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From Ancient Indian Knowledge Systems to Modern School Science: Tracing The Evolution of Science Education in India

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Abstract: *The history of science education within India has developed over time. Ancient and pre-modern South Asia had many impactful knowledge systems in mathematics, astronomy, medicine, metallurgy, agriculture, and material sciences. With the introduction of new educational systems and structures during the colonial era, new Western Science education was seen. After independence, Science education gradually began to be seen as central to education. Current education frameworks include notions of scientific temper, conceptual understanding, inquiry-based learning, and connecting classroom knowledge to real-world knowledge. This report will discuss the progression from ancient Indian knowledge systems to modern Science education within schools using a qualitative historical documentary method. This will draw on secondary research and key policy documents such as the National Curriculum Framework (NCF) 2005, National Education Policy (NEP) 2020, and National Curriculum Framework for School Education (NCF-SE) 2023. This will highlight how scientific observation, practical application, and contextual knowledge have remained, however there have been many changes in structures, evidence, curriculum, and purpose. For Indian knowledge systems to be meaningfully incorporated into science education, they must be critically contextualised to avoid romanticising previous knowledge. A historically aware curriculum will help students broaden their knowledge of science.*

Keywords: *Indian Knowledge Systems, Science Education, History of Science, School Curriculum, Scientific Temper, NEP 2020.*

1. **Introduction:** Science education provides learners with skills in questioning, observing, explaining, investigating, and decision-making using evidence. The history of science education in India is linked to the history of science and technology, learning systems, colonialism, national building, and curriculum changes. Long before Science became a specific subject, communities across the subcontinent had knowledge in number, measurement, astronomy, health, plants, water, agriculture, architecture, and metal working. This was done through practical, academic, professional, and local knowledge (Bose et al., 1971; Subbarayappa, 2013).

However, the historical knowledge seen from ancient times cannot be directly linked to modern Science education. Modern Science is taught as a structured curriculum, with concepts, investigations, standards, and assessment. Ancient and pre-modern knowledge systems were different in terms of their purpose, evidence, structure, and methods. The history of science education needs to be understood.

By implementing the National Education Policy (NEP) 2020 and National Curriculum Framework for School Education (NCF-SE) 2023, there has been renewed focus on incorporating historical Indian knowledge systems (Ministry of Education, 2020; National Council of Educational Research and Training [NCERT], 2023) in education. However, how can the history of Indian science be used to enhance Science education without romanticising or assuming claims without evidence?

2. Objectives

1. To outline key developments in ancient and pre-modern Indian knowledge systems.
2. To explore the changes seen in structure and purpose of science education during the colonial and post-independence eras.
3. To analyse the current direction of science education in relation to Indian knowledge systems.
4. To identify principles which can be used to incorporate Indian knowledge systems in science education responsibly.

3. **Methodology:** A qualitative historical documentary methodology has been used. This has resulted in a narrative, interpretative piece of work. Two types of resources have been used. Firstly, historical research into the history of science in India. General resources (Bose et al., 1971; Subbarayappa, 2013), a chapter discussing the history of science in India in relation to the global history of modern science (Kumar, 2020), and specific resources looking at mathematics and Āyurveda (Plofker, 2009; Varier, 2020; Wujastyk, 2003). Secondly, policy and curriculum resources have been looked at. These include the Report of the Education Commission (1964-6) (Ministry of Education, 1966), NCF 2005 (NCERT, 2005), and teaching of Science position paper (NCERT, 2006), NEP 2020 (Ministry of Education, 2020), and NCF-SE 2023 (NCERT, 2023). These have been carefully selected to ensure they are reputable, published/produced by a government or publisher, and are relevant to the topic.

The resources have been analysed in chronological order, focussing on knowledge systems, formal science education, curriculum, and implications. This is not an extensive historical resource, nor does it analyse how policies have been implemented through primary data. There is also a limit to the information due to more written resources being available for those who were literate and from an elite background.

4. Science Related Knowledge and Learning in Ancient India

4.1. **Knowledge Systems and Learning:** There was not one unified system of science education in ancient India. Knowledge was gained through many different methods such as through family, occupation, professional knowledge, learning centres, academic discussion, and reading. This could involve memorisation, commentary, observation, calculation, practical application, and teacher-led learning. There were many differences in the knowledge and accessibility between different time periods, regions, and social groups.

Generally, there were many advanced knowledge systems in mathematics, astronomy, medicine, linguistics, metallurgy, construction, agriculture, and water management (Subbarayappa, 2013). These knowledge systems developed in specific social contexts and interacted with knowledge from other areas. The technoscientific knowledge from the subcontinent was an eclectic knowledge system which evolved due to continual interaction with the outside world and changing social aspects (Kumar, 2020). This prevents assumptions that pre-modern knowledge systems were inferior or that they predicted every aspect of modern Science.

4.2. Mathematics and Astronomy: Mathematics and astronomy are some of the best documented knowledge systems from pre-modern India. The development and application of decimal systems, zero,

arithmetic, geometry, algebra and computational astronomy led to important knowledge systems (Plofker, 2009). Āryabhaṭa's Āryabhaṭīya (499CE) included mathematical rules and astronomical models. Later mathematicians such as Brahmagupta and Bhāskara developed more mathematics and astronomy (Bose et al., 1971; Plofker, 2009; Subbarayappa, 2013).

These knowledge systems are useful to know in relation to education as they demonstrate how calculation, patterning, and observation of cyclical patterns in the sky can promote abstract thinking. However, these should be used in a way that provides historical context and explains how they were actually carried out. Students can look at how decimal systems make calculating easier, create models for how the moon appears to change, and compare how historical predictions for eclipses were made compared to current explanations.

4.3. **Medicine, Plants, and Natural Sciences:** Medical knowledge from Ayurveda such as Caraka and Suśruta traditions include categorisation of bodily functions, observations, medicines, and health methods (Wujastyk, 2003). The history of Ayurveda is complex and has developed across many centuries. This has included changes to practice, interpretation of texts, medical education, and interactions with different communities (Varier, 2020). Knowledge of plants, seasons, food, and local areas was developed.

These can be useful to help teach observation, categorisation, health, and relationships between people and their environments. However, the descriptions shouldn't be assumed to be evidence based. Teachers can help students understand the difference between how important they were in history and how much evidence we have now. They can ask what claims are being made, how they were backed up in the past, what evidence we would need now, and how the claims would be tested using science.

4.4. **Materials, Technologies, and Practical Knowledge:** Metallurgy, pottery, construction, textiles, irrigation, and agriculture show how practical knowledge was important in the history of the subcontinent. This was often learnt through apprenticeship and continual work with materials, tools, and local areas. Historical resources discuss the development of metallurgy, amongst other technologies (Bose et al., 1971; Subbarayappa, 2013). This helps remind educators that science and technology wasn't always developed in an educational setting, but has developed through crafts, experimentation, experience, and problem solving.

This can be explored in science education using safe demonstrations, local technological studies, visiting museums/workshops, and analysing materials. Students can investigate the properties of different metals, how traditional water harvesting systems worked, and how construction can be affected by the climate. Students shouldn't assume traditional methods are better or sustainable. They should analyse how well they performed, what context they were used in, their effect on the environment, and what evidence we have.

5. From Pre-modern Knowledge to Colonial Science Education: The modern development of science education in India has been influenced by the establishment of colonial education, missionary and government schools, universities, science societies, publications, and changing priorities. During the 18th and 19th century European Science and technological education became more prevalent through education establishments and publications. However, many traditional methods were still used. Indian intellectuals and professionals interacted with, adapted, and sometimes challenged new scientific education systems and knowledge (Kumar, 2006; 2020; Subbarayappa, 2013).

With the increase in knowledge being taught formally and through exams, textbooks and standardised curricula were used. However, as Western science had authority in education, some local and indigenous knowledge systems were excluded or changed. This varied depending on the subject, region, and establishment (Kumar, 2006). A critical history should avoid assuming that science education during the colonial era was a simple gift or completely external. There were inequalities involved with translation, collaboration, conflict, and change.

Overall, there has been an increased structure to science education with links to qualifications. However, Science education may be taught as a set of textbook facts with little link to the students' real-world environments. Understanding the history can help teachers to understand why certain topics, examples, languages, and knowledge sources are included.

6. Science Education After Independence: After independence in 1947, Science education became very linked to national development, modernisation, public health, industrial and agricultural advancement, and scientific temper. Scientific temper is a term popularised by Jawaharlal Nehru (1946) and was added to the Constitution of India to become a basic duty of all citizens (Constitution of India, 1950, art. 51A(h)). The Education Commission (1964-6) argued that Science education should be an essential part of general education and should be improved (Ministry of Education, 1966). Science has become a core part of education, though the quality varies between schools and regions.

One of the main issues has been making sure Science education is meeting its aims. If Science is focused on memorisation and exam preparation, students may learn terminology but not how to ask questions, interpret data, or explain. Quality Science education will require quality resources, confident teachers, time for practical work, and assessments which reward reasoning.

The NCF 2005 promotes constructivism and links Science education to children's lives. It encourages less rote learning (NCERT, 2005). The position paper on the teaching of science also emphasises inquiry based learning, environmental concerns, and relevance to the students' lives (NCERT, 2006). This helps students to engage with questions, as they will have developed ideas at home. Teachers can use these ideas as a starting point for investigations and help students improve their ideas.

7. Current Policies

7.1. NEP 2020: The focus of the NEP 2020 is on providing holistic, interdisciplinary, experiential, and conceptual education. It also encourages incorporation of Indian knowledge systems where appropriate, alongside scientific temper and evidence-based learning (Ministry of Education, 2020). This means that the history of Science in India can be used to develop the curriculum. However, the history should be incorporated in a way to improve scientific reasoning.

7.2. NCF-SE 2023: The NCF-SE 2023 focuses on learning Science practically, through inquiry, discovery, and varied learning environments. It highlights hands on experiences, multiple representation, and links to other areas of the curriculum (NCERT, 2023). This provides opportunities to incorporate the history of measurement, astronomy, agriculture, health, materials, and local area knowledge.

However, just including historical or indigenous content doesn't guarantee quality learning. Resources should highlight the difference between claims made in the past and interpretations. It should tell students where the claim came from and the context. Teachers shouldn't assume that contentious claims are factual and shouldn't use cultural pride as a substitute for explanations. The aim isn't to say one civilisation was better than another, but to help students understand that knowledge is created within specific contexts, has developed over time, and can be improved through critical enquiry.

8. Incorporating Indian Knowledge Systems into Science Education

8.1. **Principles:** Six principles have been identified based on the analysis of the history and policies. Resources should be historically accurate. They should include references to the time and place the text, artefact, technology, and practice were from. Any uncertainty and debates should be included. Resources should link to concepts. The historical example should help students understand a scientific concept or the nature of scientific enquiry. Claims should be evaluated using appropriate evidence from the current day. Historical importance and current scientific validity should be acknowledged.

Resources should show Science as a human, collaborative, and cross-cultural subject. Indian knowledge systems developed due to the diversity within the country and interactions with other societies (Kumar, 2020). Modern Science relies on international collaboration. Multiple knowledge systems should be included. Not all knowledge claims are tested and justified. Resources should reflect diversity within the region. Oral histories, crafts, and community knowledge should be included. Permission should be sought and contributors acknowledged.

8.2. **Teaching Strategies:** A history informed Science lesson can start with a question or artefact. Historical context can then be discussed and students can investigate the concept. For example, a lesson on astronomy could include comparing historical calendars to modern earth movement. A lesson on materials could look at the properties of iron or other materials and how metal working was used historically. A lesson on environmental science could involve mapping how water management is carried out locally and evaluating how effective it is with regards to rainfall, geography, and current needs.

Primary sources, museums, diagrams, local interviews, models, and simple experiments can be used. Students can keep an evidence journal to differentiate between observations, inferences, historical interpretations, and claims needing further investigation. Assessments should reward quality questions, use of evidence, reasoning, collaboration, and ability to adapt explanations

9. Discussion: Throughout the history there has been continuity and change. People have observed nature, measured, categorised materials, developed practical skills, and passed on specialist knowledge throughout different eras. This can be useful to link to current Science education. However, modern Science is very different to previous knowledge systems. It is a structured subject with a curriculum, systematic laboratory procedures, standardised assessment, and a focus on public evidence and adaptable explanations.

Curriculum developers need to be careful to not assume that pre-modern Indian knowledge systems aren't relevant to science education. This could limit student's understanding of the history and social aspects of knowledge. However, they also shouldn't assume that ancient knowledge systems were as advanced as current science theories. A balance should be struck by acknowledging the achievements and limitations, recognising historical and current claims, and knowing that all claims can be appropriately investigated.

This aligns with the direction of the NCF-SE 2023 which encourages hands on and inquiry-based learning (NCERT, 2023). Including historical resources will be most beneficial if they help students ask quality questions, understand how ideas developed, and link scientific concepts to their communities. It can help improve inclusion by providing a variety of people, practices, and places. However, teachers will need appropriate training and quality resources to avoid oversimplifying, anachronistic, and repeating popular claims. As this is a documentary study, these implications are proposed. Empirical research into how history informed Science lessons affect students' conceptual understanding and attitudes towards evidence is needed.

10. Conclusion: The development of science education within India has a complex history. There were many varied knowledge systems in ancient and pre-modern times which have developed through colonial changes in education systems, and curriculum changes post-independence. Indian knowledge systems in mathematics, astronomy, medicine, metallurgy, agriculture, and practical technologies provide a wealth of information. However, they need to be carefully contextualised and critically analysed.

The NEP 2020 and NCF-SE 2023 provide an opportunity to link Indian knowledge systems to experiential, inquiry based, and interdisciplinary Science education. Curriculum developers and teachers should focus on providing historically accurate resources, clear sources, evidence-based evaluations, and diversity within regions. Thoughtful curriculum development will help encourage scientific temper, respect for diverse knowledge systems, and question, investigate, and reason. The aim isn't to romanticise the past, but to use historical understanding to improve Science education.

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