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Contents

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Indian School Science Education

Anu Joy

This dossier on Indian science education aims at initiating a dialogue on the issues and major challenges facing Indian school science education. It examines the present status of Indian school science education and reflects what exactly the present science education is contributing to Indian children and larger society. The Indian school curriculum and polices have forged a remarkable level of consensus that science education is important for all children attending schools. Science is a compulsory subject from elementary school onwards. What are the distinctive purposes of teaching science in schools? What knowledge is of most worth for school science education? The children who come to the Indian science classrooms belong to a heterogeneous socio-economic-regional and cultural backgrounds, who will continue to pursue science and technology related careers and who will not. How school science teaching can meet the requirements of all the students? What can one reasonably expect from a student in terms of his understanding of science after 10 years of study of science in school?

 The dossier comprises of five articles each taking a differing and complementary themes and focuses on the questions – What are the fundamental aims school science education? Why to teach science in schools? What will create a meaningful and fruitful setting for teaching and learning of science in schools? What are the major issues and challenges facing Indian school education in general and science education in particular? Looking to the future what kind of a school education and science education we envision for our children? Do we propose any difference in the way we educate children in school and the way we teach science? If so, how can we conceptualise a different school education and science education? One of the important matters of concerns is the close link between science education and the notion of development proposed under the banner of economic globalisation. In this context, how can we develop a responsible science education? Whether there are alternate requirements for the content and process of school science education? This dossier is an attempt to explore these possibilities. It aims to reassert the importance of a responsible science education in schools and a responsible approach to formulation of science educational policies.

Aims of Science Education – An Analysis of the Science Curricular Policies

The subject matter of science takes a central place in school education. The most widely acclaimed views of teaching science in schools is that it can inculcate in children certain values and attitudes –scientific temper, rationality, reasoning, problem solving, methods of science and so on. – that are essential for an enlightened citizenship; also teaching science in schools can fasten progress and development of a nation by creating scientific and technological manpower essential for continued economic growth. A wide range of influences went into the shaping and formulation of science education of Indian school classrooms – the historical and colonial influence, the Nehruvian project of creating a modern independent India, the neo-liberal economic mandate of creation of scientific and technological manpower and production of skilled labourers, the way in which larger society and parents wish to shape the lives of younger children and so on. The objectives that figured most prominently and persistently in several of Indian science curriculum and policy documents is the role of science education in eradicating poverty, and emancipating masses from social ills of superstitions and illiteracy, and training and creating a cadre of scientists who will contribute to the nation building. Thus Indian school curricular aims ascribed a transformative and emancipative role to the subject matter of science, that teaching science in schools can address challenging social issues facing the nation and liberate the minds from irrational beliefs and practices. *"In a progressive forward-looking society, science can play a truly liberating role, helping people escape from the vicious cycle of poverty, ignorance and superstition"* (National Curriculum Framework - 2005). The underlying assumption is that science education can initiate social change by bringing about changes in the outlook and attitude of people as it is a subject that is directly connected with enlightenment values such reasoning, logic and rationality. Another aim that got significantly valued in the recent science curricular reform is the creation of a scientifically and technologically literate citizenry who are sensitive to societal and environmental issues, and who can understand how science, technology and society influence each other.

While several of the post independent science curriculum and policy documents reinforced the above aims for science education, the rise of global economies and neo liberal policies created new challenges and opportunities for science education (Hodson, 2003). It has had to rise up to the realisation that science education is critical for creating a skilled labour force who can function innovatively and flexibly in the new knowledge economy and who can use their knowledge and skills for an effective competition within a market place. In this new paradigm of education, the science curriculum, textbooks and classroom processes have had to respond to the call for shifting approaches in its content and method of teaching-learning processes. School science education came under the pressure of catering to the diverse requirements of economic policies, larger societal, parental and children's aspirations – to develop creative thinkers and knowledge

workers, those who can participate in the world of work and productive labour market after secondary schooling and to the students who want to pursue higher studies in science and technology related courses. The curricular documents, for example the Kerala Curriculum Framework-2007, proposed diversification of curriculum and subject matter at the secondary and higher secondary grades as one of the solutions to address these requirements and challenges. Thus, an instrumentalist and vocational view of science education that premises its assumptions on the polarised notions of 'knowing' and 'doing' began to emerge in the terrain of science curricular and policy discourses.

The past few years had witnessed revolutionary reform measures taking place in the scenario of Indian school education with National Curriculum Framework-2005 espousing a teaching-learning process that is child centred and activity oriented. The purpose of these reforms ranged from radical restructuring of the content, pedagogy, and evaluation processes, efficient school management and governance, empowering teacher and teacher education, bringing in community participation and local resources for school learning. NCF approached children's learning in school on the cardinal phrase of 'children constructing knowledge' and premised its recommendations based on the theme of the active nature of child's learning – 'child as an active constructor of knowledge', 'child centred learning', 'joyful learning', 'child as a natural learner', 'knowledge as the outcome of the child's own activity', 'constant querying of children', 'participatory, interactive, and experiential rather than instructive', 'active learning through the experiential mode', 'child as an active participant rather than a passive recipient in the process of leaning', 'child's capabilities and potential are seen not as fixed but dynamic and capable of development through direct self-experience' and so on.

The objective that forms a keystone to this reform initiated by NCF-2005 is of making school learning closer to child's familiar everyday world and contextualising science learning in everyday world of child. Thus according to NCF-2005 school classrooms must be transformed to spaces where children actively engage with their everyday familiar world – physical, social and cultural – around them exploring, observing, solving problems, inventing and working things out, and making meaning out of it all. NCF 2005 regards this bridge i.e. between the everyday world of the child and school science learning, to be important cognitively, to make school learning meaningful. It also embraces the view of learning as a collaborative and situated process where learning and understanding are done within a community of learner. *"It is in interaction with the environment that the child constructs knowledge and derives meaning. This area has generally been neglected both in the conceptualization of textbooks and in pedagogic practices. Hence, in this document, we emphasize the significance of contextualizing education: of situating learning in the context of the child's world, and of making the boundary between the school and it's natural and social environment porous. This is*

not only because the local environment and the child's own experiences are the best 'entry points, into the study of disciplines of knowledge, but more so because the aim of knowledge is to connect with the world. It is not a means to an end, but both means and end. This does not require us to reduce knowledge to the functional and immediately relevant, but to realize its dynamism by connecting with the world through it" (NCF-2005, pp30). NCF also placed a greater emphasis on the role of teachers, their autonomy and professional competence in implementing the new form of pedagogy and emphasised on the need to revamp professional development programs. It called for radical changes in teachers' knowledge and beliefs about subject matter, teaching, children, and learning. The different constructions of curriculum about the nature of children, their learning and pedagogy, can produce different construction of the science teacher. According to NCF-2005, the teacher is a facilitator who encourages and guide children to reflect, solve problems, analyse and interpret in the process of exploring their world and knowledge construction.

While the policies and curricular aims have been ambitious, there exists a wide gap between the curricular ideals and the actual practices of school science school science classroom and learning of children. These recommendations are differentially approached and implemented by different states of the country, and thus differentially experienced by teachers, children and science classroom processes. Also in the Indian case, the school science education and teaching learning processes majorly have tended to favour children belonging to high socio-economic background and it dominantly aligns with the urban middle class values and practices. The ethos and values promoted by science education such as meritocracy and competitiveness resulted in creating disproportionate and inappropriate learning outcomes from children belonging to different socio-economic backgrounds. The science curricular and policy documents are also in a persistent search for devising a universal content and pedagogy that structures its learning programs taking the view of 'universal mind' of a learner. The school science education that embraced a 'universalist view' of science was successful enough in equipping learners to perform well in standardised year end examinations, competitive tests and in preparing scientists and skilled scientific work force to participate in an economic regime driven by science and technology. The present system of school science education is successfully created scientists, IT professionals, engineers, doctors and a labour work force for the global economy; also a technocratic and managerial class of citizens who casts their major influence on shaping the nation's policies, larger societal thinking and cultures. The children from marginalised communities and rural backgrounds still find it a distant dream to secure the hope and social mobility that the school science education promises. After several years of learning science in schools they eventually find it irrelevant to their lives and livelihoods. Science education thus continues to remain elitist in nature, inappropriate for children coming from heterogeneous socio-cultural and economic

backgrounds and whose aspirations and requirement of school education are diverse. The dominant trends in science education that are apparent in the recent decade are the marketisation and vocationalisation of school science education. The growing nexus between the public institutions and the market have not only played a major role in pushing the directions of educational policies, but also the 'pedagogy market' (Kumar, 2012) have made significant inroads to science classrooms in terms of development of teaching learning materials, guides, project books, science experiments and lab kits, assessment tools and delivering software tools and digital resources. Science related professional courses being one of the most preferred choices for students, the competition for the entry to top institutions is high with parents spending lot of money to send children for additional tuition and coaching classes for science related subjects. This has resulted in mushrooming of large number of entrance coaching and tuition centres. Such outside agencies that devise a completely new content and pedagogy for teaching and learning of science have deepened its influence not only on student's success in entrance exams but also in shaping their understanding of science and of the nature of subject matter of science

With all its claims, the value that lie at the heart of these science curriculum and reform initiatives is an aspiration to pursue a model of developed proposed by western societies and science. The idealised western imagination of science as 'objective' is treated as a truism in curricular documents that presupposes teaching of science in schools can support faster economic growth, social development and human welfare. The teaching-learning processes of science classrooms guided by such curricular and policy rhetoric provided a factual account of the world to children. The Indian school science textbooks still derives its understanding of science and scientific method from an inductivist-positivist tradition, and structures its content on the assumptions that science is 'value free' and 'neutral'. Knowledge is valid only when empirically demonstrated and substantiated. The primary concern of school science often seems to be the transfer of universal scientific principles, laws and concepts. In the science classroom process, even those focusing on activities and demonstration primacy is given to teaching the facts, and the activity was treated as a tool for making these facts realistic and interesting. Although the influence of positivist science is diminishing in contemporary philosophy of science, its role is dominant in the school science curriculum and textbook making. A conventional method of science as observing, formulating hypothesis, deducting, measuring, accepting or rejecting hypothesis based on observation is the method followed and transpired by science textbooks and classroom learning processes. The overarching emphasise of the science curriculum and textbooks on frameworks such as "inquiry based learning" "learning by doing" etc. gives primacy to investigative methods of science and gives the image that scientific facts and principles are derived only from large amount of observational data and tested hypothesis. The science curricular aims

of making learning 'relevant' i.e. connecting science to social context and everyday world, is achieved by the science textbooks by introducing topics related to Science, Technology, Society and Environment (STSE). What actually happens in actual cases is that the science textbooks and classrooms processes take a moralistic and prescriptive stand and succeed in only making children aware of the environmental issues, and social issues. Moreover while making science learning 'active' and 'relevant', the science curriculum and textbooks recognises the role of activities, experimentation and doing science. But little attention is paid by the school science on theorising in science, the nature of science, limitations of science and scientific methods, the role of history and philosophy of science, and the social nature of scientific knowledge. It often discards the numerous examples of creative thinking in science where basic ideas of matter, motion, Newton's first law of motion, etc. were theoretical constructs and derived as a result of elegant speculation and answers to philosophical questioning regarding fundamental nature of the universe (Sarukkai, 2012).

In India, the kind of inquiry and activities happens in school classrooms are more often scripted by the textbooks, syllabus and teacher handbooks developed in accordance with the guidelines set by a centrally written curriculum. Science teachers are trained to follow these predetermined scripts and procedures. The actual science classroom processes gets confined to and dependent on the content of the textbooks, specific timeframe allotted by the curriculum and syllabus, i.e. the 45 minutes time allotted by the time table of a school day and specific time period allotted by the syllabus to complete portions; also the science teachers does not have any autonomy over the selection of content and choice of pedagogic processes. The science classroom processes implemented through the teacher within the limits of the centrally written curriculum guidelines, classroom time and through scripts of the science textbooks and teacher handbook offer limited provisions to draw children's attention to the relevance of their everyday world and immediate context for learning purposes – as the curricular document envisages – and thus converting science learning a *'decontextualised'* experience for the children (Kumar, 1997). This decontextualised science learning processes of school classrooms are at odds not only with the curricular ideals and aims, but also with larger societal and community's ways of integrating children into its knowledge traditions and cultures.

Research studies from several countries and contexts bring out the differential participation and low achievement of students belonging to different socio-economic regional, cultural and gender backgrounds (Baker, 1998). Research studies also indicate the lack of participation and low achievement of women in science. There are fewer girls who opt for courses related to science and technology. The science curricular and classroom experiences, together with the invisibility and lack of representation and participation of women in the discipline of science contribute to this underrepresentation and underachievement of women in science. Undermining the voices, perceptions and

lived experiences of several sections of societies by the science curricula and classrooms made science learning an alienating experience for children. It socially excluded and cognitively alienated a larger section of children from science learning processes, which surprisingly also went into conflict with the policy rhetoric of transforming societies though inculcating scientific values in all of its children and creating an enlightened citizenry through science education.

The development of a systematic strategy for bringing in fundamental changes in the teaching and learning of a subject like science requires meaningful curricular visions, innovation in course content, modes of instruction, teacher education, student assessment and situating the learning in child's socio-cultural milieu. What is more important is the support of a state policy, funds and resource allocation. The contributions of education and science education to the development of societies and individuals have been profound. Education is the fundamental right of all children, a means for economic, social and political advancement and for empowerment of marginalised and disadvantaged sections of the society. Policies are in place to improve education for all and several measures have taken to bring the disadvantaged and marginalised children their right to education and to empower them to meaningfully participate in educational processes. What the future holds for these children and what science education has to offer for them is still a big question.

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Science Education for a Different India

M. P. Parameswaran

Education today is reinforcing the forces leading the species into self destruction. Instead, it has to play a liberative role, a transformative role, a creative role- a humanistic role.

Animals train. Humans educate. Formal education had already become a well developed activity by the time of the Great River Valley Civilisations. The earliest records of history show that there were 'teachers' and 'students'. This formal education was available, however, only to a select section of the society – 'the higher ups'. From that time onwards education was consciously used for two purposes:

(i) To help carry out the routine activities of the society more and more efficiently.
(ii) To help the hegemony of a few over the many.

In India the Brahmins constituted the 'few'. The contents of their education were, Sanskrit language, the Vedas, Upanishads, etc; Astronomy, Logic, Mathematics, and Medical Sciences. Architecture, metallurgy, instrument making, etc. were left to 'lower' castes - mostly in the form training. Advances in these branches of knowledge came from practitioners. This was true for the rest of the world too: a few hegemons and a multitude of hegemonised.

Textbooks on astronomy, life sciences, medicine and mathematics began to emerge roughly 2000-2500 years ago. The professional category of 'Teacher' (Guru) must have become important more than 4000 years ago. However, at any time, all teaching is not done by teachers. It is said that "one learns a quarter from the teacher, a quarter from fellow students, a quarter by themselves and the final quarter from life experience". What the student learns from the teacher is, essentially, the capacity to learn by himself and from life.

Every learning process has two components - learning to think and learning to do. An apprentice to a carpenter, a plumber, an electrician learns, essentially to do. A student of mathematics learns essentially to think. In between there is a continuous spectrum of different combinations of doing and thinking - starting from ITI and vocational education to university education and pure mathematics.

However today education is a Big Industry, a Big Business Enterprise. In India it involves about 4 million teachers and 200 million students.

Education Enterprise

In 1999 the findings of a study by James Tooley (1999) of the University of New Castle, UK 'Investment Opportunities in Private Schools and Universities in Developing Countries' were published as The Global Education Industry (a concept that would have been sacrilegious to many, had it been two decades ago). In June 1999, the International Finance Corporation – a member of the World Bank Group – organised a two-day conference on "Investment Opportunities in Private Education in Developing Countries" in Washington DC. The argument of the study encompasses five major points:

(i) Educational enterprises were profitable, even when financed entirely from student-fee and still were open to the masses and not merely to elites.

(ii) Many entrepreneurs have expanded into education companies with chains of schools and universities. Parents trust them because they had acquired a brand identity.

(iii) Private education can extend to all, not only to the elites. It is equitable.

(iv) Private sector is hindered in what it does by the regulatory regime and the investment climate.

(v) Public - private partnership is an emerging model.

The study found 'huge untapped markets for education', but felt 'the regulatory environments in these countries ... somewhat of a hindrance.' They just could not understand why "the issue of profit-making in education is a stumbling block for many governments, several of which make it illegal." Still, the education industry has flourished. Objetivo/UNIP started as a tuition centre for pre-university courses for 20 students in 1962 has grown into a vast empire with more than 500 campuses and 500,000 students by 1996. Educer in South Africa started as 'crammy college' in 1943 has today 127 campuses and over 300,000 students. NIIT India, started in 1979 has now 400 Centres. All these are 'for-profit' institutions.

The purpose of 'human existence' is to make profits, according to proponents of capitalism. The most unique characteristic of human species, as different from other animals, is its propensity to make profit! Corporate Watch on its web http://www.corpwatch.org/teature/education/index.html regularly publishes corporate projects in the field of education industry. Edu Ventures, an investing banking firm, which coined the phrase "education industry" estimated "its worth in USA to be about $630 and $ 680 billion and that the stock value of, 30 publicly traded educational companies is growing twice as fast as the Dow Jones average. Countless tricks and tactics like

"de-funding public education", "Educational Maintenance Organizations-EMOs", "Corporate Sponsorship," "Voucher System", etc. are used to transform education from "a social investment" into a tradable commodity. The net result is an increasing marginalisation of the majority in India. Conservative economist Milton Friedman, who first proposed school voucher system as early as 1955, argued that public education needs to be radically overhauled to accommodate the free market. In a 1995 piece in the Washington Post Friedman (1955) suggests that such reconstruction can be achieved only by privatising a major segment of the educational system i.e. by enabling a private 'for-profit' industry to develop that will offer effective competition to public schools.

Today we live in an era in which 'education' is accepted as a commodity. So also is the job of a teacher, the educator. One has to 'purchase' it at high prices.

Any commodity should have a 'use value'. Then only it can be sold and profit realised. What is the 'use value' of education? It enables the student to sell her/his labour power at a higher price and earn a better livelihood. The capitalist buys educated labour power to produce new commodities, to sell and to make larger profits. This view of education as production of labour power as a commodity, this capitalist's view of education, is more than two centuries old. However no textbook as yet, defines education as a commodity. Instead, they give lofty objectives like:

i) To impart knowledge and skills required to function as a member of the society around them, in the production of necessary goods and services (commodity element)

ii) To impart attitudes and skills to be part of the spiritual or non-material life of the society.

iii) To help develop the individuals potential to the fullest extent. There is a fourth objective, conspicuous by its absence in most of the 'standard' textbooks of education, namely

iv) To develop the student's ability to transform the society, or rather to subvert the society.

Education and development

There is a conflict between objectives (i) and (ii) on the one hand and objectives (iii) and (iv) on the other side, a tension between Being and Becoming. Objectives (i) and (ii) serve the purpose of stabilising the status quo, of strengthening the Being, of preventing it from Becoming - a new one. Objectives (iii) and (iv), especially (iv) is to use education as a weapon for social change to aid the process of becoming. We have several examples of education for becoming in our history, mostly in the informal mode. The leaders of Freedom Movement gave to the people a subvertive education for a new India, a Free India.

But, what should Free India look like? The political leaders were not united on this

issue. The vision Gandhiji had, on the future India was a union of lakhs of self reliant village republics with focus on agriculture and livelihood. He conceived an education plan suitable for it, the Nai Taleem and started experimenting with it in Wardha and elsewhere. Nehru had a totally different view of future India. He saw an India as modernised as Europe - industrialised and urbanised. The rising bourgeoise in Bombay, Calcutta etc. shared his vision sans the rhetoric on secularism, democracy and socialism. The left parties supported Nehru's vision, but giving much more emphasis to socialism. There was practically nobody to uphold the Gandhian vision of Free India. The Gandhian concept of development, both theory and practice, was rejected together with that Nai Taleem.

The first few years of independence were years of adaptation to 'freedom'. In 1951 Nehru started right in earnest to modernise India. From socialist Russia he borrowed the idea of economic planning. He began to construct 'modern temples' - power stations, industries, Universities, Institutes of Technology, Research and Development Laboratories, Atomic Energy and Space Research Departments and so on. The growth in education and research facilities, industrial establishments, power industry etc. was phenomenal. Even more impressive were the achievements in Nuclear Energy and Space Science. All these required appropriate human power, Universities, Colleges, Institutes of excellence. A multi frontal action programme was executed. The Department of Atomic Energy set up its own Training School to train nuclear scientists and engineers. (The present author was an engineer trainee of the very first batch).

India and Bharat

However, all these were concerned with only a small section of the community. Slowly two different streams of education began to develop - one an education for the Europeanised or Americanised, urbanised, rich upper class, normally referred to as India, and the other for nearly 70-80 per cent of the population which lives predominantly in the country side - which is generally known as Bharat. Universal free and compulsory education was projected as the Boat for BHARAT to cross the sea of poverty and deprivation and to reach INDIA. Elementary Education should have become Universal by 1965. But even today, even after passing the Right to Education Act, crores of children are outside the education system. Even among those who are enrolled in schools, only a small percentage gets any sort of education.

Inequalities existed in feudal India, in British India and in free India. Inequality is an essential precondition for capitalism. Education too developed in two streams - one for the elites, the 'public' schools and the 'model' schools, another for the ordinary people. The differences are only too well known to demand any further treatment. Several Commissions had been constituted and they had given recommendations on what should be done to improve education. But their recommendations were used to

serve purposes contrary to their very spirit. One of the simplest but potentially powerful recommendation was the institution of the common (neighbourhood) school system. This was never implemented. The other was on medium of instruction. Contrary to the spirit of their recommendations, English medium schools have been steadily growing. Versatility in English is important to gain admission to 'elite gang.'

The year 1990 was a turning point in post-independence India. It became, formally, a part of the global market, part of the neoliberal economy. It was this, and such transitions in the other developing countries that led the World Bank and Corporate power to the afore mentioned conference, to transform education from a 'social' good or service to a commercial one. The phenomenal growth of educational enterprises in India during the past two decades does not require any proof.

Today, more than ever, education, the increasing divide in education, is strengthening and expanding the income and social divide. India and Bharat are being torn apart more and more sharply, leading to increasing conflicts. The Maoist movements and other reactions are only one form of expression of this. Though politically wrong, because it will not lead to success, their anger is morally justified, Bharat against India.

This conflict has to be resolved. The divides are to be bridged. India and Bharat will have to become one united nation. A society based on welfare and culture, a society liberated from forced alienation necessitated by consumerism, a society with ever increasing leisure to be spent as one desires, a society with increasing health and longevity, with increasing control over one's own life can be built. Only thus we can serve ourselves and the humanity from the near possible destruction of our human culture and even the species itself, towards which the present global development path is leading us.

This is, and should be the objective of education. Education has to be liberative and hence subvertive. It will take a long time to transform the mainstream submissive education into a liberative one. But we can start at the process in the individual class rooms and by individual teachers, all inspired by the grand dream of liberation. It is against this general framework and objective of education that we have to think of Science Education.

Science education is nothing but part of general education. It gives added capability to the students to understand and transform nature, to produce goods and services for the community. However the communities in which the students will have to work after education are widely different - from Africa to America, from India to Europe, from Japan to China. Education, also science education, has to prepare the students to work in these unimaginably different communities. It will have to be different for different community. However, when we look into the curriculum and text books of the countries all over the world, one can find an astounding similarity of contents, not only in thinking but also in doing. A teacher from India can go to Africa or China, Europe or America and soon can teach there. The basic subject and pedagogic trainings they have received

are the same. True there are differences like behaviourism and constructivism, banking and discovery and so on. But essentially they are all being prepared for almost identical societies, while actual societies are wildly different.

In India the general content and pedagogy of education, including science education, is basically addressed to the requirements India and not Bharat, which is grossly neglected. However, even in the process of addressing India, in reality there is a tendency to address US and Europe. All the education given in the elite institutions, schools and colleges, are aimed at making the student to be useful for US and Europe. Bharat is summarily neglected. There is nothing in the curriculum or syllabus or pedagogy which will help the farmers, the artisans, small entrepreneurs.

A different science education

We have to redefine the objective of education and as a part of it, of science education too. Without teachers playing a leading role, education will not be reoriented in favour of BHARAT and thereby in favour of India (not INDIA) too. Only very few organisations are working with teachers with such an objective. Ekalavya was one of these groups. The Kerala Sastra Sahitya Parishat is another one.

In 1976 KSSP asked for the first time the question: what for formal education and answered in the following manner:

(i)   To develop the capabilities of the new born baby to such an extent that by the age of 18 it can undertake the varied responsibilities that the then society may put on it - productive, administrative educative, knowledge generative and cultural. It is to be futuristic and society specific.

(ii) To enable it to appreciate the cultural heritage of the society it lives in and human society at large and contribute to its advancement.

(iii) To provide it with the ability and also 'will' to overcome the hurdles before the society as it moves forward to progress and transformation.

(iv) Thus to draw out the best in every child, to develop its human potential to the fullest extent.

It is to 'draw out' and not 'put in'. It was a spontaneous understanding - not a 'banking' model but a constructivist model. Based on this understanding the KSSP conducted a variety of experiments both inside the classrooms and outside, and in 1982 came out with a formal Document on Education (1982). It was built upon the abovementioned objectives of education. The Document, amongst other materials, contained one chapter - a critique on the then existing curriculum. It did not deal with the entire gamut of education, but only curriculum for classes 1 to 7.

On Natural science it wrote

> primary (1-4) general science books give some idea of life, air, water, nutrition, health etc. But one can see no attempt to build up a scientific world out look. The objective at this stage should be more cultural than informational. The child should get an overall picture of the objective universe around it, living, non living, the small and the big, the changes constantly taking place, evolution, interrelatedness and diverseness.

> In the elementary (5 - 7) school, children are taught in biology - plants and its parts, growth and reproduction, metabolism, etc. as well as animal diversity, animal cell, mammals, reptiles etc. Again no attempt is made to view life as something holistic. Very little is given about the plants and animals which the child sees every day around it.

The same is the case with sections on human body, chemistry, physics and mathematics. Very little attempt is made to relate what the child learns in the school and what it sees and experiences, around it, daily. The two, the school and the society, are two different worlds. This is absurd. Education should be life related.

Conspicuously absent is anything to improve the psycho-motor skills of the child in the entire curriculum. Thus, later, the KSSP floated another organisation called National Association for Developmental Education and Training, to transform teachers, to enable them imparting skills and attitudes to the children. It envisaged a 120 hour course for teachers which provided for their skill upgradation and knowledge upgradation. KSSP saw that, the values imparted to students in schools, consciously or unconsciously, are those of competition and consumption - a one upman ship value. KSSP felt that school education should help children to acquire values of co-operation, sharing and caring, equity and sustainability.

For the following ten years KSSP carried out a large number of field experiments in pedagogy and curriculum. They experimented with activity based, child centreed, life related and environment oriented pedagogy. It attempted to transform a fragmented science syllabus into a holistic (integrated) science education. The sum total of nearly ten years of experimentation had gone into the formulation of the new curriculum for Kerala schools in 1996. However, it met with severe criticism, basically from the elite who felt that education should help their children in competition. Even the less advantaged people (of BHARAT) felt so, because the entire society is competitive. This brings us to the question of the objective of (science) education once again. Is it,

    (i)   to strengthen their competitive ability? or

    (ii)   to impart to them transformative ability

Education for Transformation

Currently both are required - ability to compete with India and ability to transform Bharat. The National Curriculum Framework 2005, prepared by a committee with

Yash Pal as Chairperson was an attempt in this direction. He had relied heavily on the Kerala curriculum, but has gone beyond it. However, the spirit of NCF was never understood by the teachers or parents, and was not to the liking of the dominant classes in India and the rulers of India. So what we have today is an illusory curriculum in most of the states. The concept of "local curriculum" has been rejected in practice. Without it education cannot be related to life. A transition from education for India to education for India (including Bharat) will demand the following:

1. Enhancing the capability of children of Bharat to compete successfully with children of India. This would demand imparting high level of proficiency in the use of English language and the computer, to access the world store house of knowledge.
2. Equal or higher proficiency in the 'International Science' – i.e., ability to compete in all competitive examinations including IAS, IFS, etc.
3. Ability to relate the science they learned to the variety of life supporting activities - agriculture, industry and services around. It is here that the importance of local curriculum comes in
4. Imparting a multitude of skills which the children of India lack and refuse to master. This gives Bharat a competitive edge.
5. Impart the ability and desire to unite India and Bharat to make a Grand India and finally,
6. Impart an irresistible zest for life - a sense of optimism that tomorrow can be made better than today that they can do it.

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Teaching Science: Content, Method and More?

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Science is more than facts, concepts, theories, mathematics and experiments. In the long debate on what science really is, many scientists and philosophers tend to describe science not in terms of its content, but in terms of its approach and method. Thus, definitions of science are often expressed in terms of 'a body of knowledge', 'systematic approach to knowledge', 'critical enquiry into the nature of the world' and so on. Unfortunately, the problems and exercises are rarely taught as method. Instead, they have become tools to discipline the intellect of the students; more a strategy to evaluate the intelligence and competence of students. If, instead of packaging science as is done in our school textbooks now, the same content were presented through a larger framework of human and social interaction through the disciplines of social science and humanities, we might have students with a deeper understanding of science.

What is it to teach science? How does the teaching of science differ from the teaching of other subjects? Is the difference only in the content of the subject which is taught or is there something else that is unique to science teaching, such as a process of thinking and a process of integrating? But even if we focus only on the content, are there explicit guidelines for choosing the content? For example, can the content include histories and philosophies of science as an integral part of teaching science? Or, if we consider teaching science as including the teaching of the methods of science or of teaching particular ways of thinking and arguing, then should subjects like logic and the philosophy of reason be included in science textbooks?

What should be taught and how it should be taught are also related to the larger aims of science education (SE). Why are we teaching science as a necessary subject for all school students? The belief that science teaching (ST) is necessary right from primary school is based on the view that science is an exemplar of knowledge in today's society and that a student in the contemporary world should know something about science. There is also a related belief that if education is to make students productive citizens of human society, then they should learn science since our contemporary society is a

scientific and technological society. Thus, the underlying belief seems to be that unless the students learn science, they may not be productive citizens in the long run. But given that there are a large number of people who do not work in science or use science in their profession, the aim of science education for *all* students cannot be to make all of them be a part of a larger scientific profession.

Not every student who studies science is, or should be, expected to make a career in science. This is exactly like the motivation for teaching subjects like literature or history. Not every student who studies literature is expected to become a writer. So in one sense, teaching science for every student is like teaching literature as part of the school curricula. It makes the students aware of these important human activities. It makes them scientifically literate without necessarily making them professionals in the domains of science. However, if this is the aim of science teaching then that will influence what and how something is taught. After all, in a class of say 50 students, perhaps more than half will not continue with science as a subject for higher studies. In such a scenario, what kind of science content should be taught? Should it be focussed on the students who will go on to study science and thus give them more content and more rigorous approach to the subject, or should the content be averaged out over all the students? This is the primary challenge in science teaching today since students who study science subjects seem to study it primarily for future careers in science and technology. Since we do not factor this differential future of our students, we have created generations of students who are traumatised by science and mathematics education and come out of school not wanting to do anything with these subjects.

The difficulty which students face in science and mathematics education is exaggerated by the method of teaching these subjects. They are most often taught as a set of specialised skills like problem solving with numbers and operations, or with problems relating to natural phenomena. Very often, the textbooks introduce some scientific concepts and expect the student to master certain kinds of skills. Rarely do you see teachers actually teach these subjects from a broader perspective, one that draws upon the world experience of the student.

These issues have been part of a long debate in SE. In particular, the discussion on the inclusion of the nature-of-science as part of science teaching responds to the specific problem of what it is to teach science. But even if we acknowledge that the nature-of-science has to be factored into ST, it is still not clear as to what elements of this nature have to be incorporated.

The structure of science textbooks does encode some aspects of the nature of science. For example, the questions and problems to be solved are an integral part of the lessons. A student who learns science learns by solving these problems. An essential part of science has to do with the use of both the experimental and theoretical methods. In general, textbooks would engage – however peripherally – with the experimental method.

So, in a sense, one could then argue that science textbooks not only have a content of science but they also incorporate the nature of science both explicitly and implicitly. However, there are various themes that are usually omitted in this content. For example, the history of concepts may not find a place. So while a concept like acceleration would be introduced in a lesson, the reasons why that concept was first used would not be found in the text book. Nor will there be a discussion of the historical trajectory of that concept: how it is related or indebted to other ideas, how its use changed over time and so on. In the case of certain concepts like mass or force, there will usually be no historical description of these concepts or even how different cultures have understood these concepts.

Should these elements be part of a science textbook? Those who reject the addition of these 'extraneous' elements end up primarily projecting a linear and simplified view of science. But, in their defence, they might say that science is defined only by its content as is accepted currently and other historical, philosophical or sociological issues are not relevant for teaching science.

However, this argument is based on the assumption that science education is primarily meant to make scientists out of students, or at the very least to give them technical competence over scientific concepts, theories, tools and related aspects of science. But, as mentioned earlier, only a fraction of the students who study science go on to use these technical aspects and knowledge of science. Thus, are we doing justice to the large number of students who are left out through this approach to science education?

A counter argument to this could be that the hope is to create as many trained science students as possible. If at the end of it, only a fraction continue with science it has more to do with the intellectual competence of the student and should not be seen as a mistake of pedagogy or related aspects of science education. I would argue that this claim is simplistic; and that equating intelligence and intellectual capability with a capacity to do some specific acts related to science is a very limiting view and has harmed the prospects of a large number of students over the years.

In saying this, I am not negating the importance of rigorous training in the complexities of science. Perhaps those who are competent in it and who have the capacity for it can be trained in this manner. But the problem of uniform science teaching in schools is that it imposes certain specific kinds of skills in science and mathematics as the baseline parameter for education and when some students don't perform to this level, their educational career suffers. After all, education must be more than mere science and mathematics education.

Missing from Science Textbooks

So, to motivate this discussion further, let me look at some specific absences in science textbooks and argue why their inclusion will help make science education far more

effective, not just in producing good science students but also in not excluding many students because of the lack of particular skills.

We can begin by looking at the material that is accepted as being part of science. What are the subjects that are taught as science and who decides on it? For example, lessons on cosmology often do not mention the narratives of many different cultural views and imaginations of the universe. Even in texts which give a brief introduction to the origins of science, one usually finds mention of some Greek thinkers to the exclusion of contributions from other cultures, including India. For example, it is very common for students to get exposed to Pythagoras theorem with absolutely no mention of this result being derived by other means in Indian mathematical texts.

When we look at biology, for example, there is almost no mention of the way human body was understood in ancient times in different cultures. The description of the human body is given as if it was always understood to be so, and the mention of a few select European scientists tend to add to the mystique that a few scientists had this extraordinary capacity to grasp these truths. Such presentations are not only misleading but untruthful. Even Harvey's theory of the body and the model of the heart as a pump, had its origins in earlier work, including that of Chinese theories of the body.

In the case of medical sciences, we can note the absence of different medical traditions like Ayurveda that are still practiced today. These are extremely efficacious systems which are followed by millions, but which are not accepted by scientists as being part of science. Thus, even in the choice of content, there is an implicit decision made about what constitutes science and what doesn't. For many cases, such a choice may be justifiable – for example, astrology – but there are also many other domains where the choice is contentious.

The removal of other contexts in describing science succeeds in presenting science primarily as a set of facts. This gives a wrong picture of science and also of scientific knowledge. How did these facts come into being? Historians of science have charted the history of how scientific knowledge developed and it is important to introduce concepts to children through such narratives instead of the concepts-fell-from-the-tree narrative. This historical approach makes it easy for the students to understand the difficulty of concept creation not as a personal moment of inspiration but as a historical, collaborative and contentious process. By giving them this narrative, we make the students think about how these concepts came into being and thereby engage critically with the meaning of these concepts.

There is voluminous historical material on various theories and experiments of science. There are also rich accounts of the multicultural origins of science. If all this can be somehow factored into the teaching of the content of science, the learning of science not only becomes more engaging but the social character of science will also be clearly exhibited. In the larger context of ethics, it is necessary that students understand

that knowledge production in a society is a social process and that there are ethical dimensions to it.

Science is more than facts, concepts, theories, mathematics and experiments. In the long debate on what science really is, many scientists and philosophers tend to describe science not in terms of its content, but in terms of its approach and method. Thus, definitions of science are often expressed in terms of 'a body of knowledge', 'systematic approach to knowledge', 'critical enquiry into the nature of the world' and so on. Some of the ways by which this method distils into the textbook are through exercises and problems. These exercises are designed to make the student think about a problem and find the means to solve it using the tools of mathematics, diagrams and so on. In a sense, this component of a lesson is primarily a way to teach scientific method, its processes of evaluation, of using evidence, of bringing theory and experiment together, and to process all these elements in a unified manner.

Unfortunately, the problems and exercises are rarely taught as method. Instead, they have become tools to discipline the intellect of the students. They become more a strategy to evaluate the intelligence and competence of students. Since the correct answer is so much emphasised in these problem sets, the students tend to think of science as a collection of facts instead of seeing these problems as an illustration of a particular way of thinking about problems.

Many times, even the science teachers are not aware of the relevance of exercises and problems in defining science. The reason for this is that science teachers are also normally not conversant with the disciplines of history and philosophy of science. In fact, I would argue that this lacuna is far more damaging to science teachers than the students. It is the teachers who must first be exposed to these disciplines since it makes the teachers understand science better and thus be able to teach it more effectively.

Why should philosophy of science matter to science teaching? Philosophy of science has largely been concerned with some fundamental questions about science such as the nature of scientific knowledge, the special character of scientific explanations, the meaning of scientific laws, the role of mathematics in the sciences, the structure of scientific theory, the character of experiments and observation, and the relation between theory and observation. Philosophy of science is a rich source of reflections on the nature of science and all that goes into the name of science. It also takes seriously the question of the existence of objects that science postulates, such as atoms, electrons, molecules, DNA at one end, and galaxies and blackholes at the other end. It gives us a way of making sense of the complex narratives of science.

One would think, as indeed scientists in Europe in the early 20th century did, that knowledge of philosophy of science would be very useful for doing science. We can extend this observation to science teaching, since through philosophy of science, the student can be taught the nature of science and of scientific method. Again, I believe

that it must be the teacher who must first be exposed to this, since their teaching of science will radically change after this exposure. They will be able to understand why certain concepts are developed in science, and they will be able to engage with problems not merely as a tool for evaluation but also as a tool for teaching scientific thinking. They can teach mathematics in different ways once they understand how and why mathematics came to play such an important role in the sciences. They will be able to teach students the meaning of unobservable entities which science often invokes. If through philosophy of science they get exposed to the basic methods of logic, then they can actually tell students how and why science is logical. Without knowing this, calling science logical is only a rhetorical claim. Through philosophy of science, they can communicate these ideas of logic and its relation to science to the students.

Those who say that philosophy of science is not relevant in science teaching miss the point that specific histories and philosophies of science are already present in the text the moment certain material is chosen, a specific set ofproblems are given as exercises, and an order is given to the text. So, I think that the question is not whether history and philosophy of science are essential for science education but more a question of what kinds and how much of these subjects should the teacher know and how much the student should.

Similarly, there is a rich amount of material available from the sociology of science. This subject describes the social character of the practice of science and scientists. It also shows how social and cultural factors influence the type of knowledge that is produced and legitimised. In other words, it shows us how scientific knowledge is not a mere product of private intellectual capabilities, but is more a product of social, economic, political and cultural factors. Why is this information useful for science education?

First of all, if science teachers are aware of these influences, they can demystify difficult scientific concepts and situate them within ordinary human activities. They can make science far more human, which it really is and which has been glossed over by textbooks for the specific reason of making science seem like a domain of knowledge outside human influence. They can also understand how the vagaries of human thought and action create these powerful scientific theories. There are two other important lessons that both teachers and students can learn about science when they enter science through the portals of history, philosophy and sociology of science.

First is the importance of the scientific imagination. Historically, imagination has often been viewed with suspicion since it has been closely associated with fiction, unreal worlds and so on. Imagination was also contrasted with reason, which came to be associated with science. However, without imagination there is little science that is possible. Science is not formal logic only because it draws upon specific modes of imagination. This capacity for imagination not only creates new ideas and theories but also helps to validate them.

There are numerous examples of the role of scientific imagination in the practice of science. Holton isolates thematic imagination along with visual and analogical imagination as being crucial to the creation and legitimisation of scientific ideas. As examples of imagination in science, consider how the atom was first visualised as the solar system even though they are dramatically different systems. I use this example because it is so common in science textbooks. Visual thinking is in fact one of the most important ways of teaching science. For example, look at the kinds of charts and diagrams that are used in science. Atoms and molecules are taught using physical models of balls and rods. Pictures of events are often drawn and schematic diagrams of experiments are integral to science teaching. What the students and teachers may not be aware is that these visual representations are not only pedagogical tools, but are actually ways by which scientific research advances. There is a large amount of work on the area of imagination in science which will in principle be very useful for teachers and students to know.

The second important theme from HPS is the role that mistakes and errors play in the practice of science. Unlike the picture of science that emerges from science textbooks, science is not about truth and deriving correct answers all the time. In fact the production of science is based on a large mass of discarded ideas, theories, calculations, concepts and experiments. This aspect of science is not reflected in textbooks which only 'factualise'science, i.e., present it as a domain of facts that seem outside human intervention. Moreover, there are many important theories which are accepted as true today that were actually discovered in error. Many experimental discoveries have often been made through accident. Sometimes these accidents are due to lab workers who make a mistake which leads to new discoveries that have led to the Nobel Prize! There are also many examples where mistaken theoretical assumptions or even mistakes in calculation lead to new ideas, which later turn out to be true. While some scientists might place these kinds of examples under the domain of creativity, we should also recognise that these play a major role in the creation of new scientific knowledge. This is true not only of radically new theories, but is also part of everyday science.

Brining these views of imagination and error into the content of science textbooks humanises science as a subject. This, I believe, will make science education far more effective, efficient and also easier to learn. Instead of packaging science as is done in our school textbooks now, if the same content were presented through a larger framework of human and social interaction through the disciplines of HPS, we might be surprised at how many more students will end up doing science and understanding it better!

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Breaking the Intellectual Isolation of the Science Teacher
Reflections from Whole Class Technology Research in Government School Classrooms[1]

Meera Gopi Chandran

The primary objective of programmes to introduce ICTs in teaching should not be to promote digital technology, but to find a way to address the urgent need to strengthen the knowledge base of the science teachers in a non-threatening manner that does not undermine their dignity, allows them to exercise their autonomy and choice in pacing their learning like any other professional. Experience from the on going Whole Class Technology Research shows that the short duration digital content offers such a possibility for creating a learning opportunity for teachers.

To begin with, there appears to be atleast in the public perception, a dichotomy between what teachers want and what they actually need. It is generally believed that teachers would like to, and do in fact, get away with doing as little as possible. Having had very little say in what constitutes the curriculum, they struggle to make sense of the conflicting demands made on them. As a result they stay on the safe, tried and tested path, especially since they are fully aware of their position at the very bottom of the educational system's hierarchical pyramid. This cannot be taken to mean that teachers would be immune to a rather basic human need to believe that one's work matters. It is sometimes easy to forget that scores of teachers, despite all odds are doing the best they can and many more feel the need to do a good job.

Given the fact that teachers belong to a profession whose professional status is itself held in question (Sarangapani, 2011), it is perhaps by design that teachers do not possess

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[1] This paper is an outcome of the experiences and reflections of this author from an ongoing longitudinal research being conducted with Science and Math teachers in 12 government schools in rural and semi urban areas of Karnataka. The research was designed to understand the process of teacher learning in integrating a certain type of digital technology, viz., Whole Class Technology (WCT) in regular government school classrooms all the challenges that are characteristic of the setting notwithstanding. The research itself was intended to help teachers integrate a certain type of digital technology in their classrooms to make learning more engaging for their students. What emerged was not quite what was anticipated, but was in keeping with what could be expected given the existing conditions of teaching and teachers in general and their knowledge base and professionalism in particular.

the long years of training in an academic discipline that is one of the hallmarks of any profession especially those outside of education (Hargreaves, 2000). Teachers in India in particular, are not expected to have high entry level qualifications, nor are they expected to have a sound knowledge base in any academic discipline. This state of affairs is, as eloquently analysed by Krishna Kumar (2005) owing to the legacy of our colonial past where a knowledgeable, autonomous teacher would have worked against the interests of the established bureaucratic structure and the centralised syllabi and prescribed textbooks.

What is more distressing is that the status of the teacher has remained more or less unchanged till date, as testified by the observations of the Justice Verma Commission (JVC) Report on the "institutionalised *intellectual isolation* of the teacher" and the "circumscribed engagement with pedagogy as mere technique (emphasis in the original) (2012: 12). While new standards for pre and in service teacher education are set for the future by the National Curriculum Framework for Teacher Education (NCFTE 2009) we still need to contend with the fact that a large proportion of the teachers we have in service today are grappling with a situation that is not entirely their making. Poorly qualified as they are not stipulated to have any better qualifications, severely lacking in terms of content knowledge as the training did not go beyond equipping them with a few skills to maintain order in class, knowing barely beyond the grade level they currently teach as they themselves are products of the system they now are a part of. While we continue to battle for fundamental changes to set right the wrongs of years of neglect, it is only fair that we take a more humane look at the plight of the teachers who continue to struggle to make sense of their work. The question here is, are we in a position to provide them the kind of support they need to do their work without compromising their sense of dignity, appeal to their sense of wanting to do better and afford them with avenues for professional learning that helps them perform their work better.

In this paper, I will refer to certain experiences of the teachers that were part of the WCT research to argue that digital technology, at least the kind that was employed in this research, has to some extent been able to provide the kind of support to teachers described above. Given the kind of infrastructural issues that plague most of the Indian schools, technological solutions have come to be viewed with a great deal of scepticism and justifiably so. Past experiences with ICT have, for reasons that are beyond the scope of the present discussion, failed to inspire confidence in any potential it may have to improve teaching learning in any substantial or sustainable way. But our experience here seems to indicate that we have the responsibility of not lumping together all things technological, and therefore regard them in the same light but try and separate those that offer possibilities that do not compromise our core beliefs about what constitutes sound educational practice.

The Whole Class Technology (WCT) Research as the name indicates, employed a

specific kind of digital technology meant for the whole class as opposed to the one-to-one kind of technology that is afforded by desk top computers. There are fundamental differences in the pedagogy, nature of digital content and extent of teacher engagement between the two kinds of approaches.Typically, all classroom based reforms, not just ones that have to do with technology, have tried to overturn the classroom practice from a teacher led to a student centred one. It has been argued that child centred classroom pedagogic reforms have come to signify quality, particularly in the developing world but in practice, the performance oriented pedagogic culture reinforces existing hierarchies and supports strong framing of the curriculum, rather than a weak one as required by child centric practice (Sriprakash, 2010). In cognisance of this view, the digital technology of WCT research was designed to leverage on the predominant kind of teaching that happens in most classrooms that is teacher led and promote gradual movement towards greater student participation and engagement, rather than pushing for radical change in existing practice.

The teachers were provided with laptops with specially designed digital content (DC) in the form of animated videos of 3-5 minute duration each explaining a specific topic/ concept in Science and Math for grades 5-7. The content was mapped to the textbook for easy navigation and identification of the relevant ones for a given topic. There were on an average 20-30 such DCs for each unit. There was one set of equipment given to a school to be shared between the two teachers handling Science and Math for the upper primary classes. In addition to the laptop, these schools were also provided with a small LED projector to project the content for students in the classroom and also an UPS for battery backup. Workshops were conducted with teachers to help them familiarise with the technical aspects as well as assess the digital content and choose those they deemed suitable and relevant for their students. Teachers were also encouraged to develop criteria to critically evaluate the content and not accept them at face value.

There were academic as well as logistic reasons for choosing grades 5-7. There is a gradual and discernable progression of concepts from simple to more complex in these grades that provides room for closer analysis. The lower classes upto grade 4 do not have a separate science subject and they were taught in the then newly introduced system of Nali Kali which would be very different from that of the other grades and therefore render the results hard to compare. Through workshops and school based hands on support, the teachers were helped with overcoming their initial fear of handling a high end equipment such as a laptop. Teachers, many of them who were handling a laptop computer for the very first time in their lives, were reasonably quick to overcome their initial fears. What took longer was the shift required to consider the digital content as one among the many resources/ TLMs available to the teacher. They were encouraged to carry the laptops home, peruse the content during their leisure hours and plan for integrating any content that may be of interest to the students and reject any or all

content they deemed unnecessary or not suitable. The intent was to provide teachers a new hopefully resource to add to their repertoire but also ensure they had the autonomy to decide the appropriate use of the resource.

It was noticed in the beginning that teachers would simply use the content in their classroom because it caught the attention of the students but they would be hard put to explain the academic value of the same. Gradually however, one began to notice that teachers were sharing things like, "I learnt something new about the earths' rotation from the 'video',which I did not know before, I shared it in class and my students were very excited to watch the video". Truth was, the teacher seemed more excited about the class. Another teacher revealed how she was very happy that she could show her students the flow of oxygenated blood and de-oxygenated blood on the video, something that she had never be able to explain satisfactorily before. She would then add, almost as an afterthought, "even I did not know these things before".

Yet another teacher showed us how she would set up an experiment to measure focal length of a concave mirror but the experiment would fail. She had abandoned the experiment altogether. The digital content explaining the experiment encouraged her to bring the experiment back into the class. Now she shows the experiment on screen and then lets students try it out with the actual apparatus. When something goes wrong she now knows how to explain it. Another teacher revealed how she did not follow a particular concept that was explained in the video and went up to a colleague in the secondary school to clarify her doubts. On probing she revealed that in fact she had put up her Head Teacher to seek clarification as she was hesitant to talk to a senior teacher. There was also talk of discussions in the staffroom around topics or content they found interesting. There seemed to be a new phenomena unfolding here that needed a closer examination.

It cannot be denied that science teachers particularly in the rural and semi urban schools work within severe constraints. They are not just limited by their educational background, they often have to teach science with little or no formal training in the subject, as these decisions are dictated by administrative prudence rather than academic requirement. It would be stating the obvious to even mention the paucity of actual instruction time available to them amidst the various para / non-academic activities they are pulled into with frustrating regularity. To be able first to muster the necessary content and pedagogic knowledge required to teach in a meaningful way and find and invest the time required to help students engage in the kind of deep learning that leads to mastery of a given science concept demands a great deal from the school science teacher.

Professionals in other fields have legitimate avenues available to them to enhance their knowledge and skills, and the disposition to engage in continuous learning is a desirable trait. There is considerable autonomy and self-direction involved in decisions pertaining to one's professional learning and development. However, when it comes to teachers,

the nature of professional learning is also in keeping with their otherwise low status. It is not an exercise where the said professional has a choice in the matter. Nor does she play a role in deciding the nature or content of one's learning. Instead, it is designed and executed by the state in a 'one size fits all' mode and the learning is premised on a deficit principle of compensating for the existing inadequacy.

The compounded effect of these two conditions, the lack of content knowledge or autonomy is fulfilling one's learning needs, allows little room for teachers to build their knowledge base and expertise in a legitimate fashion. Most teachers with no recourse to any material other than the text book which they then end up transacting in the fashion that we are all too familiar with. Many may go through years of service without ever having been able to admit to the difficulty they may themselves have in understanding a particular science concept or the ways of transacting the same in the classroom. In such a situation, one can very well appreciate the relief a teacher might experience when given access to a material which is meant for her students but addresses some of the doubts she may herself have had. This she can do in the privacy of her home or staffroom and use it as a starting point for discussion with peers or seniors without having to expose her own lack of knowledge. Clearly, the duration of the digital content also held greater attraction for none of them are more than 5 minutes long. Teachers admitted that they had very little time for preparation for a class and in any case the chalk and talk method did not require any.

The research also deliberately downplayed the technical aspects and focused on the content and pedagogic aspects. Teachers were encouraged to think of the content and pedagogic requirements of their classroom and then consider the gaps that the DC can be used to fill rather than think of how to use the available content. This has significant implications as it not just alleviates the stress of intimidation that technology evokes, but also entices teachers to view it as a 'symbol of change, offers them a licence to experiment' (Sandholtz et. al.). Teachers noted that although they were nervous about technical glitches marring their class, use of the equipment was never a goal and they were encouraged to view it as a tool that would add value to the teaching learning process. It could be seen that, armed with the new technology, the self-image of the teacher underwent a subtle but significant shift to from someone who is isolated in the classroom to someone capable of learning and adopting a new practice. No less significant is the effect of the shift in students' view of teachers from outdated to savvy and the newfound confidence perhaps provides an incentive to relook at ones' own practice as well.

Armed with little more than the ubiquitous textbook, these teachers were emboldened to inject some inquiry into their classes. This seemed like the beginning of what could be a virtuous cycle. What helped too was maintaining the familiar teacher-led format of the class that ensured that the teacher could still control the ebb and flow of the lesson

allowing for a loosening of control in the form of a discussion only to the extent with which she was comfortable.

It is now well understood in education theory that good teaching comes from a sound knowledge of content as well as pedagogy of a subject. The failure of pre and in service teacher education to focus on strengthening teachers' subject knowledge and focus instead on mastery of a few skills intended for classroom control has led to teachers becoming de-intellectualised and rendered incapable of deep engagement with their subject. In addition to this, the increasing pressure on the teacher to engage students in child centred learning as exhorted by every policy document, leaves teachers completely at a loss.

It must be noted here that it is too simplistic to assume that all teacher led pedagogies are didactic in nature and therefore less effective and learner centred pedagogies are by definition constructive and lead to effective learning (Hughes and Longman 2006: 16). One can conceive of ostensibly child centred activities that lack coherence or clear objectives leading to little or no real learning. As Brown (1992:169) observes, "There is considerable evidence that didactic teaching leads to passive learning but by the same token, unguided discovery can be dangerous too." On the other hand, well-executed whole class teaching could be as effective in motivating and engaging students in in-depth class discussions. Perhaps our preoccupation with child centred strategies needs to be re-evaluated and efforts channelled instead towards deep learning of both the teacher and the students.

There also needs to be a rethink the possibilities that digital technology has to offer in the domain of teacher professional learning. One of the greatest fears to do with technology has been its potential to replace the teacher in the classroom. This is a possibility that would readily find favour with some of the arguably influential proponents of the case for making our schools more cost effective. Such arguments are obviously in line with the thinking that is gaining currency not just in India but across the globe, that educational institutions can be run along market principles (Kumar, 2011). A host of studies locate this thinking within the framework of neoliberal policies that have set in motion a specific set of actions, which camouflaged under the language of efficiency, performativity, measurable outcomes and quality (Ball 2003, Mc Gregor 2008, Apple 2009). ICT, the way it is practised today as smart classes etc., is in the greatest danger of furthering the interests of this constituency. Obviously one is well aware and wary of the danger posed by arguing for the use of digital technology in the resource starved classrooms; but the answer does not lie in ignoring ICT altogether either. Even now, the National Policy on ICT talks of providing computers to schools and training teachers in ICT use, a road that has been travelled before with no success whatsoever. It is imperative that experiences of the kind that teachers in this research have had are voiced so as to inform such policies.

What the experience of this research has shown albeit on a very small scale is that we cannot ignore the urgency of addressing the professional learning needs of teachers in service today. This is particularly so for science, as the number of students opting for science has dwindled over the years and there are only a handful of trained science teachers. More and more teachers with no previous training or experience in teaching science are being asked to teach the subject. It is the teacher whose knowledge base needs strengthening if we expect her to truly enhance her status of a professional and it can be seen that digital technology and ICT offers immense potential to achieve this. It is also providential that Science as a subject seems to lend itself rather well to this approach. The overused cliché of empowering the teacher was perhaps never more appropriate than in this context.

The primary objective is not to promote digital technology but to find a way to address the urgent need to strengthen the knowledge base of the science teachers in a non-threatening manner that does not undermine their dignity, allows them to exercise their autonomy and choice in pacing their learning like any other professional. The experience from this research shows that the short duration digital content offers such a possibility for creating such a learning opportunity for teachers. The content employed in the research were not all of similar quality. The first need would be therefore to generate high quality content that teachers themselves should play a role in creating. It was found that the very process of sifting through and selecting good content and rejecting the not so good ones was a learning process in itself as they were required to articulate their reasons for such a decision providing them further opportunity to engage in professional learning.

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Three Challenges Facing
Indian School Science Education

Padma M. Sarangapani

A serious lack of adequate equipment, of trained teachers and most importantly, a consensus on what should be taught in school science impede any positive movement on expanding quality education in science. We have still not had any national discussion or debate on critical issues in science education, much less a review of the possibilities to build a national consensus of what science should be taught in schools, particularly in a curriculum of compulsory schooling.

Science education in India is faced by three practical challenges today. The first is the most basic problem that has persisted and resisted solution since Independence. This is our inability to provide schools with labs and equipment to be used while teaching science.

Science is knowledge about the material, natural world. It is knowledge produced from systematic observation, measurement, experimentation, exploration, and speculation and theorisation about natural objects, their properties and their interactions. Whether the topic of forces in Physics or the solubility of substances in water from Chemistry, or germination in Biology, the science curriculum directs attention to the material world, to things and processes in it, about which it would like children to learn—to notice, name and think about things based on concepts and theories that characterise these disciplinary approaches. However, this material world is conspicuously absent in the Indian science classroom and the school.

The science classes are no different from history or geography or language. They are also taught by teachers from textbooks. The textbooks talk about things, experiments and processes and show pictures. They often take the route of not only describing the experiment, but also telling children what they will observe and what they should conclude!—an implicit acceptance by those designing the textbooks that children will not actually get to do or see the things that are to be learnt about. So tell all.

Nehru had dreamt of the day when every science classroom would have a microscope and children would have the direct experience of viewing the microscopic world. All of us have studied about the paramecium in our school biology textbooks, which told us that it was a slipper shaped single cell organism. Yet how many of us have viewed

a drop of ordinary water through the microscope, learnt to adjust the focus and see this for ourselves? We have all seen pictures in our book of Saturn and its rings. But most likely we have never been asked to look and spot Saturn in the sky and watch it through a pair of ordinary binoculars to see its rings.

It is not just a problem of providing infrastructure in schools. Even in private schools which could afford the infrastructure, few school managements actually make this provision. Of 85 schools that we visited in one education block of Hyderabad as part of a recent survey, we found labs or at least some lab equipment in only five of them. We were more likely to find virtual computer based lab, and short videos to be projected during the class. It seems that as a country, although we boast our large numbers of science graduates, we are not really serious about how they learn their science, considering that we have not yet equipped our schools with labs and nor ensured that children have practical experiences.

The second challenge we face is a shortage of science teachers and elementary school teachers who have studied science at least up to the 12th class level. No doubt there is regional variation in this, but everywhere with more lucrative and higher status jobs available for science graduates, we find a disproportionate number of young people from the arts and social science backgrounds rather than mathematics and science coming to be trained as teachers. While primary school teachers are expected to teach all subjects, most are not confident about their own knowledge of mathematics and science. This has serious implications for the mathematics or science that they can teach in turn. Elementary teacher education programmes need to be adapted so that they can address this problem. Students need to have additional curriculum inputs in these domains. At the secondary education level, neither states nor private management are able to find suitable trained science and mathematics teachers to employ. An option being considered is to directly employ those with science degree qualifications and undertake teacher education on the job, although it is unclear if such post appointment education will be taken seriously and bring about desired professional development. Following the NCERT's model of B.Sc., B.Ed., many Central Universities are considering offering this programme—this has found endorsement in programmes such as the National Mission on Teachers and Teaching with the argument that such early commitment to teaching will strengthen professional formation. While not discounting the higher quality of teacher education that is achievable through such an integrated degree, in my view this does not adequately factor in the need for the teaching option to be made available later rather than earlier in the person's life-cycle. It is likely that young people will seek admission to this programme as a way to study science rather than education/ teaching. And it is very possible that many of the graduates with dual degree will go into science related streams rather than into science teaching. There is need to provide channels into education at later stages where people with science degrees, after having

pursued other careers shift into education because they are now interested in working with young people. It is also necessary to consider stipendary programmes for science teacher preparation, making it more financially attractive. We may also need to consider adding another year of study of science in teacher education programmes and allow such graduates to be employed starting at a higher salary.

The third practical challenge facing Indian school education is with regard to what should be included in the science curriculum. Following the Right to Education 2009 we are much more aware of the diversity of children entering our classrooms, to whom the curriculum must address itself "constructively". I use this last word deliberately to emphasise the need of the curriculum to make sense to those who are learning it, so that it is not just learnt to be remembered now, with the hope that it will finally make sense. This requirement could be approached in different ways.

One interpretation is that this means we should move away from a 'subject approach' towards the 'discipline approach'. This emphasises the need to teach science as a way of understanding the world, and comes with the view that knowledge of science—both the content and the method—is important as it informs our understanding of the everyday physical world which would not be available to us through common sense and everyday experience alone. Such knowledge is important for everybody and hence such disciplinary science would be a part of a compulsory school curriculum. It would, include 'big ideas' of science which deeply influence our understanding of the world and our relationship to the world—such as the human immune system and causes and treatments of diseases, or of photosynthesis, or evolution, or projectile motion. A combination of the specific ideas and concepts and ways of reasoning, thinking, proving and discussing science, would be the focus of such as curriculum.

A second interpretation could be that this requires science to be made 'relevant' to the students from the point of view of their lives and their futures. This could take the direction of being 'functional' with useful science being the focus—understanding the human body and its wellbeing, sanitation and public health, reproductive health and those relative to vocational contexts such as agriculture or animal husbandry, could potentially take centre-stage over the traditional disciplines in such a curriculum.

A third approach could be to review the disciplinary strong hold on the curriculum and move towards the inclusion of new areas of science such as the environment studies, engineering, technology and design, material sciences, animal behaviour, medicine, sexuality and gender, and science and society.

There is a fourth possibility that is relevant in the Indian context, which is that of local knowledge and indigenous sciences. Admittedly this a difficult terrain to navigate with claims being asserted to the scientific status of 'Astrology'. But clearly systems of health and wellbeing whether Ayurveda or Yoga are strong contenders for inclusion in a curriculum. Alongside, particularly knowledge of habitats and environments from

systems of non-western science are alive and rich repositories of valuable knowledge which is even more at risk of being obliterated through universal spread of schooled knowledge. Only the first of these four possible responses has received serious and systematic efforts over many decades and in some ways refers back to the earlier two challenges as well. The other three possible approaches all exist in the discourse on curriculum and its revision, but have not received systematic review and response. Nevertheless, we notice that in some states, notably Kerala, the government school curriculum has increasingly presented a vocational and applied version of science, while the NCERT has moved towards the disciplines and to some extent now includes newer disciplinary areas such as the study of environment. However, we have still not had any national discussion or debate on these issues, much less a reviewof the possibilities to build a national consensus of what science should be taught in schools, particularly in a curriculum of compulsory schooling.

Mainstreaming Science Curricular Innovations
Lessons from the HSTP Experience

Ajay Sharma

What are the challenges of mainstreaming curricular innovations? Perhaps, the effort should not be to mainstream specific curricular innovations, but to enable wider circulation to the enabling discursive practices in which in-situ curricular innovations can happen. Such innovations will not only suit the context in which they are engendered, and will also be more easily appropriated by the teachers. Discursive practices that promote innovation are, in turn, critically dependent on a democratic, dialogic collaboration between different stakeholders that recognises the centrality of empowered, capable teachers in the instructional dynamic.

Bringing about change in education is difficult, more so when it involves changing the age-old structures, beliefs and practices regarding the key issue in education – what should the teachers teach and the students learn in schools. This is partly because the curriculum represents the knowledge, skills and practices that the older generation decides to pass on to the younger generations (Grumet, 1998), and thus serves as the cornerstone of social and cultural reproduction and transformation through schooling (Anyon, 1981; Collins, 2009). Further, our ideas about curriculum, and thus of what knowledge is most worth, also acquire stability on account of their deep imbrication with the role and status of teachers traditionally accorded in a society. But at the same time, curriculum as practised in the school is hardly a static entity. As any teacher will tell you, because of the improvisations and innovations by the teacher the curriculum-in-use is very different from the official or overt curriculum in any classroom. Some of these innovations are surely worthy of dissemination and mainstreaming, but many aren't. However, almost all of them are either short-lived or remained confined to a classroom or a school.

Of course, as is the norm in India, curricular innovations also originate from the top of the education system and percolate downwards.When the dominant discourse one education changes at the top on account of shifts in the composition of the political elite, these changes reverberate in the curriculum policy documents and lead to changes in the official curricula that can sometimes be called innovative in a positive sense. When such curricular 'innovations' reach the classroom, teachers 'glocalise' and adapt them

to suit their own beliefs, abilities and resources (Robertson, 1995; Sharma, 2008). One can say, then, that these top-down innovations do get 'mainstreamed', but rarely in ways that show fidelity to the intended spirit and objectives of curriculum innovators at the top. As a result, despite changes in the official curricula we find that the curricula-in-use in Indian classrooms today doesn't look that different from the one implemented a generation ago, and the challenge of mainstreaming curricular innovations in Indian classrooms remains largely unmet.

Some worthy attempts have indeed been made in India, and they did achieve varying degree of success in mainstreaming curricular innovations. In this paper, I draw on one such attempt – the Hoshangabad Science Teaching Programme (HSTP)-to conceptually analyse the issue of mainstreaming of science curricular innovations from a Bakhtinian dialogic perspective with the intention of indicating the likely parameters of any successful effort at mainstreaming of science curricular innovations that move beyond official documents to become a part of the daily curriculum-in-use at the classroom level.

This paper is an exercise in interpretive analysis of my own six year long experience with the programme, and a tentative attempt to draw lessons from a sample of N = 1. However, as qualitative interpretive research has convincingly shown, through naturalistic generalisations single case studies can yield valuable insights that help us understand similar phenomena in different sites (Melrose, 2010). It is my contention, therefore, that current and future attempts at science curriculum innovation and reform have much to learn from its experience, especially if they intend to influence the mainstream in any meaningful way. In fact, it is my belief that the lessons to be learnt from the HSTP experience can be extended to curricular reform in other disciplinary areas as well. I begin, therefore, by first summarising the nature and scope of science curricular innovations by the HSTP.

Science curricular innovations in HSTP

HSTP had a modest beginning in 1972 when two voluntary organisations in Hoshangabad, Kishore Bharati and Friends Rural Center, brought together teachers from 16 rural middle schools of the Hoshangabad district, a group of science teachers from the All India Science Teachers' Association (AISTA) and scientists from the Tata Institute of Fundamental Research, Mumbai to develop a programme for an inquiry oriented, environment-based science teaching in schools. The main objective then was to reimagine science learning as a critical input to social, cultural and economic transformation in local rural areas (Eklavya, 2005). Soon enough, however, it was apparent to the collaborators that HSTP could become a launching pad for a serious attempt at reform in science education at the state and even national level. As a result, beginning with the district level expansion of the programme in 1978 and until its

demise in 2002, continuous efforts were made by Eklavya, the organisation created to oversee the programme, to expand and mainstream the programme throughout Madhya Pradesh and in other states as well. Though they were often hurdles, the programme did achieve some measure of success in spreading its curricular and other innovations to regions beyond Hoshangabad. Between 1983 and 1990, the programme spread to some school clusters in twelve other districts of Madhya Pradesh. And from 1990 onwards, consistent efforts to mainstream the programme in the state, transplant its core ideas in other states and influence the policy discourse at the national level (Eklavya, 2005).

Before any discussion of curricular innovations by HSTP, it needs to be recalled that the programme was a holistic and integrated attempt at science education reform, and thus, encompassed innovative interventions in almost all major components of formal and nonformal science education, such as curriculum, in-service teacher professional development, academic and administrative structures, assessment, experimental kit production and distribution, academic support at school level, and extra-curricular inputs. Further, the programme became possible only because of a rare multi-party and multi-scale collaboration over a comparatively long period of time between all important stakeholders in public schooling. Within this innovation oriented ecosystem of science education reform, I have come to see the main curricular innovation of HSTP as the development of a science curriculum that:

(A) Supports an inquiry oriented, environment based pedagogy: Taking inspiration from some earlier science education reform attempts, such as the Nuffield Science Programme in UK, the HSTP built a science curriculum based on the widely accepted but rarely implemented principles of 'learning by discovery', 'learning through activity' and 'learning through environment'. This curriculum required and supported science teachers in practicing an inquiry oriented, locally environment based pedagogy in their classrooms.

(B) Aims at the understanding of nature of science and development of scientific habits of mind rather than transmission of scientific knowledge and information: The programme strove to develop a science curriculum that facilitates an understanding of the nature of science and inculcation of scientific habits of mind among the student. Students were expected to be like young scientists who would 'discover' scientific principles, concepts and ideas through experimentation, questioning and evidence-based reasoning.

(C) Empowers science teachers and reimagines their role in science instruction:Rather than basing instruction on a traditional looking textbook, teachers were given a book to implement the curriculum that looked more like a knowledge deficient workbook that had to be filled with science content generated through joint efforts of the teacher and the taught. As a result, the teacher acquired a greater freedom in making instructional decisions. Further, their role shifted from a more or less passive vehicle of transmission of pre-processed scientific knowledge, to a facilitator in an engaged collaborative process

of generation of scientific understanding and knowledge through carefully designed and conducted experiments and evidence-based reasoning.

(D) <u>Can be implemented even in resource deficient schools:</u> When the programme began, it used to be a conventional wisdom among policymakers and education bureaucracy that inquiry oriented science curriculum will perforce be resource intensive, and thus could be ill-afforded for public schools. It was a signal achievement of HSTP that it was able to refute this perception by developing a science curriculum in which students could learn science through experiments and activities that needed only a minimal investment that most schools could afford.

As mentioned earlier, for much of its existence the programme made a conscious and sustained effort to spread these curricular innovations beyond a few schools to the regional and national level. Though the programme has long ceased to exist, this effort still continues though in different and diminished ways. The success and failures of the HSTP in mainstreaming its innovations can be understood from multiple perspectives, and from the standpoints of different stakeholders, such as students, parents, teachers and education administration. Each of these perspectives and standpoints carry the potential of offering valuable insights that will be helpful to current and future science education reform efforts. Being hostage to my personal history of working in the programme and current vocation as an education researcher, I can't help but occupy the standpoint of an ex-insider and use one of the theoretical tools of my trade to retrospectively analyse the HSTP experience. Thus, in the remaining segment of the paper, I look back at the HSTP's success and failures in mainstreaming its innovations from a couple of mutually compatible theoretical perspectives, and draw some overall conclusions.

Factors critical for mainstreaming: The HSTP experience
Looking back at the successes and failures of the HSTP in mainstreaming its curricular innovations, it appears to me that three factors were critical in determining the fate of its efforts to spread its innovations: *what* was mainstreamed; *how* it was mainstreamed; and to *whom* it was mainstreamed. Let us examine each of these three factors.

(A) <u>Mainstreaming – *what?*</u>As mentioned earlier, curriculum development was just one among many components of the programme. Because the programme's mandate was to show that an alternate way of science teaching and learning can work on a sustainable at a reasonably large school within the government school system, and there were hardly any successful programmes of similar nature to learn from, innovation in all components of formal and nonformal science education was a necessity right from the beginning. That is, curricular innovation was never a one-off or a sporadic event, but existed as an integral discursive practice within a wider discourse of innovation animating the entire programme. Curricular innovations were encouraged at all levels of the programme and at all fora. If a teacher figured out a new way to do an activity or an experiment, it was

discussed and shared during teacher monthly meetings, written about in field reports and teacher journals, such as *Sandarbh,* perfected by other teachers, incorporated in annual in-service professional development workshops (the so-called 'HSTP summer teacher trainings'), and considered for inclusion in the next round of workbook revision.

In retrospect I find that while mainstreaming it mattered whether we were trying to spread the curricular innovations as off-the-shelf products or the discursive practice of innovation that led to such innovations. In the early stages of expansion of the programme, it appears to me that it was possible to spread the discursive practice of curricular innovation, and not just the curriculum as a finished product. This was largely because then we were able to disseminate all the components of the programme together as a total integrated package. Later on, the mainstreaming became piecemeal and it became harder to successfully transplant the discursive practices of innovation that characterised the programme in its home region of Hoshangabad. As a result, to schools and teachers in other areas curricular innovations were not able to serve as templates or exemplars for local curricular innovation, but came across largely as non-native products that were to be artificially grafted onto local educational contexts.

(B) Mainstreaming – *how?* Curricular ideas being textual in nature come embedded in a discourse that shape their representation and intention, give them an ideological orientation, influence their meaning and imbue them with a specific addressivity with respect to the audience. Mainstreaming of curricular innovations entails their appropriation by others who were hitherto not associated with the programme. However, one cannot assume this appropriation to be an easy process because as Bakhtin says, "Language is not a neutral medium that passes freely and easily into the private property of the speaker's intentions; it is populated – overpopulated – with the intentions of others. Expropriating it, forcing it to submit to one's own intentions and accents, is a difficult and complicated process." (1981; pp. 293-294). According to Bakhtinian perspective, discourses can be placed on a continuum between hard to appropriate a*uthoritative discourses* to easy to make one's *own internally-persuasive discourses.* As Bakhtin (1981) asserted, authoritative discourses are harder to appropriate because "It enters our verbal consciousness as a compact and indivisible mass; one must either totally affirm it, or totally reject it. … One cannot divide it up – agree with one part, accept but not completely another part, reject utterly a third part. … It is not free appropriation and assimilation of the word itself that authoritative discourse seeks to elicit from us; rather, it demands our unconditional allegiance" (p.343).

The discourse in which curricular ideas of traditional school science are embedded is a good example of an authoritative discourse. This is because its self-representation as an authoritative canon of truths about the world, its abstruse and ambiguous nominalised lexico-grammar that invites memorisation but not comprehension, its relegation of lived experiences of the world of students to the margins, and its lowered intertextuality that

is inimical to differences in meanings can only invite allegiance but not an appreciative understanding and willing appropriation (Sharma and Anderson, 2009). An internally persuasive discourse, on the other hand, is much easier to make one's own because of its "semantic openness to us, its capacity for further creative life in the context of our ideological consciousness, its unfinishedness and the inexhaustibility of our further dialogic interaction with it. We have not yet learned from it all it might tell us; we can take it into new contexts, attach it to new material, put it in a new situation in order to wrest new answers from it, new insights into its meanings, and even wrest from it new words of its own" (Bakhtin, 1981; p. 346). Curricular ideas and innovations passed on from one teacher to another on a day-to-day basis often come embedded in such an internally persuasive discourse.

Of course, it is also possible for a discourse to be both authoritative and internally persuasive. As Bakhtin (1981) acknowledged, "Both the authority of discourse and its internal persuasiveness may be united in a single word – one that is simultaneously authoritative and internally persuasive." (p. 342). Scientific discourse that guides work in scientific research communities (much different from school science discourse) can be seen as an example of a discourse that is both authoritative and internally persuasive (Sharma and Anderson, 2009). My personal view is that HSTP also tried to spread its curricular innovations through such a discourse that aimed to be both internally persuasive as well as authoritative. Schools and school administration in other regions were encouraged to adapt it for their own contexts and dialogise it with their own ideas, resources and concerns. It was spread in a democratic manner through sustained interaction, dialogue and friendly persuasion. In that respect, HSTP discourse, in my view, was remarkably internally persuasive. In many cases, it was also authoritative because of the support of the administration and the strong backing of an influential segment of the scientific establishment in India.

Mainstreaming of curricular innovations was more successful when this was the case. Examples would be its expansion from a few schools in Hoshangabad to the entire district, and then after several years to selected school complexes in eleven other districts of Madhya Pradesh. Mainstreaming efforts began to falter when the programme lost its influence with the administration and policy makers, its authoritativeness weakened, such as after the closure of the programme in 2002, and the programme was left to rely on its internal persuasiveness alone. Curricular discourse can rely on its internal persuasiveness for dissemination and widespread adoption only when teachers are empowered enough to take curricular decisions affecting their classrooms. But, in the Indian context, that is unfortunately rarely the case. Thus, at least for the Indian government school system, it seems fair to conclude that unless the role and status of teachers change drastically mainstreaming of curricular innovations would need the

support of a curricular discourse that can achieve the rare distinction of being both internally persuasive and authoritative.

(C) Mainstreaming – *to whom?* Capability approach is a normative framework for understanding and assessing social justice policies and ideas about social change in society (Robeyns, 2005). Though there are several versions of this approach, broadly speaking it shows that people's well-being, protection of human rights and development not only requires creation of enabling conditions and availability of requisite means, but also development of their capabilities that will allow them to make the best use of supportive conditions and means made available to them. If we view mainstreaming of curricular innovations from this perspective, it is clear that the capabilities of the intended target teachers and the context in which they work will be a critical factor in deciding the fate of the mainstreaming effort. This is because any curriculum comes with implicit assumptions about the teacher, students and their educational context.

If these assumptions do not match with the reality, then it is hard to see how the teachers can appropriate and implement the innovative curriculum in meaningful ways that serve the interests of the teacher and the taught, while also maintaining a reasonable degree of fidelity to embedded educational objectives. Realising this truth, HSTP tried to offer professional development to science teachers, create scientific equipment and kit material supply chain, and create enabling administrative and academic structures in regions it tried to expand. However, this was not always possible. Thus, wherever capability enhancement could not be done, efforts to spread the curricular ideas could not succeed.

Conclusion:

HSTP was a unique experiment that happened in a context that may not be easy to replicate. However, some tentative ideas do emerge that may be helpful to keep in mind while taking on the challenge of mainstreaming curricular innovations. Perhaps, the effort should not be to mainstream specific curricular innovations, but to enable wider circulation to the enabling discursive practices in which in-situ curricular innovations can happen. Such innovations will not only suit the context in which they are engendered, and will also be more easily appropriated by the teachers. Discursive practices that promote innovation are, in turn, critically dependent on a democratic, dialogic collaboration between different stakeholders that recognises the centrality of empowered, capable teachers in the instructional dynamic. HSTP has shown that curricular innovations can happen in a government school system. The challenge then is to show that it can be done again and again in schools all over India.

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Brief Glossary

Appropriation - the act of taking or using something especially in a way that is illegal or unfair.

Authoritative Discourse – A term introduced by Russian linguist Mikhail Bakhtin in 1934. Authoritative discourse is communication, or oral transmission of knowledge which is not open to interpretation. Bakhtin says authoritative discourse '... demands to be assimilated by the reader or listener; examples might be religious dogma, or scientific theory, or a popular book. This type of discourse is viewed as past, finished, hierarchically superior, and therefore demands "unconditional allegiance" rather than accepting interpretation.

Bakhtinian Dialogic Perspective – According to Mikhail Bakhtin, every level of expression from live conversational dialog to complex cultural expression in other genres and art works is an ongoing chain or network of statements and responses, repetitions and quotations, in which new statements presuppose earlier statements and anticipate future responses.

Brand Identity – Brand identity is commonly taken to mean how a business wants a brand's name, communication style, logo and other visual elements to be perceived by consumers. The components of the brand are created by the business itself, making brand identity the way in which a business wants consumers to perceive its brands, not necessarily how it is actually perceived.

Capability Enhancement – Capability enhancement refers to activities conducted to make better skilled and oriented individuals, more responsive and effective institutions, and a better policy environment for pursuing development goals.

Constructing Knowledge–Constructing knowledge is a term derived from the theory of Constructivism. Constructivism is a theory based on observation and scientific study about how people learn. It says that people construct their own understanding and knowledge of the world, through experiencing things and reflecting on those experiences.

Didactic - designed or intended to teach people something.

Differential Participation – Differential participation refers to differences in the quantity of classroom interactions experienced by pupils according to their social class, race and gender.
Discipline Approach vs. Subject Approach –In the education system a subject-centred approach means that only modules related to the core subject are taught. A discipline approach to education generally refers to scholars conducting a wide range of studies that includes basic and applied research, encompassing one or more subjects.

Discursive Practices - Discursive Practice is a theory of the linguistic and socio-cultural characteristics of recurring episodes of face-to-face interaction; episodes that have social and cultural significance to a community of speakers. Discursive practice addresses the processes by which cultural meanings are produced and understood.

Educational Maintenance Organisations (EMO) - Companies known as Education Maintenance Organisations (EMOs) contract with a school district or an individual charter school to improve the quality of education without significantly raising current spending levels. EMO involvement becomes increasingly possible as more schools switch to site-based management, the administrative philosophy that allows for more local control at individual schools.

Expropriating – Expropriation can mean to deprive one of possession or proprietary rights, or can mean to transfer (the property of another) to one's own possession.

Focal Length - The focal length of an optical system is a measure of how strongly the system converges or diverges light.

Glocalize - Glocalization (a portmanteau of globalisation and localisation) is the adaptation of a product or service specifically to each locality or culture in which it is sold. It is similar to internationalisation.

Harvey's Theory of the Body - William Harvey (1578 - 1657), was an English physician and the first to accurately describe how blood is pumped around the body by the heart.

Imbrication - Arrange (scales, sepals, plates, etc.) so that they overlap like roof tiles. To imbricate can also mean to overlap.

Inductivist-Positivist Tradition - Inductivism is the traditional model of scientific method explained in 1620 by Francis Bacon. In Baconian model, a scientist observes nature, tentatively poses a modest axiom to generalize an observed pattern, confirms it by many observations, ventures a modestly broader axiom, and confirms that, too, by many more observations, while discarding disconfirmed axioms. In the 1830s, opposing metaphysics, Auguste Comte explicated positivism, which, unlike Baconian model, emphasisedpredictions, confirming them, and laying scientific laws irrefutable by theology or metaphysics.

Inquiry Based (or Inquiry oriented) Learning - Inquiry-based learning starts by posing questions, problems or scenarios - rather than simply presenting established facts or portraying a smooth path to knowledge. The process is often assisted by a facilitator. Inquirers will identify and research issues and questions to develop their knowledge or solutions. Inquiry-based learning includes problem-based learning, and is generally used in small scale investigations and projects, as well as research.

Instructional Dynamic -Instructional dynamics may be defined as the composite of techniques, resources, procedures, and strategies used by faculty engaged in classroom instruction to impart knowledge and skills to students under variable conditions of time, space, technology, and learning context.

Intertextuality – Intertextuality is the complex interrelationship between a text and other texts taken as basic to the creation or interpretation of the text.

Investment Climate - The economic and financial conditions in a country that affect whether individuals and businesses are willing to lend money and acquire a stake in the businesses operating there is collectively called the investment climate of the country. Investment climate is affected by many factors, including: poverty, crime, infrastructure, workforce, national security, political instability, regime uncertainty, taxes, rule of law, property rights, government regulations, government transparency and government accountability.

Kerala Sastra Sahitya Parishad - Kerala Sastra Sahitya Parishad is a voluntary organisation working in the state of Kerala, India. It was founded in 1962 by a 40-member group consisting of science writers and teachers with interest in science from a social perspective. Over the past four decades it has grown into a mass movement with a membership over 40,000, distributed in more than twenty two units spread all over Kerala.

Knowledge Economy – Knowledge economy is a system of consumption and production that is based on intellectual capital. The knowledge economy commonly makes up a large share of all economic activity in developed countries.

Learning by Discovery - Learning by discovery is a theory of learning put forward by Jerome Brunner. It is an enquiry based, constructivist learning theory that takes place in problem solving solutions where the learner draws on his or her own past experience and existing knowledge to discover facts, relationships, and new concepts.

Learning through Activity–Learning by activity is part of the Activity Theory put forward by Vygotsky, Leont'ev, Luria in the 1920's. The Activity theory is more of a descriptive meta-theory than a predictive theory which considers the entire work/activity system (including teams, organisations, etc.) beyond just one actor or user. It accounts for the environment, personal history, role of the artefact among other factors contributing towards a dynamic goal.

Nai Taleem – Nai Taleem is a spiritual principle which states that knowledge and work are not separate. Mohandas Gandhi promoted an educational curriculum with the same name based on this pedagogical principle. It can be translated with the phrase 'Basic Education for all'. The three pillars of Gandhi's pedagogy were its focus on the lifelong character of education, its social character and its form as a holistic process. For Gandhi, education is 'the moral development of the person', a process that is by definition 'lifelong'.

Nali Kali – A joint initiative by Karnataka's Mysore district and the UNICEF which began in 1995, Nali Kali strategy adopted creative learning practices to help retain children in school and bring in those not attending school.

Neo-Liberal - Relating to or denoting a modified form of liberalism tending to favour free-market capitalism.

Nuffield Science Programme – The Nuffield Foundation Science Teaching Project began in 1962. It began with O level courses in biology, chemistry and physics, followed by mathematics

and junior science courses for 5- to 13-year-olds, a science course for teaching in secondary modern and comprehensive schools, and a suite of advanced level science courses. It was the first large-scale attempt to reform both teaching approaches and content in school mathematics and science.

Objetivo/Unip–Universidade Paulista (UNIP) is a branch of the Brazilian media and education group Goal Group. It is a for-profit- university which has multiple centres in Brazil.

Performativity - Performativity is an interdisciplinary term often used to name the capacity of speech and gestures to act or consummate an action, or to construct and perform an identity.

Public Private Partnership - A public–private partnership is a government service or private business venture which is funded and operated through a partnership of government and one or more private sector companies. These schemes are sometimes referred to as PPP, P3 or P3

Regulatory Regime – Regulatory regime a system of regulations and the means to enforce them, usually established by a government to regulate a specific activity.

Sandarbh - Sandarbh, a bimonthly in Hindi, was conceived in 1994 to allow teachers to access curricular teaching resources in Hindi. Sandarbh means 'context', and carries articles on various topics in Science and Education. These articles are meant to be a resource primarily for middle and high school teachers and students, who teach and learn in Hindi.

Smart Classes – A Smart Class is one that is equipped with multimedia components to enhance instruction and learning.

Stakeholders - A person with an interest or concern in something, especially a business.

Teacher Education - Teacher education refers to the policies and procedures designed to equip prospective teachers with the knowledge, attitudes, behaviours and skills they require to perform their tasks effectively in the classroom, school and wider community.

Teacher Professional Learning - A teacher's professional learning journey is an ongoing process of inquiry into, and reflection on their practice, punctuated by learning activities and programs designed to enhance their professional knowledge, skills, and attitudes.

Virtual Computer Based Lab - Virtual lab is an interactive teaching product that assists students to perform their experiments in step by step procedure, by giving proper instructions and extending its limitations.

Voucher System - A school voucher, also called an education voucher, with the system overall being called the voucher system, is a certificate of funding issued by the government, which the parents of a schoolchild have control of and are able to direct towards the public or private school of their own choosing to fully or partially pay for the tuition of their child. In some countries, states

or local jurisdictions, the voucher can be used to cover or reimburse home schooling expenses. In some countries, vouchers only exist for tuition at private schools.

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