Science and Technology in Ancient Sri Lanka

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Sri Lanka is a country with an ancient history. People who lived during that period faced but overcame various types of challenges for their survival. Included amongst these were the influences of various degrees of issues created by nature, as well as by the challenges associated with the management of socio-political changes which arise when a society continuously exists for a long period of time. In order to successfully face these, it becomes necessary to develop some sort of common social adaptations. History shows that Sri Lanka had such a tradition, and this note expects to discuss them.

Even though superficially the natural world appears to be a simple static admixture of matter and energy, in actual fact it constitutes a complex rhythmic series of events with regularity in change. We continuously face change, but if any condition remains unchanged for a considerable length of time then we sense it. When things remain unchanged we call it 'continuity'. A characteristic feature of living things is their adaptation to continuous conditions which exist for a long time. If there is an adaptation to a continuing condition, it becomes a necessity to adapt again if there is any change. As continuity and change are regular features in the natural world, in order to respond to these, it is necessary to understand the mechanism of how nature operates. In other words it is necessary to comprehend the basic principles which generate the respective conditions in the natural work, and then plan the practical strategies to respond to these conditions. The first of these approaches is considered as scientific thinking and the second as technology.

The moment we hear the terms science and technology, we get the idea or feeling that we have received them from the western world. This is the very reason why we are always compelled to think that science and technology are associated with what is regarded as modern. This is the reason why we question as to what extent is anything scientific if we are to accept it. Any knowledge which is not modern is considered outside and is echoed in this attitude. Rather than understanding the real truth we have been taught to believe that this is the truth. During the period when the modern scientific resurgence was taking place in Europe, most of the western countries which already had ancient civilizations with long scientific and technological traditions had declined due to various reasons. This made it easy to make us believe that modern science is an intellectual feat that developed and united Europe. Even though the required intellectual background for the birth of modern science developed in the thirteenth century, its direct translation began in the sixteenth and seventeenth centuries centered around countries in Europe.

Copernicus, Galileo Galeli, and Newton are the pioneers who were responsible for initiating this development which was based on Astronomy and Physics. The basis for the discoveries by these illustrious scientists was provided by the scientific method of Francis Bacon, and by the methodology introduced by the philosopher Rene Descartes. The methodology of Francis Bacon could be applied to survey of information, while that of Descartes was relevant to analysis and inference. This led to the development of a global perspective which was different from the philosophical background which provided the basis for the scientific ideas of the Aristotelian tradition,

which existed in Europe up to that time. All these aspects taken together was regarded as modern science. In actual fact this concept is a creation of the Jewish - Christian intellectual tradition.

The method of Descartes was analytical, breaking up thoughts and problems into components and rearranging them in a logical sequence. This is the special idea that Descartes contributed to modern science. It is this analytical approach to modern science which enabled man to set foot on the moon. The famous statement 'There I stand' *"Cogito ergo sum"* made by Descartes has been discussed in all philosophical theories, and is regarded as the intellectual stand of Descartes with respect to the concept of mind and body. This thinking of Descartes emphasizes that the mind does not belong to the body, and the body does not belong to the mind. This Cartesian division is the central philosophical approach of modern science. Thus modern science learnt to view the world in a mechanical manner, due to this reason. Not only did rationality and analysis became the methodology of science due to the philosophy of Descartes, it also had an influence to spread authority and control over the world. This is why there is no similarity between the ancient scientific ideas that existed in the eastern countries and the intellectual horizon of modern science. The philosophical basis of scientific ideas that existed in the eastern countries during the pre-modern period was based on a unification of wisdom, understanding and natural order, while the methodology of modern science aimed at analysis. The methodology of oriental science concentrated on synthesis and integrated equilibrium. At least by the beginning of the second millennium B.C., the people of China, India, Sumeria and Egypt, which had great civilizations had already acquired and accepted the modern scientific views. By 2000 BC the Chinese knew the principles of the basis of producing bronze and also the technology to use it for practical purposes . Such bronze objects used in rituals have been discovered from tombs of the Shiya dynasty. By 3000 BC Sumerians had derived mathematical equations which could be applied to analyze complex phenomena. In fact the invention of the sexagesimal method (that is 60 seconds = 1 minute, 60 minutes = 1 hour, circle has 3600 etc.) depicts the glory of their advanced thinking capability. The Egyptian concept of mummification was recognized as a great embalming strategy. In order to undertake mummification practically, it is not only necessary to understand the factors that affect the changes in living matter in the natural world, but also there should be a clear understanding of the method to control these factors. This is relevant to the empirical strategy of controlling variables as employed in modern science. Our neighbour India also possessed an unchallenged scientific tradition in ancient times. Aryabhata, Bhashkara and Brahmagupta are three unique mathematicians of such a tradition. Trigonometry which is taught in modern mathematics had been used in India two centuries before the method was used in Europe.

Sri Lanka also had undergone socio-political transformations of various degrees after the 13th Century AD. As a result the institutional framework which maintained the inherent scientific knowledge of ancient civilization got disintegrated. It is in these circumstances that the colonial Euro-centric movement was successful in spreading the concept of modern science and technology in eastern countries. The extent to which such thinking had taken root in societies including those of Sri Lanka which have been subjected to colonization, made these societies to think that the local tradition used by them was not scientific. The missionary education method created a system of education for the colonies, that facilitated such thinking. The serious challenge that confront the society of this country, which has become the victim of such a situation is not the comprehension of modern science but liberation from the belief that modern science is the only salvation that will solve all our problems. One of the main tasks to be done to liberate from such imitative thinking is to recognize indigenous intellectual knowledge and understand and develop the underlying conceptual basis for their utilization or employment.

We will understand the nature of the local scientific tradition which existed in our ancient society by investigating a few of their applications. The rest of this document will attempt to look at these aspects.

The scientific ideas of the early period

Examining the material culture of the ancient Sri Lankan society provides an opportunity to understand the manner by which the people who lived then interacted with material in the natural world. There is sufficient evidence to indicate that by at least 2000 BC the society of this country had an

understanding of the dynamics of the operations of the natural world. Historical and archaeological sources provide evidence for the tradition responsible for the organization and dissemination of the relevant knowledge. The word *'Achariya'* had been used in the inscriptions of 250 BC or close to that period. This word has been used to refer to the teachers who disseminated knowledge. The historical sources of this country, refer to the institutions called *'ashtamula'*. This refers to the eight intellectual schools which existed in this country about 2000 years ago. These institutions played a decisive role in maintaining suitable standards in the system of knowledge necessary for the society at that time.

In order to provide proof for this statement I have produced a limited number of examples which reflect scientific knowledge belonging to a few time-space dimensions.

Concepts of symmetry and dynamics of force

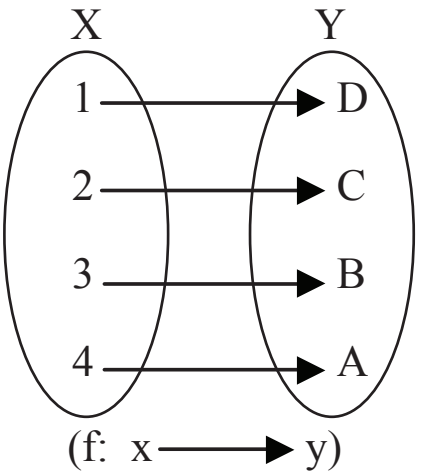
Symmetry is a principle of the natural world. It defines the equilibrium in a system. According to a strict definition, symmetry in one way is an indicator of harmony and visual balance. In another sense it is a mathematical admixture of patterned self-similarities.

A few stone implements which reflect a definite mathematically explainable symmetry have been discovered from several places in Sri Lanka (Image 1). These archaeological objects have been assigned to a period between 2400-1750 BC using radioactive dating techniques. Another similar stone implement has been dated to about 25,000 years of age.

The type of chert rock used to make these implements is a hard rock. If a model conceptualized by man is to be given to this rock which has a crystalline structure, then it is necessary to process it transcending the linear grid pattern conferred to it by nature. When a force is applied to a chert or quarts stone, it disintegrates along its crystal facets. However, the small stone implement shown in the photograph is a result of conscious effort made by man to overcome the natural forces inherent in the relevant rock. We can consider according to modern knowledge the mathematical basis accepted and practically applied by the people who lived in this country at least during the period of about 4400 years ago.

The symmetry of any phenomenon is dependent on the equilibrium of communication between the constituent sets of units. This feature is referred to by the term bijection. It is a mathematical concept. Bijection can be explained as follows:

Image 1: A Stone which reflects a definite mathematically explainable symmetry.



The mathematical sub-group of the symmetrical model of the stone implement shown in the photograph belongs to the type known as rotational symmetry. This example seeks to show the fact that even though not based consciously on mathematical concepts, man possessed the intuitive knowledge required to confer such mathematical relationships to matter. The development of the specialized cells called mirror neurons in the brain, provide the force necessary to generate such symmetry. It is said that these cells persuade the mind to imitate. These cells help to copy a thing correctly. The Acheulian hand axe invented by *Homo erectus* man is a clear example of how the instinct to think mathematically initiated in man. What I mean here is that the inherent ability to understand the basic principles of nature is a tendency related to the prehistoric development of the brain.

At this stage we must introduce and explain how a knowledge of physics had been used in an ancient construction innovation of this country. They are the ancient graves/tombs that have been dated to the period 1350 BC, or 3350

years ago, using radio active dating methods. These graves, found in the village of Ranchāmadama of the Ratnapura District, are elliptical in shape and built with sun dried clay bricks (Image 2). Generally the height of such a tomb is abovt 70 cm aboue ground level. The

Image 2: A tomb found in Ranchāmadama.

thickness of a wall is between 8-10 cm. The walls have been erected on the original natural rock in the site. Places with natural rock existing not beyond a depth from ground level have been selected, from which soil is removed and the walls of the tombs built perpendicular to the ground. Why have the people who lived 3350 years ago think of such an idea and acted accordingly? The only answer for this question is that they wanted to provide a practical solution to prevent the possibility of the clay walls collapsing to a side. Although this affirms to be a simple construction we know that there is an underlying scientific principle. The mathematical principles relating to resolution of forces make it clear that when a solid object stands alone on a flat surface it is possible to neutralize the vertical force by placing it perpendicular to the surface. The fact that the clay walls of the Ranchāmadama graves have remained intact and have not collapsed for over 3000 years is due to the manner in which these inhabitants followed the general laws of nature.

It is the human skeletons and not the dead bodies that have been cremated in the above mentioned graves. Evidence from excavations have confirmed that the skeletal remains have been placed in the tomb and cremated after closing with a lid. It is clear that combustion cannot take place in a closed airtight space where the limited amount of oxygen can get depleted. Then how was combustion made possible inside these graves? Excavations have revealed that they have employed a suitable method to meet this requirement. A hole of about 10 cm in diameter had been made in one of the walls of the tomb and a tube made of burnt clay has been fixed in to it (Image 3). This shows that when combustion was in progress, a mechanism had been employed for air from outside to be supplied in an organized manner. This is a fine example to show the extent to which man had understood the relationship between combustion and air during that period. It appears that it is only in the 17th century that such a relationship between combustion and air had been discussed in detail in the western scientific thinking. The phlogiston theory of Yohan Joachim Betcher (1667 AD) can be considered a typical example in this respect. History of science shows that it was Antonio Lavosier (1843-1894) who explained in the 18th century that oxygen is a definite factor for combustion.

Image 3: A tube made of burnt clay was used to provide air to tomb.

The concept of time and space

There is an inscription on a natural rock in an ancient temple at Kirinda in the Hambantota District. It belongs to the second century AD. In this inscription there is a phrase that reads as *'aparimitha lokadathuya'*. The expression *'aparimitha lōkadāthuwa'*, which appears in the Sanskrit language, has been written in Sinhala Prakrit in this manner. At the time of writing this inscription people were aware that the 'world' is infinite. Modern scientific usage of the terms 'infinite universe' or 'expanding universe' embodies the same idea. The concept of infinite universe came into theoretical discussions only in the middle of the 20th century, and this should have been after the scientific researches of David Bohm (1917 - 1992).

Eastern tradition possessed a wide knowledge structure to describe the concept of time associated with that of space. According to the ancient vedic texts and ancient literary work the smallest unit for measuring time was

mentioned as *'Paramanuwa'*. This was equivalent to 17 microseconds. A microsecond is equivalent to one millionth (1/1,000,000) of a second of modern usage. The scale to measure time ranged from that point to *'Maha manwantharaya'* (311.04 trillion years). This system to measure time was a cosmic one based on the movements of the sun and the moon.

The oldest inscriptions of Sri Lanka that refer to dates, belong to the second century AD. For this purpose the term *'Havajara'* has been used in the inscriptions. This is the Sinhala Prakrit expression of the Sanskrit word *'Sanvathsara'*. The word refers to a year that comprise of 12 lunar months. In the inscriptions of the 9th century AD of Sri Lanka, this system of dating based on the lunar months had been used very clearly. In these inscriptions it is seen that by taking the year of coronation of a particular king as a base, the date had been noted with reference to the elevant lunar month and the movement of the moon for 30 days. For example, the expression *'Wesanga masa pura dasawak davas'* refer to the 10th day of the waxing moon of the month of Wesak. In this concept of measuring time, the day has been further sub-divided into *'hōra'* hours and *'thithi'*.

An example of how the daily movement of the earth was used to measure *'hōra'* or the hour in modern usage has been discovered from the vicinity of the *'Mahāpāi'* alms-giving hall at Anuradhapura. It is a square slab of stone, with a small hole at the centre. The hole has been used to fix vertically an erect stick of wood or a similar structure. This stone slab situated near the stone 'rice canoe' meant for collecting food for the Buddhist priests, had been used to determine the time of day so that serving of the mid day meal to the priests could be completed before noon. Even though the shadow of the stick or rod fixed into the stone slab falls on the slab before noon, it completely disappears when the sun is just overhead or at noon (at 12.00 noon as used now). Although this is simple technology, the underlying basic principle is complex. This hour disc (time measuring device) has been used in the 8th century AD or close to that period.

Systematic measurements required to understand space has been used in our country during the ancient times. References to such measurement are seen in ancient writings *'Aangula'* *'Waduriyana'* and *'Danda'* are some of them.

An iron rod used as a carpenter's measuring stick *'Wadu Riyana'* and owned by a craftsman named Godapola Galladda in the Kandy area had a length of 31 inches (according to modern usage) as recorded by Ananda Coomaraswamy, the famous Historian of Arts. *'Waduriyana'* is divided into 24 sections. Units such as *'Gauwa'* and *'Yoduna'* have been used to measure long distances. King Nissankamalla is known to have installed *'Gav kanu'* (mile posts) on major roads. These were known as *'Gāvuthakanu'*. Such *'Gāvuthakanu'* have been discovered at Katugahalge and Weligaththa.

Measurement of matter

Measurement of matter is essential for science. Once the behaviour of matter is understood, it becomes necessary to manage it quantitatively in order to interact with it. The ancient Sri Lankan society followed an organized system to measure matter. The unit *'Kalanda'* can be given as an example for measuring weight. It is used even today to measure certain types of herbal ingredients. A *'kalanda'* is equal to 4.66 grams according to modern usage. It is a unit of a wider table of units used in measuring weight. The table of weights as given in the text *'Abhidhanappadeepikawa'* is as follows.

4 *vēha*	=	*gunjā* 1
2 *gunjā*	=	*masaka* 1
2.5 *masaka*	=	*akha* 1
8 *akha*	=	*dharana* 1
5 *dharana*	=	*swarna* 1
2 *swarna*	=	*pala* 1
100 *pala*	=	*thulā* 1
20 *thulā*	=	*bhāra* 1
8 *vēha*	=	*manchādi* 1
20 *manchādi*	=	*kalan* 1

During an archaeological excavation of the ancient Abhayagiri temple in Anuradhapura, conducted under the Cultural Triangle project, a gold nugget was discovered. On this nugget the words *'randevisi kalandai'* had been inscribed in a script used in 9th century AD. During that period metal weight had been used as a unit of exchange. Since exchange was a decisive factor in managing the economy, it was extremely important to safe guard the standard of weight measurements.

Some evidence useful in understanding the system followed in ancient Sri Lanka with regard to accounting is found in inscriptions. Whole numbers as well as fractions were in usage. In the Perimiyamkulam inscription installed by King Vasabha (67-111 AD), the phrase *'sakotasin eka*

kotasa dini' (one part of six parts was donated) can be seen. What is meant by this is, one part of six parts or 1/6. Numbers such as *'æka' (1) 'dhvi'* (2), *'thîni'* (3), *'chathara'* (4), *'dasa'* (10) indicating multiples of 10's, *'siyaka'* (100) and *'sathasahasa'* (100,000) have been in usage. Symbolized figures needed to display these numbers have been inscribed in these inscriptions.

Concept of hydrostatics and pressure

It is possible to give two historical examples to illustrate how the basic principles of hydrostatics and pressure have been put into practical use through technology. The first of these is the irrigational structure called the *'bisokotuwa'*. This structure is a sluice gate, which is an innovation to lead water out of water reservoirs (tanks) with tall bunds. The *'bisokotuwa'* has been constructed so as to generate the resistance necessary to control and manage the disastrous pressure caused by a body of water which is thousands of acre feet in area and over 100 feet in depth. It is not possible to provide a detailed account of the technology of this construction in this document. However, it can be realized that it is not possible to construct a *'bisokotuwa'* without calculating the massive pressure generated by such a huge body of fluid. *'Biso kotuwa'* was in use by 2nd century AD.

Another significant example illustrating the knowledge of hydrostatics is the discovery during the excavation of 'Kotavehera' in Dedigama of a metal elephant lamp which has a model of a man seated on a tusker. In this lamp the oil first fills into the elephant's abdomen.

Image 4: A metal elephent lamp found in 'Kotavehera' in Dedigama.

This the oil drips into the lamp through the sex organ of the animal. As the oil in the lamp decreases, an equal quantity of oil begins to drip into the lamp. The understanding of the scientific principle associated with this technology, requires an understanding of fluid dynamics. This technology of about the 10th century AD demonstrates the extent of the indigenous knowledge of the relevant subject.

There are various examples to show that in the interaction with nature, the people of ancient societies, not only in Sri Lanka, but also of other countries were conscious of the basic principles of nature, and worked accordingly. They acquired this knowledge through experience, and not by spending time in laboratories, controlling variables. The basis of this vision was to find the most practical approach to work in a harmonious relationship with nature. The need to live with an amicable understanding of nature was the basis of their existence.

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