians were familiar with metals such as gold, silver, copper, iron, lead, and tin, and their applications in medicinal practices. Metals like gold and silver are referenced in texts such as the *Ramayana*, *Mahabharata*, *Raghuvamsham*, and *Kumarasambhava*, highlighting their cultural and therapeutic significance (Satpute, 2006).

The Indian alchemical discipline 'Rasa Shastra' takes a complex approach to chemistry, emphasising the purification of metals and the creation of therapeutic substances. The use of mercury, sulfur, and herbal mixtures for medicinal purposes, as well as methods for alloy-making and mineral purification, are described in texts such as *Rasaratnakara* (Satpute, 2006). For example, the preparation of *bhasma* (calcined metal ashes) involved complex chemical processes that resemble modern pharmaceutical chemistry (Basham, 1999). These practices prefigure modern metallurgy, particularly in the standardisation of compounds.

Indian alchemical knowledge, transmitted through Persian and Arabic texts, influenced medieval European alchemy. For instance, Jabir ibn Hayyan's works on alchemy drew on Indian sources (Frawley, 1991). In metallurgy, the Iron Pillar of Delhi, dating to the 4th century, showcases advanced smelting techniques, remaining rust-free for over a millennium due to a protective phosphate layer. The Wootz steel of ancient India, known for its strength, was exported globally and marketed as Damascus steel (Balasubramaniam, 2000). *Rasa Shastra*'s ongoing relevance highlights India's critical role in the advancement of chemical sciences, despite colonial prejudices and the destruction of Indian scientific literature.

The history of chemistry in ancient India is comprehensively documented in *A History of Hindu Chemistry from Earliest Times to the Middle of the Sixteenth Century CE* by Ācārya Prafulla

Chandra Ray. This seminal work is a definitive resource on the ancient and medieval chemical traditions of India.

Architecture (Vastu Shastra): Engineering and Technology

Ancient India produced timeless technological wonders through impressive feats in engineering and architecture. The Vedic and pre-Vedic eras saw the development of highly sophisticated manufacturing technologies, town planning, civil engineering, temple architecture, and rock-cut structures. During the post-Vedic era, urban architecture and engineering flourished until around 1100 CE. Even though advancements persisted after that, several factors caused a sharp decline. The temples and stupas that have survived serve as reminders of ancient India's mastery of architecture and engineering.

Ancient Indian literature, including *Vastu Shastra* texts such as *Mayamata*, *Manasara*, and *Samarangana Sutradhara*, as well as the *Matsya Purana*, *Agni Purana*, *Brihat Samhita*, and *Arthashastra*, provides detailed references to architectural practices. These texts outline the selection of stones, materials, specifications, and tools used in construction (Basham, 1999).

The astronomically aligned Harappan cities, such as Mohenjo-Daro, demonstrate engineering precision with grid-based urban planning and sophisticated drainage systems, dating back to 2600 BCE (Kenoyer, 1991). Architectural feats like the rock-cut temples of Ellora and the time-reckoning Sun Temple of Konark reflect a deep integration of science and aesthetics (Basham, 1999).

Indian engineering extended to irrigation systems and shipbuilding, with the terms 'navy' and 'navigation' derived from the Sanskrit word 'Nav-gatih', evidencing India's vast and advanced maritime trade networks (Chauhan, 2024). These technologies influenced Persian and Arabic traditions, yet colonial destruction of technical knowledge obscured India's contributions. These advancements affirm India's role as a leader in ancient engineering and architecture.

Life Science (Ayurveda and Yoga): Medicine and Health

The history of plant science is the oldest of all sciences developed in India. The Vedic culture was perfectly in tune with nature, which can be understood from the Vedic hymns, such as *Rigveda* (7.58.2-3), and the vast ocean of other literary works. The Vedic literature is filled with the names, characteristics, classifications, properties, and benefits of animals and plants. The *Yajurveda* and *Atharvaveda* are full of animal names. The *Yajurveda* (Ch 24) describes the multifarious use of 42 animals and 73 birds. In the *Atharvaveda*, snakes and worms (16 types) are discussed in detail. According to a study, more than 260 animal names are used in Vedic literature.

Indian life sciences, embodied in Ayurveda and Yoga, show a holistic approach to health and medicine. The *Sushruta Samhita* documents advanced surgical techniques, including cataract removal, rhinoplasty, and cesarean sections, practised around 600 BCE (Chauhan, 2024). Acquiring knowledge of plant and animal lives, the *Charaka Samhita* emphasises sustainable preventive healthcare and personalised medicine with principles that resonate with modern integrative medicine (Sharma, 1999). For example, Ayurveda's tridosha theory (vata, pitta, kapha) offers a framework for diagnosing and treating imbalances, akin to modern personalised medicine (Basham, 1999).

Yoga, focusing on physical and mental well-being through asanas, pranayama, and meditation, has become a global practice, influencing contemporary wellness paradigms, as seen in its adoption by the World Health Organisation (World Health Organisation, 2013), despite colonial practices that marginalised Ayurveda's recognition, Indian medical knowledge, transmitted through Arabic translations by scholars such as Avicenna, influenced Islamic and European medicine (Frawley, 1991). The timeless value of Yoga and Ayurveda highlights India's pioneering contributions to the biological sciences.

Ecology and Agriculture (Krishi Parashar): Culture, Traditions, and Daily Routines

Ancient Indian culture integrated ecological and agricultural practices that prefigured modern sustainability principles. The Vedic culture and traditions revered trees, rivers, and animals, fostering a deep respect for the ecosystem and promoting nature conservation long before modern ecology and environmentalism. An ecological ethos can be seen, for example, in the veneration of rivers such as the Ganges and the peepal tree (Chauhan, 2024). Crop rotation, soil management, and weather forecasting based on astronomical observations are among the sophisticated farming methods described in the ancient agricultural text known as the *Krishi Parashar* (Sadhale, 1999).

These customs, ingrained in everyday rites and cultural routines, ensured ecological equilibrium and provided a practical model for world peace and harmony. Vedic agriculture, for instance, uses organic manures and intercropping, which align with contemporary sustainable farming practices (Sadhale, 1999). Although colonial disturbances destroyed these traditions and practices, their revival offers valuable insights for sustainable farming. India has made significant contributions to global sustainability, given its agricultural and ecological heritage.

Comparative Timeline of Scientific Contributions

The following timeline highlights parallel developments and cultural exchanges between significant advances in IKS and those of other ancient civilisations, placing India's contributions within the context of global intellectual history.

Timeline: Key Scientific Contributions (Text-Based)

- 800 BCE: *Sulba Sutras* describe geometric principles, including a precursor to the Pythagorean theorem (Chauhan, 2024). Babylonian tablets record base-60 mathematics, used for astronomy (Pingree, 1981).
- 600 BCE: *Sushruta Samhita* details surgical techniques like rhinoplasty (Chauhan, 2024). China's *Huangdi Neijing* outlines holistic medicine, emphasising acupuncture (Needham, 1959).
- 499 CE: *Aryabhatiya* proposes the rotation of the Earth and calculates the Earth's diameter (Shukla, 1976).
- 628 CE: *Brahmasphuta Siddhanta* formalises the concept of zero and algebraic rules (Thibaut, 1889). Chinese mathematics advances algebraic equations in *Jiuzhang Suanshu* (Needham, 1959).
- 1150 CE: *Siddhanta Shiromani* refines astronomical calculations (Chauhan, 2024). Islamic scholars, like Al-Biruni, translate Indian astronomical texts, influencing European astronomy (Frawley, 1991).

This timeline highlights India's significant contributions while acknowledging the rich scientific traditions of other civilisations.

Conclusions

The chronology above highlights the parallel developments and cultural connections between important advances in the Indian Knowledge System and those of other ancient civilisations, presenting India's contributions from the perspective of world intellectual history. From the logical rigour of Darshana to the mathematical innovations of Ganita, the astronomical precision of Ganita Jyotish, and the sustainable practices of agriculture in *Krishi Parashar*, ancient India developed a holistic knowledge tradition that prefigured and, in many cases, directly influenced the modern scientific paradigm. Though centuries of invasions and colonial prejudices masked India's scientific heritage, the dissemination of these concepts through Persia, Arabia, and Greece facilitated their incorporation into international knowledge systems.

The revival of the Indian Knowledge System, accelerated by programs like the National Education Policy 2020, offers a fantastic opportunity to restore the knowledge ingrained in India's scientific legacy and incorporate its insights into contemporary research and education. By valuing the contributions of ancient Indian thinkers such as Aryabhatta, Brahmagupta, and Sushruta, we contest the Eurocentric narrative and recognise India's crucial role in scientific thought and innovation. This work underscores the need for continual study and research in IKS to fully grasp its impact on the world's scientific heritage, promoting a renewed sense of cultural and intellectual identity.

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