Aspects of science education in India: a synoptic review and possible directions for the future

Ramjit Kumar and Smriti Singh*

Science is the constitutive feature of modern society. It has not only changed the world but has also changed the way we understand the social and natural world. Apart from alleviating us from the traps of ignorance, illiteracy and penury, it has challenged the centrality and dominance of metaphysical beliefs in society. The attributes of science like rationality, and open-mindedness, and scientific worldviews are universal values, essential for the growth of an individual as well as the society. In post-independent India, our Constitution adopted the goals of establishing a society based on scientific temperament, humanism and spirit of inquiry. The same is also enshrined in Article 51 A(h) of the Constitution that states that it is the fundamental duty of every citizen of the country to inculcate, propagate and further disseminate scientific temper in society. This underlines that science education is central to our modernity project and the idea of society predicated on scientific rationality, democratic values and open-mindedness. Introducing the idea of science as a process at curriculum level, exposing students to the nature of science are some of the important components of pedagogical content knowledge that can be leveraged in today's science education programme to make science education enjoyable, productive and intrinsic to the learning process. It will also bring the issue of educational praxis at the centre of learning.

Keywords: Post-independent India, science education, society.

As a human enterprise, science aims at acquiring objective knowledge of the world. Modern science arose out of 17th-century enlightenment when society was passing through what Karl Polanyi[1] called 'the period of great transformation'. It was a time when words like science, scientific thinking, and scientific worldview along with the ideas of liberty, justice, and equality came into society as a new entity that increased convulsions, as positivistic society was taking over theological society. In an article, the sociological roots of science, Zilsel[2] traced the origin of a scientist and defined science as activities that scientists do. But what scientists do, changes over a period of time. According to him what we today call a scientist was historically a first class artisan, plumber, etc. This underlines that methodologically science is more than a dogma – it is a process, a method, and a philosophy embedded in the social milieu of society.

The attributes of science like rationality, open-mindedness and critical thinking are universal values. These values are essential for the growth of an individual as well as the society as a whole. At the heart of science lies the inquiry system. If content of science is on one side of the coin, on the other side is scientific inquiry. The aim of science education is not only to make learners aware of scientific facts and concepts but also to make them aware about the benefits of using scientific thinking in personal and public probity. Similarly, dissemination of scientific values is an integral part of our educational process of learning science. Chunawala and Natarajan[3] suggest that it is essential to have scientific temper of mind to participate in democratic decision making as it does affect the person's choice of taking up an action in both personal and public life. In the context of the Indian education system, they suggest it is essential to develop an understanding of science that promotes scientific rationality and educational praxis.

The increasing importance of science in society has made science education important in the 21st century. We can also see increasing influences of science education in different social, economic and political forces and vice-versa. Science education has a distinctive character and is different from other subjects. It has a special role to play in steering scientific rationality in society. As it is located in the broader context of knowledge production and

Ramjit Kumar and Smriti Singh are in the Indian Institute of Technology Patna, Patna 801 103, India.
*For correspondence. (e-mail: ramjit.hpsss@gmail.com)

politics of society, what happens within the classroom has important implications for learners lifelong. In this context, the need of our time is to develop an approach of teaching science that enables learners to deal with significant problems in their lives.

Science education in post-independent India

In post-independent India, our Constitution adopted the goals of establishing a society based on scientific temper, humanism and spirit of inquiry. It is also enshrined in Article 51 A(h) of the Constitution that, it is the fundamental duty of every citizen of the country to inculcate, propagate and further disseminate scientific temper in society. In fact, India is the only country in the world that has a Constitutional obligation to develop and spread humanism, scientific temper and spirit of inquiry. In 1981 'A Statement on Scientific Temper', endorsing the need for scientific temper in our society was advocated by the Nehru Centre[4]. It was expected that scientific inquiry would help people form and develop their ideas and arguments that would finally negate the prevailing obscurantism and superstitions in society.

Science education policy in India is based on the recognition that scientific thinking has a special place in an open and democratic society. It is the cherished value of human efforts, yearning and struggles against the culture of fear and limitations. It is necessary for the advancement of society towards social progressivism to achieve the goals of social, moral and spiritual values and material wellbeing. However, in recent decades, it has been seen that there is a retreat of reason from the public sphere as anti-science attitude and religious revivalism is on the rise. This poses a great challenge to the idea of dissemination and democratization of science and science education in a society that is considering expanding science and science education at all levels and has made science educators concerned about devising a framework and approach to science teaching and learning that will help people make intelligent decisions and form informed opinions that are supported by scientific reasoning.

The National Council of Education Research and Training (NCERT) Position Paper on science[5] has pointed out that our science textbooks are overloaded with scientific facts. The Position Paper on National Teaching Group on Science Education mentioned that science teaching in India suffers from the following problems: (i) It is still far from achieving enshrined values like humanism, scientific temper and social justice that are mentioned in our Constitution. (ii) Science education, even at its best, does not encourage inventiveness and creativity. (iii) Overpowering examination system is the fundamental problem of science education. Similar conclusions have also been drawn by Aikenhead[6]. According to him, students are increasingly disenchanted with school science. School science transmits content which is socially sterile, intellectually boring and dismissive of a student's life work. Most students are not able to understand science taught in classrooms and are hardly able to correlate contents of science with their own lives. This has proved fatal for the development of science learning as a source of intrinsic joy. This has also lessened the popularity of science as a subject among students and has helped propagate the myth that science is a difficult subject. Sarangapani[7] laments the pathetic way in which science is being taught in classrooms. She says that as a country we may take pride in the success of our science graduates abroad, but have failed on the question of the seriousness of science teaching and learning in classrooms. Among other problems, the inadequacy of science curriculum is the central problem. She also emphasizes the need to move away from subject approach to discipline approach to include themes like constructivist approach to learning, Science, Technology and Society (STS) approach to science teaching, indigenous perspective on science to make science education productive in the classrooms. The culture of teaching in India hardly provides autonomy to learners and teachers and believes in the absolute and strict interpretation of textbooks[8]. Kumar[8] called it allowing the prevalence of the idea of textbook culture. Sarangapani[7] traced the roots of such an outdated monolithic culture of learning to the colonial origin of education system that was shaped between 1830 and 1870. According to her, the British system shaped the modern educational school system in India by destroying the indigenous system of education. The British system cut-off all financial help and supplanted the indigenous system with western education.

Mukherjee[9] in an article, *Science Education in India* took a historical look to map the trajectory of science education in post-independent India. According to him, in spite of the tremendous socio-political odds, the success of Raman, Saha and Bose had triggered a sense of pride and jubilance among the people. In 1961, an Indian Parliamentary and Scientific Committee was formed under the leadership of late Shri Lal Bahadur Shastri to determine the problems faced in the area of science in the Indian school system. The other problems considered were finding the relationship between central and state government science education policies and courses offered in schools and other educational systems. In 1964, the Indian Education Commission that was set-up under the chairmanship of D. S. Kothari, pointed out that science in India is in a pathetic condition. This report pointed out that Indians have failed to reckon with the explosion of knowledge in science. In order to address this challenge, an upgrade of school curriculum and textbooks was recommended. In 1968, a National Policy of Education (NPE)[10] was launched with the aim of connecting the development of the nation, citizenship education, and science education. It laid emphasis on social

reconstruction and also on mitigating regional imbalances in the development of the educational system. In 1986, NPE[11] emphasized the agendas of inclusive education, vocational training, technical and professional education and reduced female illiteracy. The educational policy was thus finally linked to the spread of scientific literacy and scientific awareness. This energized the education subsystem to produce skilled workforce needed for reviving the economy to catch up with the West. But in this process, school science textbooks were loaded with more and more factual information – a phenomenon and ideology called the pipeline production by the famous Canadian science educator Aikenhead[6].

In 1970s, science educators, independent resource groups and educationists collectively came together to challenge the orthodox nature of Indian school science and pitched in for formulating an approach that contextualized science education from the learner's perspective. The Hosangabad Science Teaching Program (HSTP) was one such programme that was started in 1972 in Hosangabad district of Madhya Pradesh in India. The experiences of HSTP suggested changes to science teaching in India. HSTP advocated that the country needed a fresh start to developing a science education teaching paradigm. For this, science educators, teachers and civil society as a whole need to come up with an outside-the-box solution. Although closed, HSTP took pride in the fact that innovative concepts like learning by methods of discovery, inquiry, etc. are not only included in the latest policy documents at the national level but also practiced within classrooms. Similar efforts of curriculum-making were taken up in other countries like in United Kingdom by the Nuffield Reform and by the US National Science Foundation.

New science education and curriculum

Education is an integral part of the larger social system. It does not operate in isolation. The late 20th century and the beginning of 21st century witnessed unprecedented socio-economic changes due to advancement in information technology and globalization that has necessitated the agenda of reforming the curriculum. Science curriculum reforms across the countries have aimed at helping students to develop an informed and enriching understanding of science and to experience science learning by innovative methods like learning by doing, learning by inquiry and discovery. Scientific knowledge not only entails knowledge of products of science offered in school science textbooks but also learning processes, procedures, cultures and practices of science. It also includes knowing methods used by scientists to practice science. In other words, it addresses how scientific knowledge emerged and came into being. It also includes questions on what demarcates science from other ways of knowledge-like religion and philosophy. In other words, good science education of the 21st century demands not only comprehensive knowledge of science but also knowledge about science. No doubt, Allchin's[12] formulation of conceptualization of science is a good ground to begin with for the development of comprehensive knowledge of science.

In 1975, NCERT developed a framework of curricular objectives to lay down the objectives of education. NCERT defined curriculum as the sum total of all deliberately planned set of educational experiences provided to the child by the school. Kala and Ramadas[13] reviewed the trends in science curriculum reforms that have occurred worldwide. According to them, Piaget's influence in the domain of science education reforms led to a shift from behaviourism to constructivism and by the 1970s, the major trends in science education research shifted from constructivism to philosophy of science. Philosophy of science, specifically the work of Popper, Kuhn and Lakatos became current in the domain of science education. Ideas such as theory-laden observations and nature of scientific inquiry started to impinge on school curriculum theories and texts. They explained the justification for applying ideas from philosophy of science to science education. It can be found in the 'child as scientist' metaphor, which was subtly present since Piaget. As a child can be considered as a novice scientist, researchers in science education thought that philosophy of science, which attempted to lay down the foundations for science, could similarly be used to interpret children's conceptions of science and provide guidelines for interpreting such conceptions. Confrey[14] pointed out that philosophy of science has allowed researchers to critique the underlying inductive conception of science which has permeated science textbooks in the form of the scientific method. However, Kala and Ramadas[13] contend that unfortunately in the practice of science education research and curriculum-making in India, developments in domain independent science education research like epistemology studies and cognitive psychology are yet to be seen.

Conclusion

The idea of teaching science as a process/inquiry and value system has drawn attention and is reiterated in the National Curriculum Framework Policy (NCF)[15], 2005 of India. NCF 2005 has recommended that cognitive validity, content validity, process validity, historical validity, environmental validity, and ethical validity should be part of any science textbook for ideal science teaching in classrooms. But unfortunately, today's science textbooks project the image of science that is both simplistic and reductionist, ignoring the epistemic, cognitive and social dimensions of science. Consequently, an overwhelming

majority of students have a naïve conception and understanding of science and teachers continue to structure their science instruction in a way that is incommensurate with how scientists undertake inquiries into natural phenomena in real life situation and proceed with scientific activities and scientific deliberations. This provides a firm ground towards introducing the idea of science, as scientists practise science, rather than what they say they practise. The assumption is that an understanding of science as a dynamic enterprise of human activities would benefit the learners in the long run. Such a system of pedagogy is complemented by teaching history, philosophy and sociology of science (HPSS), nature of science (NOS) and also pedagogical content knowledge. It would help to spread functional scientific literacy in society. This underlines why there is a higher need to introduce the idea of science as a process. Across the nation-states, the increasing importance of science in dealing with issues of socio-scientific issues in society has been gaining ground to incorporate: (a) teaching nature of science along with the content of science; and (b) the knowledge of how science is being practised, that also includes the contributions of affective side of humans, like the role of creativity, imagination and errors, and socio-psycho effects of scientists in the making of scientific knowledge.

Reforms in science curriculum necessitate taking cognizance of science teaching as a process. It is needed to disseminate scientific temper as the dominant mode of thinking in a society that helps people base their reasoning on the cause-effect relationship. In fact, scientific thinking is an attitude of mind that favours the value systems supported by egalitarian, secular and rational values, and develops the collective conscience of society based on the spirit of inquiry. The spirit of inquiry is accepted on the basis of the right to question and be questioned, that involves knowing the grammar of science to apply it to many aspects of life – from ethics to politics to economics.

1. Polanyi, K., *The Great Transformation: The Political and Origin of Our Time*, Beacon Press, Boston, 2001.
2. Zilsel, E., The sociological roots of science. *Soc. Stud. Sci.*, 2000, **30**(6), 935–949.
3. Chunawala, S. and Natarajan, C., A study of policies related to science education for diversity in India. In *Towards Effective Teaching and Meaningful Learning in Mathematics, Science, and Technology*, Proceedings of ISTE International Conference on Mathematics, Science and Technology Education, South Africa, 2011.
4. *A Statement on Scientific Temper*, Education Documentation Center, 1981; http://el.doccentre.info/eldoc1/setdev/810725mns1B.pdf (accessed on 16 June 2016).
5. NCERT Position Paper on Science 2005; http://www.ncert.nic.in/new_ncert/ncert/rightside/links/focus_group.html
6. Aikenhead, G. S., *Science Education for Everyday Life: Evidence-based Practice*, Teachers College Press, New York, NY, 2006.
7. Sarangapani, P. M., Three challenges facing Indian school science education. In *Science Education: Few Takers for Innovation* (ed. Joy, A.), IKF (IRIS Knowledge Foundation), Mumbai, 2014, pp. 32–35.
8. Kumar, K., *What is Worth Teaching*, Orient Blackswan, New Delhi, 2004.
9. Mukherjee, A., Science Education in India, 16 August 2007; http://www.thehindu.com/todays-paper/tp-opinion/science-education-in-india/article1892821.ece
10. Government of India. National Policy on Education – 1968, Ministry of Education, New Delhi, 1968.
11. Government of India. National Policy on Education – 1986, Ministry of Education, New Delhi, 1986.
12. Allchin, D., *Teaching the Nature of Science: Perspectives and Resources*, Ships Education Press, Saint Paul, MN, 2004.
13. Kala, L. and Ramadas, J., History and philosophy of science, cognitive science and science education: issues at the interface. *Indian Educ. Rev.*, 2001, **37**(2), 3–21; http://www.hbcse.tifr.res.in/research-development/vsr/jr-and-lk-history-and-philosophy-of-sciencecompressed.pdf
14. Confrey, J., A review of the research on student conceptions in mathematics, science and programming. *Rev. Res. Educ.*, 1990, **16**, 3–56; doi:10.3102/0091732X01600100.
15. National Curriculum Framework NCERT, 2005; http://www.ncert.nic.in/rightside/links/pdf/framework/english/nf2005.pdf

Received 10 August 2016; revised accepted 19 February 2018

doi: 10.18520/cs/v114/i09/1825-1828