Teachers' Perception of Inquiry-based Science Education in Indian Primary School

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Abstract

Within science education reforms, a pedagogical shift from a teacher-centred, textbook-based instructional paradigm to a student-centred, inquiry-based model is called for. Despite strong theoretical grounding, there is limited evidence that primary teachers effectively engage students in pedagogical approaches associated with inquiry-based science curriculum in classroom settings. This study examines the constraints faced by primary school teachers in practicing inquiry-based environmental studies curricula using multiple case study design. Classroom observations, semi-structured interviews, and focussed group discussions were used for conducting cross-sectional thematic analysis of the data. It emerged that owing to accountability pressures, non-synchronisation between curriculum and assessment practices backed by their personal beliefs in lecture method receded inquiry based teaching-learning practices in classrooms. Finally, possibilities for embedding inquiry-based science in classroom practices are explored.

Keywords: *Inquiry-based science education, scientific inquiry, inquiry-based teaching, Environmental Studies, Teacher perceptions, constraints.*

Introduction

Inquiry has been the central term in the past and present rhetoric of science education reform movement across the world. Rutherford (1964), an early proponent of inquiry learning, emphatically argued that;

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> When it comes to the teaching of science it is perfectly clear where we, as science teachers, science educators, or scientists, stand; we are unalterably opposed to the rote memorisation of the mere facts and minutiae of science. By contrast, we stand foursquare for the teaching of the scientific method, critical thinking, the scientific attitude, the problem-solving approach, the discovery method, and, of special interest here, the inquiry method. (p. 80)

Inquiry Approach to science teaching-learning is about enabling students to internalise the ways of knowledge construction in science, acquainting them with nature of science by suggesting them that the knowledge in science is not the sacrosanct truth but is tentative and modifiable (DeBoer, 1991). This approach is true to science, true to child and true to life (NCERT, 2006). Inquiry-based science education develops an intrinsic motivation in children as joy of finding out, excitement of exploration, and discipline becomes part of life (Harlen, 2000). The origin of inquiry approaches can be traced back to the work of John Dewey who placed "less emphasis on what information is learned and greater emphasis on the logical thinking processes by which new knowledge is acquired" (Dewey, 1938).

Inquiry-based Science Education and the Teacher

Teachers may lead students in scientific inquiry through a variety of pedagogical processes, such as facilitating group work, argumentation, dialogue and debate, as well as providing for direct exploration of and experimentation with materials (Haury, 1993). National Science Teachers Association's position statement on scientific inquiry notes that teachers undertaking inquiry-based science programme for their students design and manage learning environments that provide students with the time, space, and resources needed for learning science through inquiry. At the same time, research suggests that planning and executing inquiry-oriented science lessons require teachers to have good command over the scientific content knowledge (Smith et al. 2007). They should organise classroom talk in a way that questions used (Kawalkar & Vijapurkar 2013) and feedback provided (Chinn, 2006) scaffold science talk to support children's emergent scientific understandings.

This paper examines teachers' instructional practices while implementing inquiry-based science curricula in primary grades. The purpose of the paper is to identify the factors and conditions facilitating or impeding the teaching-learning of inquiry-based science curriculum in real-time classrooms.

The Context: Inquiry-based Science Education in India

In the post-independence India, great thrust was laid on science and technology as cornerstones for building a prosperous nation. This emphasis percolated to school science in India too and school textbooks were overwhelmingly loaded with factual information to make students fit for the knowledge economy (Correia, Chandran-Wadia, Vishwanathan, & Muralidhar, 2014). Somehow, laboratory work got declined in the quest of learning various brands of science. Eventually, factual information encoded in the school syllabi remained unsupported by any kind of activity, which could make it comprehensible to the students (Mukherjee, 2007).

An attempt to challenge the orthodoxy of Indian science education was raised through People's Science Movement (PSM). The role of PSM is not only restricted to communicating and simplifying science but also to question every aspect of science-related activities (INSA, 2001). An outcome of the PSM was in the form of Hoshangabad Science Teaching Programme (HSTP), a programme for teaching middle school science through experiments, which started in 1972 as a pilot project in 16 schools of Hoshangabad district in Madhya Pradesh. An important difference between the HSTP and mainstream science teaching is that the former emphasised the processes of science — observation, recording, performing controlled experiments, etc., using locally available materials. Whereas, the mainstream school science teaching continued to lay stress on the 'products' of science — laws, theories, etc. One of the major contributions of HSTP is development of textbook series '*Bal Vaigyanik*' for middle grades. PSM has grown and spread all over the country and has led to the upsurge known as *Bharat Gyan Vigyan Jath*a which worked to create the necessary social ethos for absorption of science and scientific ways of thinking among the larger masses (Correia et al., 2014).

The other initiative aimed at developing inquiry-based science education is called exploratory, developed by educators in Pune, where school and college children can explore and experiment, invent, innovate, design and fabricate. There are no teachers in the exploratory method of science education, but highly experienced guides who explore along with the students the basic concepts in science through carefully designed activities (INSA, 2001).

Arvind Gupta led a movement in science education by enabling children experience the connection between science and life through small science activities and construction of toys from locally available materials. *Anveshika*, is another initiative of Indian Association of Physics Teachers that creates centers across India in schools and colleges where students and teachers can learn experiment-based physics and try out their own ideas. They organise interaction sessions with students, short and long term teacher-training programmes; develop new teaching demonstrations and other activities. The Agastya International Foundation, a non-profit organisation, whose mission is to develop scientific inquiry for economically disadvantaged children and government school teachers, has created 125 Mobile Science Vans which take science education to the village doorstep, 45 Science Centers for disadvantaged children, 260 Night Village Schools, and 108 science laboratories.

Similar thrust to inquiry-based science education has been laid by Homi Bhabha Centre of Science Education. They have developed 'Small Science' textbook series for elementary grades.[1] Various organisations like National Institute of Science Communication and Information Resources (NISCAIR), and Vigyan Prasar have been established by the Government of India for the sole purpose of encouraging science inquiry. Despite such variegated endeavors spread across the entire country, it remains a fact that the inquiry-based science education (IBSE, henceforth) has not been taken up in science classrooms (Correia et al., 2014).

National science academies— National Academy of Science (NASI), Indian Science Academy (ISA), Indian National Science Academy (INSA)— have all recognised the need to amend the ways of science teaching- learning at school level which directly influences science education at undergraduate and post-graduate levels. The National Curriculum Framework (2005) acknowledges the 'product' obsession of school science and has recommended a move towards weakening of disciplinary boundaries and linking school knowledge with learners' context as the avowed goals of school science education. Observer Research Foundation's recent report on state of science education in India clearly indicates an urgent need to support science education at primary and secondary levels as our states are faring much below average score in Programme for International Student Assessment (PISA) educational surveys (Correia et al., 2014). Figure 1 expresses a nuanced version of problems associated with science education in Indian educational landscape, thus, reinforcing the need for a closer investigation of the ways in which primary school science is being practiced in the classrooms. The particular focus of this study is teaching of environmental studies in primary classrooms.

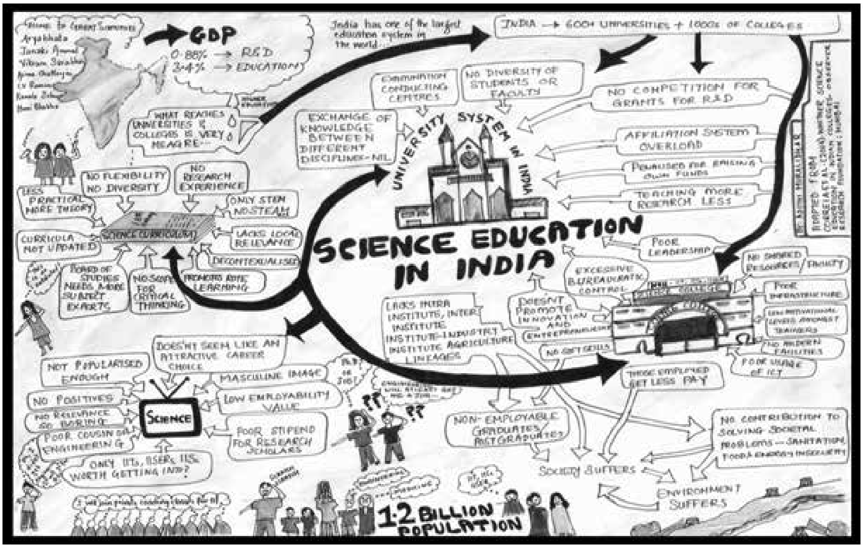

Figure 1: State of science education in India

Source: www.thealternative.in/society/how-do-we-improve-the-state-of-science-education-in-india- image

Inquiry-based Science Curricula

Inquiry-based curricula provide "context in which students can learn to reason scientifically" (Chinn, 2002). BouJaoude (2002) developed an analytical framework to analyse inquiry–based science curriculum. The framework comprised four aspects—knowledge of science, investigative nature of science, science as a way of thinking, and interaction of science, technology, and society. Essential features of inquiry-based classroom science include engaging students in scientifically oriented questions; gathering, organising, and analysing data; formulating explanations from evidence to address scientifically-oriented questions; evaluating their explanations in light of alternative explanations; and communicating and justifying their explanations; best promote students' science learning (NRC, 2000).

Position Paper on Teaching of Science Identifies the Following as Goals of Science Teaching at Primary Level

i) To nurture the curiosity of the child about the world (natural environment, artefacts and people), ii) to have the child engage in exploratory hands on activities to acquire the basic cognitive and psychomotor skills through observation, classification, finding patterns and relationships, iii) to emphasise design and fabrication, estimation and measurement as a prelude to development of technological and quantitative skills of later stages (NCERT, 2006).

Learning Indicators of Environmental Studies at Primary Level (NCERT, 2014, p.134) are Stated as Follows

1. Observation and Reporting — Explores, shares, narrates and draws, picture-reading, makes pictures, collects and records information, tables and maps.
2. Discussion — Listens, talks, expresses opinion, discovers.
3. Expression — Expresses through gestures/body movements, expresses verbally, expresses through drawing/writing/ sculpting, expresses through creative writing.
4. Explanation–Reasoning, makes logical connections, describes events/situations, formulates one's own reasoning's, makes simple gestures, thinks critically, and makes logical connections.
5. Classification — Identifies objects-based on observable features, identifies similarities and differences in objects, sorts/groups objects based on observable features. Compares objects and classifies them based on physical features.
6. Questioning — Expresses curiosity, asks questions, raises critical questions, frames questions.
7. Analysis — Defines situations/events, identifies/predicts possible causes of any event/situation, makes hypotheses and inferences.
8. Experimentation (Hands-on activities) — Improvises, makes simple things and performs simple experiments.
9. Concern for Justice and Equality — Sensitivity towards the disadvantaged or people with disability, shows concern for environment.
10. Cooperation — Takes responsibilities and takes initiatives, shares and works together with empathy.

Following the guidelines of *National Curriculum Framework* (2005), textbooks have been revised to provide requisite opportunities to learn inquiry for students. It is assumed that teachers using these textbooks will make inquiry-based teaching a central component of their pedagogical practices. However, research indicates that even when using inquiry-based science curriculum materials, elementary teachers may not always effectively engage students in science as inquiry (Forbes & Davis, 2010; Appleton, 2002; Pine et al., 2006). Furthermore, with the recommendations of NCF (2005), an assessment practice in India has been revised. Continuous and Comprehensive Evaluation is implemented in all the schools managed by Central Board of Secondary Education (CBSE) since 2009 which suggests a minimalistic use of content-based paper-pencil tests and encourages teachers to use diverse and authentic ways of student assessment. However, Nawani (2013) notes that school-based assessment practices are still hitched onto behaviourist traditional forms of content-based paper and pencil tests.

Research Questions

This study examines the ways in which inquiry-based science curriculum encoded in textbooks is being transacted in real-time classrooms. The study attempted to find answers to the research questions.

- What are the philosophical and practical conceptions of inquiry in science classrooms?
- What are the factors and conditions, internal or external to educational settings, which may impede or facilitate inquiry-based science education?
- How is science inquiry mediated through instructional discourse?
- What are the perceived gaps between inquiry-based science curriculum and its classroom transaction?

Method

Setting and Participants

The study adopted a multiple case-study design (Holliday, 2007) to understand pedagogical processes associated with teaching of inquiry-oriented environmental studies curriculum[2]. Three teachers, (referred as Teacher A, B and C in this study), teaching in three different schools, run by Government of Delhi, voluntarily participated in the study. Table 1 describes the professional profiles of these teachers. Purpose of the study was communicated to all the teachers and their school authorities. These schools were part of the large sample of schools to which pre-service teachers studying in Bachelor of Elementary Education, University of Delhi visited for internship purposes. Purposive sampling of the schools was conducted due to ease of access in these schools owing to researcher's positioning as a teacher educator, visiting these schools regularly for mentoring of pre-service teachers.

Table 1

Professional Profiles of Teachers Participating in the Study

Teacher	School	Teaching Experience	Class Strength	Other Responsibilities
A	Senior Secondary	10 years in the same school	Varied between 40-70	Assisting the supervisory head of the primary wing of the school
B	Primary	5 years in this school and 2 years in a private school	Varied between 30-49	Organising collaboration among other teachers teaching Grade 3
C	Primary	3 years in this school and 1 year in a private school	Varied between 30-57	None

Data Sources

The teachers included in the study taught all the subjects to the students of Grade III as primary classrooms in India adopt an integrated approach to teaching-learning. Classroom observations constituted that part of their day when they were teaching environmental studies. A total of 24 hours of classroom observations, eight hours per teacher, constituted the data being reported in this paper. Along with this, teachers were interviewed (total 8 hours) using semi-structured questionnaire to examine their pedagogical planning, perceptions of scientific inquiry, views about changes in textbooks, their self-efficacy to conduct inquiry and infrastructural support required for conducting inquiry. Three focussed-group discussions were conducted with students to identify the ways in which they perceive inquiry and to draw out their experiences associated with inquiry-based teaching, if any.

Data Analysis

Inquiry is understood as not only a 'hands-on' approach but also as 'minds-on' approach to science in this study. The purview of inquiry adopted in this study entails hands-on activities; open-ended questions, surveys, teacher-led demonstrations, whole-class discussions, textbooks, interactive digital material, etc. Inquiry is interpreted as stimulation of curiosity among children to enable them to engage in scientific processes of reasoning out, observation, critical analysis of data, communication, etc.

Keeping this view of inquiry under consideration, the present study used thematic data analysis to allocate data into categories or themes, which emerged from the data itself, as per its relatedness to various themes.

Findings

Although inquiry offers compelling opportunities for science learning, it emerged from the study that there are many challenges to the successful implementation of inquiry-based learning. The challenges are described in the subsequent paras.

- *Non-synchronisation between inquiry-oriented curricula and assessment practices:* Teachers included in the study opined that inquiry is incorporated in textbooks but not in assessment processes which are still rooted in traditional content-based paper-pencil tests. Therefore, teacher A suggested that she "won't take a risk of spending time in inquiry which may hamper student achievement". Also, teaching of science was somehow correlated by the teachers with students' taking up of entrance examinations for entry to higher educational institutes of medical and engineering professions which often includes the curriculum of both classes XI and XII. In teacher B's opinion, "*Science ka content yaad karne ki aadat nahin hogi to aage kya karenge, aage entrance bhi to deni hoti hai*". Thus, there existed a covert focus on rote memorisation of scientific content, receding inquiry-based classroom practices.
- *Conception of science and science teaching:* Teachers seemed to be adhering to John Locke's conception of *tabula rasa*, thus, equating science with a dossier of information and facts which is to be parceled from an expert to novice. Teacher B argued, "*hume bhi to aise hi padhyi gai thi science*", suggesting that they themselves had been taught science through lecture

method which has reaped gains in terms of professional growth. Therefore, an affinity towards lecture method emerged owing to teachers' personal belief in its benefits for students' outcomes and academic growth. They argued that when compared to lecturing, teaching science through inquiry takes a lot of instructional time which could have been fruitfully utilised in covering the course outline as prescribed in the syllabus.

- *Accountability pressures:* Teachers argued that instructional time is considered to be well spent by school administrators and parents if it is used in direct lecturing. The 'additional' time needed to engage in inquiry is perceived as less efficient when compared with lecturing about science concepts. Thus, accountability pressures motivated them to focus on scientific content more than the processes entailed in scientific inquiry.
- *Perceiving inquiry as elitist:* Teachers suggested that inquiry is an elitist practice as it involves playing around with the materials. To them inquiry-based science teaching can only be conducted in science laboratories requiring huge and costly paraphernalia. All the more, inquiry-based science practices were linked to students' socio-economic backgrounds and their possible future prospects. The following interview transcript with Teacher C elaborates this view further.

T (Teacher): *Madam, ye sab in bachon ke liye nahin hai…*

Rr (Researcher): *Ye sab kya?*[3]

T : *Ye inquiry…inhe koi scientist nahin banana… inhe to rickshaw wala hi banana hai…uske liye kaun si inquiry chahiye… ye to un bachon ke liye hai jo bade public schoolon mein jate hain jinko age chalkar scientist banana hai…. (pause)…unnnn…aur saman kahan se laoge aap bataiye* (This inquiry…these children will not grow up to become scientists, rather they will become rickshaw pullers only…. which inquiry is required for the profession of rikshaw pulling, tell me… all this is for students who go to big public schools and may grow up to become scientists in the future…unnnn….. (pause)…from where will we get stuff for inquiry-based activities?)

Rr : *Aapko kya lagta hai saman ke bina inquiry nahin ho sakti* ?

T : *batao na kaun sa experiment kar sakte ho?*

Rr : *Maine kitab dekhi thi…usme kuch surveys, discussions, sinking-floating jaise experiments diye the…kya nahin ho sakte*? (I have seen some forms of surveys, discussions, sinking-floating experiments were given in the textbook... can they not be done?)

T : *Mushkil hai....ye tik ke to baithte nahin hain aur (emphasis in tone) kya hamein koi assistant mila hai yahan* (It seems difficult.... these students do not have etiquettes to sit properly in classrooms... and have we got any assistant to help us out?)

Rr : *acha, assistant mile to phir...*(Ok, if you get an assistant then...)

T : (irritated sound) *dekhenge tab...*(We will see then...)

It emerges that although teachers believed that they are engaged in inquiry-based science education since they voluntarily participated in the study yet they lacked confidence in conducting inquiry. They assumed scientific inquiry to be related to one's socio-economic backgrounds, and particular professions of science only. Another constraint in carrying out inquiry-based science education was their perception that scientific inquiry demands lots of manpower and infrastructural resources.

Closing Remarks

"The integration of theoretical knowledge and its application with the associated skills is at the heart of a qualitative change of science education at the schooling stages" (APEID, 1991, p. 62). This study suggests that in order to bring out this change in reality it is crucial to deal with the challenges faced by teachers in school contexts because teachers are the real crusaders of change. Teachers need to overcome their transmissionist views of teaching-learning of science to accommodate progressive and constructivist views of teaching science. To facilitate attitudinal changes in teachers, it is crucial that school provides adequate resources— infrastructure, pedagogical content knowledge, time— to teachers so that they can work collaboratively and creatively to translate inquiry-based science curriculum into practice.

Appendix 1

This is an excerpt from the semi-structured interview conducted with Teacher A in the initial phases of the study.

Rr : What do you understand by scientific inquiry?

TA : It is about asking questions, doing activities, relating their real lives to school science

Rr : Who is supposed to do all this... the points you have mentioned as scientific inquiry?

TA : Teacher, obviously,...I mean...you can't expect these small children to perform scientific activities....

Rr : So, teacher is the key actor of inquiry... right?

TA : No, I think...*bache bhi kuch kuch to kar hi sakte hain...* (Children can also do certain things)

Rr : *Jaise ki....*? (Like what?)

TA : Simple stuff like sink-float, classification, etc..

It emerged that the teacher ostensibly believed in scientific inquiry and envisioned an active role of learners in the IBSE.

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