Literature Module

Introduction to History of Science and Technology

Objective

In this module, an introduction to Literature is provided with the perspective of History of Science and Technology in India. For various complex reasons, the Indian contributions to Science and Technology has not been available in the public sphere as much as European contributions. This module will discuss and present significant Indian contributions to the advancement of science and technology, as is extant in the available literature. The methodology adopted, to begin with, is to examine economic history with the support of material evidence.

Background

It is often emphasized that those who do not study History and learn from it are condemned to repeat the same mistakes. Mediocre people learn from their own experiences whereas intelligent people are those who learn from others' experiences also, including from the study of history. The history of mankind which includes the progress it has achieved in various endeavors, while encountering trials and tribulations is quite fascinating. In essence, history may be viewed as a history of ideas: some ideas that are eternal, some ideas which have worked well for a while, some ideas which failed, some ideas which traveled far and wide and was absorbed by various people and societies in differing ways. Humanity is only now beginning to realize that as we understand more and more of the world around us, we get to see and understand history from newer and wider perspectives. Scholarly historians suggest that as a society, we must revisit and rewrite our history at least once in fifty years. This module is a small effort undertaken in that direction.

Science and Material Advancement

Advancement of any society in the fields of Science, Art and Literature can happen only when the basic needs of water, food, clothing and shelter are met for a majority of the population. Even for doing general good to the society or humanity at large; apart from noble intentions, one does needs access to resources. This is said in the second *Cāṇakya-sūtra* as "*dharmasya mūlam arthaḥ*"[1] (at the root of just and harmonious living is wealth).Therefore, in spite of there being multiple kinds of histories – natural history, political history, scientific history, religious history – it is economic history that scores above all as the most important one to be studied.

Economic History of the World

The OECD (Organization for Economic Cooperation and Development) with 36 member nations commissioned a research into the economic history of the world for the past two thousand years, under the leadership of Angus Maddison[2]. The findings of Angus Maddison came as a shock to the very people who were researching and those who commissioned the research project. It turned out that India and China together were having nearly fifty percent of global GDP (Gross Domestic Produce) continuously for almost 17 centuries. It also came to light that most of Western Europe's development from the 16/17th century onwards was not so much because of the industrial revolution, but from colonization of much of Asia (mainly India), Africa and America. Figure 1 summarizes the findings of Angus Maddison. [1]

Figure 1 reveals that India and China together held more than 50% of world GDP continuously till at least 1700. After 1700, India's share of world GDP consistently declined and reached about 4% at 1947

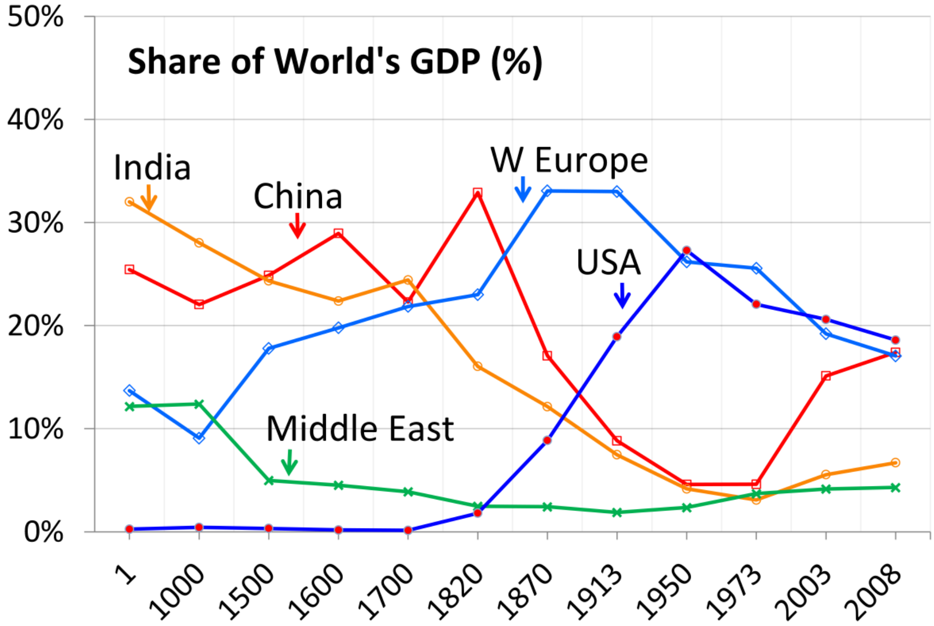

Figure 1: Country-wise share of world GDP through history [1]

when the country became politically independent. One may argue that for the time-period shown in Figure 1, the geographical extent of India has not remained the same. And for much of this history, India was not also one political entity. Nonetheless, the cultural unity of India was more than obvious to both Indians and non-Indians. [2]

Today, the USA holds about 14% (one-seventh) share of world GDP, which is the highest for any country today and is mostly considered as an economic superpower. Figure 1 shows that India in 1st century CE held about 33% (one-third) share of world GDP. One can imagine how much of an influence India would have had on the rest on the world. It is an interesting coincidence to note that Christopher Columbus accidentally discovered[3] America when he was actually trying to find a sea-route to India!

History of Literature and Scientific Heritage

Just as how today one finds some the best universities in the world in the USA and Europe, back then in the 1st millennium CE, most of best universities in the world were in India:

- *Takṣaśilā* (c. 1000 BCE to c. 500 CE), [3]
- *Puṣpagiri* (3rd to 11th centruy CE), [4]
- *Nālandā* (c. 425 CE to c. 1205 CE), [3]
- *Valabhī* (c. 600 CE to c. 1200 CE), [3]
- *Vikramaśilā* (c. 800 CE to c. 1203 CE), [3]
- *Odantapurī* (8th century CE to c. 1193 CE), [5]

to name a few[4].

The previous section certainly raises this question as to how did India manage to have such a large share of world GDP that too consistently for so long. It is quite well-known in history that India never invaded any other country and forcefully took away their resources unlike what the European powers did post 15th century. Furthermore, there was no slavery in ancient India unlike in ancient Egypt, Greece, the Roman empire, the Middle East, or pre-civil war USA (where we even find slave markets). As a result of studies during the past two centuries, we are slowly beginning to understand that India could achieve this feat through the following:

- a continuous research and development of science and technology and its application with strong ethical background and environmental concern

- well-developed agricultural practices and understanding of seasons, rainfall etc.
- production of quality goods required by people of foreign lands
- trade (mainly overseas trade)
- a harmonious social structure avoiding unnecessary wars
- maintaining a trade surplus with foreign lands continuously for a long period of time, implying indigenous production and consumption of a large percentage of goods
- evolving a sustainable economic model[5]

In particular, strong evidences which are emerging suggest that India had made significant strides in the following areas and was well ahead of her contemporaries of other lands, which directly and indirectly contributed to her lion's share of world GDP:

Metallurgy For many centuries, India was leading in iron and steel manufacturing, and pioneered the extraction of zinc.

Ship-building Harappan seals have been found as far as the Gulf of Oman and the horn of Egypt. India had a thriving ship-building industry and a good number of people were employed full-time in building ships.

Mathematics Decimal place value system, trigonometry, algebra (working with unknowns), infinite series are some of the major pioneering Indian contributions.

Calendar Indians had devised very good calendar systems taking into account celestial observations coupled with mathematics, to track seasons and model rainfall patterns to enable efficient agriculture and navigation.

The above listed achievements must have been discussed and documented in literature in some form. The places where we can find such literary evidence of Indian science and technology include

- *śāstra* texts
  - like *Arthaśāstra* which discuss taxation of various goods produced, exported and/or imported
  - like *Dharmaśāstra* which discuss the guidelines for a person's life in society
- user manuals such as *vākya* and *karaṇa* texts
- stories encoded in *Veda, Itihāsa, Purāṇa*
- epigraphical and copper-plate inscriptions
- accounts of foreign travelers visiting India[6]

We are given to understand that ancient India had numerous merchant guilds and artisan guilds; where people underwent training, not merely to clear exams and accumulate degrees, but to excel at the craft of their choice and also thereby earn a livelihood. All this provokes us to ponder over the Indian approach to knowledge systems.

Further, is it to be recognized that today's India is the second most populous country and seventh largest in terms of land area. Even in the past, the population of India had been pretty large compared with that of Western Europe or any other region of a similar size. Therefore, the above listed achievements seem even more significant since our ancients knew how to manage such a large population by adding value to their lives and not letting the large population become a burden on the country and its resources. Hence, there is a thing or two which can be learnt from the way human resource development was addressed in ancient India.

Goals of this module

In the rest of this module, we will delve more deeply into some of the reasons that were listed above which caused India to be an economic powerhouse in the past. As we see in European history around the 15th century; when money started pouring into Europe through colonization, science, art and literature flourished. Similarly in India, with general prosperity of the society based on their own naturally available resources and effort (at least for five millennia), science, art and literature flourished in a big way, making present-day Indians the inheritors of one of the most glorious cultural and scientific heritage. With Europe beginning to flourish from the 15th century with science, art and literature; it came to be called the 'Age of Enlightenment', casting away the yoke of the dark ages under the clutches of the Christian Church. And even to this very day, most of the world is taught that 'Age of Enlightenment' was the origin of Science and that scientific thinking developed from there. This is the state of affairs despite the fact that Europe heavily borrowed the knowledge of many non-European civilizations and built upon them. [6] These non-European contributions to the development of science and technology has not been sufficiently acknowledged. [7] In order to sensitize the reader to this issue, a list of some of the famous discoveries/inventions is made, along with a mention of when the said discovery was made in India and in Europe in Table 1.

Table 1: Comparison of the timelines when important discoveries very made in India and in Europe

Name of Discovery /Invention	**In India**	**In Europe**
Decimal place value system and zero as a number	*Āryabhaṭa* uses them in his *Āryabhaṭīyam* (c. 499 CE), hence probably known at least a century prior.	Leonardo Bonacci or Leonardo Bigollo Pisano (Fibonacci) introduces this as Indian numbers in his work *Liber Abaci* c. 1202 CE
Trigonometric functions	*Āryabhaṭa* calls them as *jyā* and *koṭijyā* and defines them in the context of a circle in his *Āryabhaṭīyam* (c. 499 CE)	Hipparchus? [Strange that trigonometry comes before place value system!]
Fibonacci sequence	*Virahāṅka* proposes these numbers in his *Vṛtta-jāti-samuccaya* in the context of *mātrā-chandas* (prosody) in c. 7th century CE. The seeds of this could be found even in *Piṅgala*'s *Chandaḥ-śāstra* and *Bharata*'s *Nāṭyaśāstra*. [8]	Leonardo Bonacci or Leonardo Bigollo Pisano (Fibonacci) himself mentions these as Indian numbers in his work *Liber Abaci* c. 1202 CE
Negative numbers	*Brahmagupta* introduced the concept of negative numbers and called it as *ṛṇa* (debt) as opposite to *dhana* (property). He also defined the arithmetic with negative numbers as *ṛṇa* × *ṛṇa* = *dhana* (negative × negative = positive).	Although introduced in Europe by Leonardo Bigollo Pisano (Fibonacci), it was resisted by European mathematicians and looked upon with suspicion till the 17th century CE.
Pell's equation	*Brahmagupta* studied this equation and found an integer solution, called by the name *Cakravāla* in his *Brahmasphuṭa-siddhānta* (7th century CE).	This equation is known in the name of a 17th century British man, John Pell although he neither gave the equation nor gave a solution to that equation.
Pascal's Triangle	*Halāyudha* (c. 10th century CE) clearly mentions this triangular array as *Meru-prastāra* in his work *Mṛtasañjīvanī*, a commentary on *Piṅgala*'s *Chandaḥ-śāstra* (c. 2nd century BCE).	Blaise Pascal, a French mathematician, introduces this in 17th century CE
Infinitesimals (Instantaneous motion)	*Muñjala* talks about *tātkālikī gatiḥ* (c. 932 CE), which is the seed of differentiation. He also states that $\sin w' - \sin w = (w' - w)\cos w$ where $w' - w$ is small. Today we recognize this as 'derivative of sine is cosine'.	Isaac Newton and Gottfried Wilhelm Leibniz are usually credited with the discovery of calculus, also differential calculus in 17th century CE.

Infinite Series (Taylor-Gregory Series or Leibniz's series)	*Mādhava* of *Saṅgamagrāma* (Kerala) gave this series in c. 1340-1425 CE. [9]	Re-discovered by James Gregory in 1668 CE
Heliocentric model of the solar system	*Nīlakaṇṭha Somayājī* (1444-1544 CE) proposed a partial heliocentric model in his *Tantrasaṅgraha*, in which Mercury, Venus and Mars orbit the Sun, which in turn orbits the Earth; based on a rich tradition of astronomical observation and mathematical calculation. [10]	Nicolas Copernicus claims heliocentric model without making any observations himself, based on arguments of simplicity, elegance *etc.*, first published in 1543. Giordano Bruno (1548 – 1600 CE) who extended the Copernican model by proposing cosmic pluralism was burnt at the stake for opposing core Catholic beliefs. Tycho Brahe and Johannes Kepler proposed a lesser accurate heliocentric model in late 16th century CE.
Numerical integral	Numerical integration was discussed by *Jyeṣṭhadeva* in his Malayalam text *Yuktibhāṣa*.	The term "numerical integration" first appears in 1915 CE in a publication by David Gibb.

It may be observed therefore, that most scientists who are famous today made some discovery/invention after the 15th century CE, following the dark ages in Europe. Therefore, between Ptolemy in the 2nd century CE and Galileo in 16th century CE, hardly any outstanding scientist's name is seen. Whereas in India, such dark ages never occurred; though some setbacks could have occurred in select regions due to foreign invasions. So, we see a continuous string of outstanding scientists throughout history such as

- *Suśruta*, *Agniveśa*, *Caraka* (2nd century CE), *Vāgbhaṭa* (c. 7th century CE) contributing to *Āyurveda* (health-care)
- *Parāśara* (2nd millennium BCE), *Vṛddha Garga* (c. 500 BCE), *Āryabhaṭa* (c. 499 CE), *Varāhamihira* (c. 6th century CE), *Bhāskarācārya* I (7th century CE), *Brahmagupta* (c. 7th century CE), *Mahāvīrācārya* (c. 9th century CE), *Śrīdharācārya* (c. 870 – 930 CE), *Bhāskarācārya* II (c. 12th century CE), *Mādhava* (c. 14th century CE), *Nīlakaṇṭha Somayājī* (c. 1500 CE) contributing to astronomy and mathematics
- *Nārada* (*Nāradaśilpa* c. 4th century CE), *Bhojadeva* (*Samarāṅgaṇa-sūtradhāra*, 11th century CE) contributing to architecture and iconography (*śilpaśāstra*)
- *Surapāla* (*Vṛkṣāyurveda*), *Parāśara* (*Kṛṣiparāśara*, prior to 6th century CE), *Haṃsadeva* contributing to Botany and Zoology

In subsequent portions of this module, we will make an attempt to understand some of the contributions made by Indian scientific stalwarts, along with some insights into related aspects of India's past glory.

Takeaway from this module

- Understanding the Economic history of the world
- Understanding of Indian achievements in Science and Technology that made it an economic superpower in the past
- Contemplate on India's future course in sustainable and all-inclusive development supported by a study of India's past

References

[1] Angus Maddison. *Contours of the world economy, 1-2030 AD : essays in macro-economic history*. Oxford University Press, Oxford, 2007.

[2] Radha Kumud Mookerji. *The Fundamental Unity of India*. Bharatiya Vidya Bhavan, New Delhi, 1960.

[3] D. G. Apte. *Universities in Ancient India*. Franklin Classics Trade Press, 2018 (Reprint of book published in the 20th century).

[4] Scott L. Montgomery and Alok Kumar. *A History of Science in World Cultures: Voices of knowledge*. Routledge Taylor & Francis Group, London and New York, 2016.

[5] Sailendra Sen. *A Textbook of Medieval Indian History*. Primus Books, 2013. pp. 34.

[6] C. K. Raju. *Cultural Foundations of Mathematics: The Nature of Mathematical Proof and the Transmission of the Calculus from India to Europe in the 16th c. CE*. Pearson Longman, New Delhi, 2007.

[7] C. K. Raju. *Is Science Western in Origin?* Multiversity and Citizen's International, Penang, 2009.

[8] Parmanand Singh. The So-called Fibonacci Numbers in Ancient and Medieval India. *Historia Mathematica*, 12(3):229–244, 1985. doi: https://doi.org/10.1016/0315-0860(85)90021-7.

[9] Kim Plofker. *Mathematics in India*. Princeton University Press, Princeton, 2008.

[10] K. Ramasubramanian, M. D. Srinivas, and M. S. Sriram. Modification of the earlier Indian planetary theory by the Kerala astronomers (c. 1500 AD) and the implied heliocentric picture of planetary motion. *Current Science*, 66(10):784–790, 1994.

Notes

[1]The first few *Cāṇakya-sūtra*s are सुखस्य मूलं धर्मः। धर्मस्य मूलम् अर्थः। अर्थस्य मूलं राज्यम्। राज्यस्य मूलम् इन्द्रियजयः। For further details, please see चाणक्यसूत्राणि along with Hindi translation and explanation by *Śrī Rāmāvatār Vidyābhāskar*.

[2]It is a strange irony that in India, which is home to the world's oldest and continuing civilization, such a research into history is not considered to be worthy of investment. Much worse, an average graduate in India is ignorant of even the names of genuine and honest scholars who have spent their lives researching into various aspects of Indian history, such as Dharampal, Jadunath Sarkar, C. K. Raju, B. V. Subbarayappa, K. M. Munshi, B. B. Lal, R. C. Majumdar, Sita Ram Goel, Ram Swarup, Vasudev Sharan Agarwal, Radha Kumud Mookerji, Vishnu Sitaram Sukthankar, D. V. Gundappa, and such other stalwarts; in spite of having gone through 16 years of school/college/university curriculum.

[3]This 'discovery' is from the point of view of Europe. Of course, native Americans inhabited the lands of America much much prior to the arrival of Columbus. Also, in the Christian terminology, 'discovery' means to go to those lands where Christians are not present and to convert the *heathens* living there to Christianity.

[4]We also hear the names of *Jagaddāla and Somapura* as ancient universities in India. However, it is important to note that education in ancient India was not limited to these universities. For details, see Dharampal's *The Beautiful Tree*.

[5]We may compare this with the models developed by Europe, as *Śrī* S. Gurumurthy says, colonialism (which did not last 200 years), market capitalism (which did not last 100 years), Marxism (which did not last 50 years) and globalization (which did not last 25 years)!

[6]Strange, as it may seem, is that accounts of Indians who have traveled to foreign lands is hardly discussed.