Examining Pre-service Science Teachers Pedagogical Orientations in an Era of Change in India

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Abstract This chapter examines the historical development of science education in India, beginning with the policy context in pre-independence India to the present day, with a specific focus on school science education and teacher education. Specifically, this study examines the pedagogical orientation of pre-service science teachers, who had been a part of two-year Bachelor of Education teacher education program in India. They had taught middle grades science during their school internship program in different genres of schools, ranging from state-funded to private-funded during internship. Assessment items in Pedagogy of Science Teaching Test (POSTT) were used to identify their pedagogical orientations, and reasons for their specific orientations were probed through interviews. It comes out that pre-service teachers develop varying pedagogical orientations, ranging from direct instruction to open inquiry, emerging from several school-related factors like class size, availability of resources, leadership guidance; discrepancies between professional development and school culture, and other personal constraints.

Introduction

Many countries are focusing on policy decisions with regards to curriculum design in science teaching and learning in order to prepare students for the demands of the twenty-first century. Because the success of any educational change depends upon how teachers perceive that change (Bryan & Abell, 1999), it seems crucial to understand how their beliefs and practices are constructed during professional

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development programs and influenced by various social and contextual factors in the schools.

For this study, we have adopted Friedrichsen, van Driel, and Abell's (2011) definition of a teacher's science teaching orientation as describing the beliefs that they hold regarding (a) a teacher's understanding of the goals and purposes of teaching science (b) their view of the practices of science as a discipline, and (c) their beliefs about science teaching and learning. Thus, while referring to the 'pedagogical orientations' of teachers towards science teaching we are referring to this collective set of beliefs.

This study focusses on the current Indian experience with curriculum restructuring of one of its teacher education program—Bachelor of Education (B.Ed.). In order to contextualise the study, we begin our chapter by tracing the historical roots of science education in the country. The discussion then moves on to delineating the current practices of school science education in the country. Elaborating the problems associated with school science education, and how teachers are held responsible for the poor execution of policy in classrooms, it moves on to examine pre-service teachers' pedagogical orientations towards science teaching, post-curricular reform in teacher education in the country, through a specific research study. The research study attempts to identify the pedagogical orientations of pre-service teachers graduating from a professional development program, namely the B.Ed., in India.

This study was conducted shortly after the introduction of a new curriculum that led to restructuring of the B.Ed. program, making it a two-year program instead of one year and offers an enhanced understanding of the effectiveness of the reform process. Further insights about socio-cultural and contextual factors that might affect the reform process may be gleaned from this study.

Background

Historical Roots of Science Education in India

This chapter traces the historical and ideological trajectory of science education (SE) in India to contextualise educational practices in science. Sangwan (1990) analyses complexities inherent in SE in pre-independence India. He identified three phases which SE underwent during the pre-independence era. In the first phase, the British colonizers displayed indifference towards the education of their Indian subjects due to an inherent belief that education would awaken their minds to escape the clutches of colonial rule. However, the second phase witnessed an extension of indigenous systems of education (Sanskritic education) in India. This move was criticised by influential Indian reformers who appealed for the diffusion of European sciences into Indian education. With the pressing demand for engineers to tap water reservoirs through dams, canals and the requirement of trained personnel for constructing roads and railways, an emphasis on SE was finally laid in the third phase. The ideological interests of one of the British Governor-generals, Lord Macaulay, resulted in an overemphasis on European literature and science at the expense of indigenous science and knowledge systems. All education was imparted in the English language which restricted democratic access of sciences by the masses.

Post-independence, there was a calculated emphasis on the spread of SE in India. SE was considered a harbinger of national development which would liberate citizens from irrationality and superstition (Agarkar, 2017). Article 51(A) of the Indian constitution states that one of the fundamental duties of every citizen is to 'develop the scientific temper, humanism and the spirit of inquiry and reform.' (http://www.constitution.org/cons/india/p4a51a.html).

It was coupled with unprecedented support for SE by the State. Huge amounts were invested in the setting up of research and development institutes like the Bhabha Atomic Research Centre, the Council of Scientific and Industrial Research, the Department of Atomic Energy, the Indian Space Research Organization, the Indian Medical Council, the Indian Council of Agricultural Research and premier higher education institutes like the Indian Institute of Technology, the Indian Institute of Science Education and Research, to name a few. Despite all these systematic endeavours, the impact of SE on the cultivation of scientific temper in the public at large has not been achieved (Sarukkai, 2014). Sarukkai further observed that Indian scientists, in spite of being good at their profession, observe unfounded religious practices, thus, indicating a dichotomy between their private and professional beliefs. Another common trend, according to him, is that students study science primarily for getting lucrative jobs without accepting the virtues of rationality, application of logic and reasoning, and the avoidance of bias and preconceived notions in arriving at decisions which are associated with the scientific ways of thinking. This scenario raises the following questions: Why is SE divorced from the public sphere? Why is the spirit of SE not taken up by the masses in India? Is the problem rooted in the state of school science education? The next section will probe the status of school science education to explore probable answers.

School Science Education

School science education, post-independence, was considered a pathway to instill scientific values and attitudes amongst youth (Agarkar, 2017). The National Council of Educational Research and Training (NCERT) was established to look into matters of education. It developed curriculum, and resources for education at all levels. Policy recommendations incessantly laid stress on SE. The Kothari Commission (1964–66) emphasised the compulsory teaching of science for the first ten years of schooling using an investigatory approach for all students (NCERT, 1970). Twenty years later, the National Policy on Education (1986) argued for the importance of science education for the country's economic growth and the development of a scientific temper among the masses (GOI, 1986).

While taking stock of the state of school SE, the National Curriculum Framework (NCERT, 2005) highlighted that, due to students not having opportunities to experience scientific phenomena during instruction, science learning has been reduced to a body of facts which is to be memorised and reproduced in examination situations. In fact, the National Policy on Education (NPE, 2016) categorically declares that poor performance in science and mathematics is the prime reason for high failure and dropout rates after formal end of year examinations occurring in Grade X. This state of affairs raises the following questions: Why, in spite of strong State support, students in India failing in science? What are the prime reasons for the experiential distancing of students in science classrooms? What has been done so far to make teaching-learning practices in science classrooms meaningful for students?

Sarangapnai (2014) argues that one of the prime reasons for the deplorable state of science education in schools, apart from lack of infrastructural facilities necessary to engage students with scientific practices (such as, laboratories), is the paucity of skilled teachers who possess the necessary pedagogical training. This training is provided in India by various teacher education programs, like the B.Ed. Many of these teachers are directly recruited into the school system after completion of Grade 12.

Although the statutory body governing teacher education in India, the National Council of Teacher Education (NCTE) makes it mandatory for teachers to have professional training through B.Ed. and other degrees, this rule is not consistently adhered to. This is because the demand for trained teachers burgeoned with the launch of the Right to Free and Compulsory Elementary Education (RTE, 2009) Act in April 2010. It made it an obligation of the government to ensure admission, attendance and completion of elementary education by all children in the 6–14 age group without being charged any kind of fee. Hence, an urgent need is to not only raise the number of teachers but also the quality of teachers entering the teaching profession (NPE, 2016).

However, the quality of science teaching undertaken by those teachers who have undertaken professional teacher training is no better than their untrained counterparts. It was noted by National Policy of Education (NPE, 2016) that, in order to meet the increasing demand for teachers, a large number of private universities and institutions providing teacher education have mushroomed all across the country. These 'teaching shops' are ill-equipped and operate with unqualified staff, often under the patronage of influential people who have little interest in education. This has resulted in a large group of trained professionals who are not fit to undertake innovations and match their teaching to the changing demands of the education system and society at large (NPE, 2016).

Even teachers graduating from premier teacher education programs often lack training in practice, for instance in performing science experiments. For instance, the B.Ed. program was so fast-paced during the reform period that, despite provision of space in the curriculum, there was no time to conduct experiments by pre-service teachers (Sarangapani, 2014).

The National Curriculum Framework of Teacher Education (NCFTE) notes that there is a dire need to upgrade the status of B.Ed. program which have outlived it's relevance in the twenty-first century (NCTE, 2009). Furthermore, the document identified that owing to structural and time constraints, one-year B.Ed. program has become weak both in theory and practice.

This recommendation spurred on the structural transformation of the time frame of the B.Ed. program from one-year to two-years, a key change in the history of teacher education in post-independence India. The new curriculum provides pre-service teachers opportunities to integrate ideas, experiences and professional skills through hands-on experience as they develop curriculum and learning materials, and design appropriate activities for children of different age groups.

B.Ed. Curricula Post-reform

The NCFTE (2009) observed that initial teacher education programs have a major role to play in the making of a teacher. These programs should be geared towards imbuing pre-service teachers with the knowledge-base and repertoire of pedagogical strategies essential for providing quality teaching. Following this realisation, India's teacher education underwent reform which culminated in a landmark revision, in the year 2015, of the curriculum, structure and organisation of one of India's teacher professional development programs, the B.Ed. This change embodied the current understanding of the needs and demands of India's science teachers and the school science curriculum, and it is hoped that it will lead to high-quality science education in Indian schools.

The new B.Ed. curriculum (NCTE, 2009), with specific reference to science education, offers a subject called 'Pedagogy of Science' in the first year of the program. This subject focuses upon developing the epistemological and pedagogical understanding of science as a discipline. It broadly comprises three areas: first, the nature of the school subject, including disciplinary knowledge and understanding of the social history of the subject in the school curriculum; secondly, the aims and pedagogical approaches for teaching of the subject at different stages of schooling; and thirdly, a deeper theoretical understanding of how children in diverse social contexts construct knowledge. This subject is assigned three hours of teaching per week and is followed by a 70 mark external examination towards the end of the academic year. An internal assessment of 30 marks requires pre-service teachers to write various assignments.

During the pedagogy lessons, which are conducted in the first year of the B.Ed. program, pre-service teachers are given opportunity to critically examine teaching and learning processes that incorporate inquiry, discovery, conceptual development and activity-based learning. They are encouraged to develop teaching-learning resources for various conceptual areas pertaining to the teaching of science during the school internship program to be happening in the concurrent year.

The School Internship program occurs for a period of 20 weeks in diverse school contexts—government and non-government (see Table 1)—where pre-service teachers are required to work like full-time teachers, participating in all school-related activities. This program is designed to lead to the development of a broad repertoire

Table 1 Types of schools

School type	Salient features
State-run/government	Managed by the State from the public funds collected through taxes. The State provides funding for faculty, student-related resources (e.g., school uniforms, curricular materials, stationery, meals to name a few), school building and other infrastructural facilities. Students in these schools are entitled to receiving free education and resources. These schools barely meet the basic requirements of hygiene and resources (Gupta, 2007)
Private/non-government	Managed by private bodies who charge students for their tuition and other facilities. They often have adequate and high-quality resources and infrastructure to support student learning (Gupta, 2007)

of perspectives, professional capacities, teacher dispositions, sensibilities and skills amongst pre-service teachers. Internship in schools includes an initial phase of one week for observing a regular classroom with a regular teacher, followed by teaching two school subjects for rest of the period. Other projects to be conducted during internship include peer observations, teacher observations and observations of pre-service teachers' lessons by faculty. Pre-service teachers are encouraged to write reflective journals during the internship programme and reflect on different aspects of their teaching experience and other school-related aspects.

Now, the question emerges as to how successful the new B.Ed. program is in developing the repertoire of content knowledge, and pedagogical competencies needed for teaching science among pre-service teachers. In order to develop an enhanced understanding of this issue, we employ the framework of pedagogical orientation as discussed in the next section.

Pedagogical Orientations and the Teaching of Science

Shulman (1986, 1987) coined the term pedagogical content knowledge (PCK) which includes knowledge of effective instructional practices pertinent to specific content areas. For science teaching, PCK must include understanding of 'scientific inquiry' (Lowery, 2002) and how to reflect and model scientific inquiry in science instruction.

Anderson and Smith (1987) coined the term 'orientation' and defined it as 'general patterns of thought and behaviour related to science teaching and learning' (p. 99). Magnusson, Krajcik, and Borko (1999) further theorised that teachers' pedagogical orientations were a component of PCK which provides teachers with a 'conceptual map that guides [their] instructional decisions such as daily objectives, the content of student assignments, the use of textbooks and other curricular material, and the evaluation of student learning' (p. 97). Thus, teachers' pedagogical orientations act as filters through which teachers selectively absorb specific purposes and goals for teaching science at a particular grade level (Abell, 2007; Friedrichsen et al., 2009). It was furhter identified in the above mentioned study that while enacting a set of orientations (or beliefs) into practice, teachers unconsciously merge their newly formed belief systems with their pre-existing belief systems, which were formed out of their own learning experiences as students of science. Thereby, teachers develop multiple belief systems towards teaching of science (Nargrund-Joshi, Rogers, & Akerson, 2011). Magnusson and her colleagues (1999) identified nine different science orientation: (1) process, (2) academic rigour, (3) didactic (4) conceptual change (5) activity driven (6) discovery (7) project based (8) inquiry and (9) guided inquiry.

Two themes have often been reported to influence a teacher's pedagogical orientation. One of these themes refers to external or contextual constraints that include physical learning environment (e.g., building structure and infrastructural resources), the human or cultural environment (e.g., student, parent and administrative expectations), and the political environment (e.g., policies and cultural norms) (Ford, 1992). The second theme refers to personal constraints such as a lack of understanding of the nature of science (Lederman, 2007).

Literature on teachers' science pedagogical orientations is plentiful across the globe, however, it is rarely studied in non-Western contexts (except, Zhang et al., 2003 in China; Ramnarain & Schuster, 2014 in South Africa, and Nargrund-Joshi, Rogers, & Akerson, 2011 in India). Moreover, pre-service teachers' pedagogical orientations have hardly been examined not sure in the Indian context, specifically, at a point of time when the country has seen a key change in teacher education policy and professional development curricula. Therefore, this study contributes to the research base, not only in understanding pre-service science teachers' orientations for teaching in non-Western contexts, but also in how contextual factors such as government policies and cultural traditions contribute to the development of their pedagogical orientations. These may impact our understanding of how to take a more global approach to teaching science.

Science Pedagogical Orientation Spectrum

In order to theoretically ground this work, this study uses the framework of 'science teaching orientation spectrum' developed at Western Michigan University by Schuster and Cobern (2011) and further pursued by Ramnarain and Schuster (2014). They suggested that teaching practices in science classrooms cover a wide spectrum ranging from didactic exposition to open inquiry learning. They considered four main orientations in the spectrum denoted as (A) didactic direct, (B) active direct, (C) guided inquiry and, (D) open inquiry. The first two practices are variants of direct instruction in which science is often presented as a body of facts by the teacher through direct instruction (ready-made science) while the remaining two are variants of inquiry-based instruction, in which a science topic is approached via scientific inquiry (science-in-making) with varying degree of guidance. In summary, the framework reflects two contrasting epistemologies, each with two common variants. The four approaches are further described in Table 2.

Table 2 Description of science teaching orientations

Science teaching orientation	Description
Didactic direct	Teacher presents the science concept or principle directly and explains it. Illustrates with an example or demonstration. No student activities only question-answer session
Active direct	Initially direct exposition, followed by student activity based on the presented science, e.g. hands-on practical verification of a law
Guided inquiry	Student exploration of a phenomenon or idea, with the teacher guiding them towards the desired science concept or principle arising from the activity. Teacher may explain further and give examples to consolidate
Open inquiry	Minimally guided by the teacher, students are free to explore a phenomenon or idea and devise their own ways of doing so. Teacher facilitates but does not prescribe

Goals of the Study

The specific focus of the study was understanding pre-service teachers' pedagogical orientations post-curricular reform in teacher education. However, it seemed crucial to understand the historical and educational policy context within which this study is placed. This need to examine the socio-cultural-policy context emerged from the understanding that educational practices are necessarily social actions embedded deeply in the context of that era. Keeping the importance of context in consideration, this chapter examines the historical development of science education in India, beginning with the policy context in pre-independence India to the present day, with a specific focus on school science education and teacher education.

Given the inquiry-based emphasis of the new teacher education curriculum and the enormous diversity in the schools where pre-service teachers go for their internship; it is important to assess the pedagogical orientations that teachers assume towards their classroom teaching after an internship; and, to identify factors which influence the same.

The following research goals guided the study:

- To investigate the pedagogical orientations of pre-service science teachers, completing the two-year teacher preparation program, B.Ed. in India, towards science classroom teaching;
- To probe how pre-service science teachers' pedagogical orientations vary with the genre of school in which they are placed during their internship;
- To determine what factors shape pre-service science teachers' pedagogical orientations towards science teaching.

Research Method

In order to situate the problem in the socio-cultural-political-historical context of the country, we used a comprehensive literature review (Onwuegbuzie & Frels, 2016) methodology. We systematically collected books, journal articles, policy documents, media reports and other documents available on the topic of science education in the country. The literature review began broadly with an intent to examine the status of science education in India. However, keeping in view the specific goals pursued with regards to pre-service teachers' pedagogical orientations, the literature review gradually tapered towards school science education and teacher education in the country. Themes emerging from the literature review were organised systematically to identify relationships among them which often led to a process of re-organisation of data, introduction or dropping of themes. The ideas emerging from the review are finally synthesised in this chapter to draw a vivid picture of the context through which the existing educational practices have come into being; and how different dimensions, namely, curricular reviews, educational vision in the policy documents, situational factors and others interplay with each other to give science education its' present shape in the Indian educational ecosystem.

To teach science effectively, one requires an integration of different types of knowledge, which includes knowledge of content, pedagogies, science teaching methods, inquiry, and how to apply these to teaching specific topics to specific groups of learners (Ramnarian & Schuster, 2014). In consonance with this view, any examination of teachers' science pedagogical orientations should be based on specific teaching scenarios where they get an opportunity to choose particular pedagogical approaches for teaching specific science topics. The test items used in this study were compiled from a collection of assessment items of this nature developed at Western Michigan University by Schuster et al. (2007), Schuster and Cobern (2011), and Schuster et al. (2012) and was named the Pedagogy of Science Teaching Test (POSTT).

The general structure of each assessment item is comprised of a classroom teaching vignette describing a realistic teaching situation for a particular topic, followed by a question which asks respondents to indicate how they would teach in that situation. Respondents have to make a choice from the set of options reflecting a set of four instructional types, namely, didactic direct, active direct, guided inquiry and open inquiry, and describe their reasons for making that choice. A selected response format was particularly suited to our purposes since it explicitly presents contrasting alternatives. Pedagogical preference items, provided as options to the classroom vignettes, may look like conventional 'multiple choice questions', however, there is no single 'correct' answer or 'wrong' distracters; rather, the options offer alternative teaching approaches, whose character is consistent across items, for respondents to indicate their preference. The nature of this new kind of pedagogy assessment is best illustrated by an example provided in Fig. 1.

This item involves alternative approaches for teaching-learning laws of flotation. The item consists of vignette, question, response options and space to write reasons.

Sink or Float

Ms. Hema has her students gather around a small pool of water. She has a set of objects of different sizes and different materials; some will sink and some will float. Ms. Hema's goal is for her students to first distinguish the objects by whether they sink or float, and then realize that this does not depend on the size of the object but on what it is made of (e.g., the stones will all sink no matter how big or small they are, and the wooden blocks will all float).

Thinking of how you would teach this lesson, of the following, what would you most likely do?

- Drop objects one by one into the water, and have the children notice that some sink and some float. Point out that all the stones sank, no matter how big or small, and all the wooden blocks floated, etc. Conclude by stating the lesson objective that it is not size that matters but the material the object is made of.
- Have students come one by one and drop an object into the water, with everyone calling out whether it sank or floated. Point out that all the stones sank, no matter how big or small, and all the wooden blocks floated, etc. Conclude with the lesson objective, that it is not size that matters but the material the object is made of.
- Have students come by one by one and drop an object into the water, with everyone calling out whether it sank or floated. Ask them to suggest what this depended on; when some suggest size and others what it is made of, have them test these ideas by dropping more objects. Then have them agree on a conclusion.
- Have all the students drop various objects in the water and seeing what happens. Then have them talk among themselves about this and ask volunteers to give their ideas about it, with others saying if they agreed or not.

Fig. 1 Example assessment items

Note that for illustrative purposes, the options in the above example are presented in ‘spectrum’ order: didactic direct, active direct, guided inquiry and open inquiry, while in practice, the options were ordered randomly.

Thirty-one pedagogy items were selected from suitable earlier Pedagogy of Science Teaching Test (POSTT) items. The POSTT consists of twenty-one items from physical sciences and ten from biological sciences. This compilation in the form of an instrument appropriate for Indian context was named POSTT-India. The curriculum appropriateness of the chosen items for the Indian curriculum and context was investigated by a panel of one Indian science education researcher and one in-service school teacher who had been teaching middle-grade science in the Indian school context for more than fifteen years. The panel established that all item vignettes were on science topics taught in the Indian school curriculum. Panellists also classified, individually, the options for each item into four intended pedagogical orientations. There was 100% agreement on the classification, and this also confirmed the validity of the orientations specified by the developers for the response options. The instrument was piloted with twenty pre-service teachers, and interviews with these teachers on the readability and clarity of items resulted in minor modifications.

Adopting a ‘sequential explanatory mixed methods’ design (Creswell, 2003) which enables the researcher to ‘collect both quantitative and qualitative data, merge the data, and use the results to best understand a research problem’ (p. 564), quantitative data collected in the first phase, was followed by the collection and analysis of qualitative data in a second phase that builds on results of the initial quantitative results.

Data Collection Procedures

POSTT Instrument and Questionnaire Administration

Quantitative data were collected by means of the POSTT—India instrument to examine the pedagogical orientation towards science teaching of seventy pre-service teachers teaching Grade 6–8 in a cosmopolitan city of India. This study was conducted with the first cohort of pre-service teachers who were going to graduate from the new B.Ed. program post-reform in the year 2017.

Focussed Group Discussions

Five sessions of focussed group discussions (FGDs) were carried out with teachers who had responded to the questionnaire. The group size varied between 10 and 15. Half of the teachers in each group belonged to the State-funded government schools, while the other half belonged to private schools. The theme of FGDs entailed detailed discussion of the pedagogical choices teachers made in response to each item, as well as why other options were not chosen. Discussions ensued on the situational factors that promoted or inhibited choice of particular pedagogical approach.

An assistant researcher was contracted to take detailed field notes of FGDs which were later transcribed verbatim. In addition, during all these sessions, teachers were asked to write reflective notes describing the primary reasons behind their pedagogical orientations towards science teaching. Further, one of the researchers observed the science classrooms of a group of six pre-service teachers as a regular mentor while she observed other pre-service teachers' science classrooms on a rotational basis. Field notes and reflections garnered from these classroom observations substantiated the findings.

Data Analysis Procedures

Quantitative Data

The data was analysed using MS-Excel. An example representing the choices made on the POSTT-India Item in Fig. 1 is shown in Fig. 2. Further, comprehensive analysis of all responses for all items and participants will be provided in a journal article to follow.

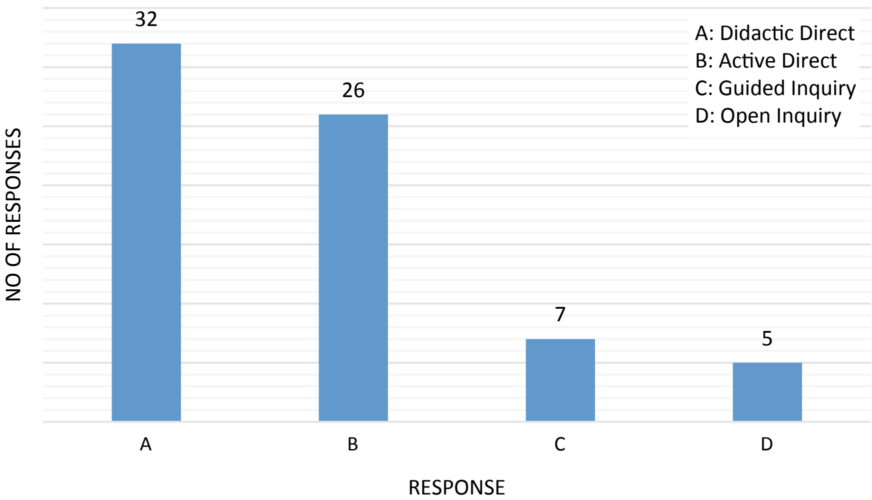

Fig. 2 Response choices on POSTT item provided in Fig. 1. *Note* A strong orientation of teachers toward direct instruction methods rather than inquiry for this item emerges, despite the fact that guided inquiry-based methods are now advocated in India for science teaching. Several reasons for this preference in the real teaching situation became clear from the survey and teacher interviews, as described below in the qualitative part of the study in the next section

Qualitative Data

Qualitative data collected by means of focussed group discussions, teacher interviews, classroom observations, and pre-service teachers' reflective notes were recorded and transcribed. The data was then coded and classified, a process that involved breaking up data into bits and bringing it together again in a new way (O'Donoghue, 2007). We firstly did an open coding of data, looking for reasons that could explain the options chosen. We then grouped the codes into code families.

Results

This section discusses the major themes, emerging from qualitative analysis of the data and further substantiated by quantitative results, which were found to influence pre-service teachers' pedagogical orientations.

School Related Factors

School culture seemingly created a 'figured world' (Holland, Lachicotte, Skinner, & Cain, 1998) through which the school's philosophy, vision and mission were communicated implicitly to pre-service teachers which, in turn, influenced their pedagogical orientations. Schools observed for the study had a variety of philosophical orientations vis-à-vis science teaching, ranging from inquiry-orientation to didactic teaching. Some of the school-related factors that influenced classroom practices are detailed below:

School Culture

Pre-service teachers were influenced by the implicit expressions of school culture and planned their lessons accordingly. To illustrate, in schools where a culture of scientific inquiry was already in place pre-service teachers felt motivated to adopt inquiry-based pedagogical approaches. They noted

> Students are so used to doing it themselves (referring to science activities), asking questions, performing activities….and all those inquiry stuff, I have to plan my lessons accordingly….

Mostly, pre-service teachers in private schools had to deal with highly inquisitive students. These students had exposure to varied forms of knowledge through out-of-the-box tasks developed by their regular school teachers, easy access to internet resources both at home and at school. Pre-service teachers teaching in private schools observed

> They ask too many questions which hinders the way I had planned the lesson
>
> Their questions are nonsensical at times, they just ask to trouble me…if I say later or I don't know they start laughing at me….
>
> … to satiate their queries I have to be prepared with lots of scientific content…
>
> Students provided lots of examples…it ranged from India to abroad….it enriched my knowledge as well….

Pre-service teachers placed in private schools had to plan their lessons innovatively in order to hook students' attention so that they felt motivated to engage with science.

Factors which contributed to inquiry-based scientific practices in these schools included systemic support, in-house professional development opportunities provided to the teachers, regular workshops, seminars and lectures for teachers, time provided for teachers to access the school library during their regular timetable hours, active school-based professional learning communities, support in science lesson planning provided by senior teachers to junior faculty and new recruits, and peer observation of classroom teaching by colleagues and experts. While situated amongst such contextual factors, pre-service teachers felt encouraged to plan and deliver scientific inquiry-based lesson plans. In such schools, it was observed that pre-service teachers were supported by school faculty to adapt to inquiry methods through constant academic as well as non-academic support.

On the other hand, pre-service teachers placed in Government schools (although exceptions existed) observed that students were so accustomed to unquestioning obedience to the teachers and the textbook that they never raised questions. Some of the teachers placed in government schools explained their views as follows:

> It was difficult for me to gauge whether whatever science I was trying to develop is being understood by them or not….they will neither ask nor they will answer. Only one student may say few things now and then…
>
> It's not like they are dumb…but they don't speak up…I pushed them so much, it seemed initially that they had no view of their own…however, later things began changing in my class. They started asking questions, providing arguments and counter-arguments…it was very slow…what I did was I deliberately planned a component of active direct to guided inquiry for them in some form or the other…it was very basic stuff that they could do at their houses, such as, planting a tree and measuring its' growth, examining bread mould in different conditions, examining rate of decay of a banana and comparing it with that of apple, and so on….

Teachers teaching in schools where a culture of silence existed found it difficult to engage large numbers of students in inquiry-based science teaching.

Availability of Resources

Resources, both in terms of quality and quantity, differed in government and private schools. Moreover, their access was limited in some scenarios which eventually limited their usage by pre-service teachers in their pedagogical planning.

Government schools often faced a scarcity of resources. To elaborate, in one government school, there was no science laboratory while in other it was used to dump waste, and in yet another case, where it existed and was functional, it emerged that the infrastructure was too limited to accommodate the class size. As a consequence, the class was divided into two groups- ‘good and bad’ students. Only ‘good’ students (referring to students who were high academic achievers in formal tests) performed experiments while ‘bad’ (low-achievers) ones were made to sit in their classrooms.

Pre-service teachers placed in government schools noted that they often prepared their lesson plans around scientific inquiry but a lot of it got lost when it came to execution. They noted that owing to *large class sizes* which in some cases went up to 70 students per class, teachers found themselves helpless to engage students even in guided inquiry. In government schools, many mergers of classes occurred due to frequent teacher absences or teachers being engaged in completion of the school’s administrative work. In such scenarios, pre-service teachers survived by dictating notes or performing demonstrations to make students sit quietly. One teacher placed in a government school noted:

> Demonstrations work as a better option. At least there is something visual for students to connect to…

To which another teacher teaching in another government school added,

> I find even demonstrations difficult, unnnn….you see the other day I wanted to show them how different materials get attracted to magnet, attraction and repulsion between different poles of two bar magnets,…. I had the necessary stuff and my classroom had only 45 students that day…but the space is so cramped…they all had to jump over each other to see what I was doing….I decided to move between rows of seats but I was almost falling down…so after showing it once…I just passed the material….my entire class time got finished in this…I couldn’t discuss the scientific content or their observations from the materials….

Similar observations were reiterated by another teacher who was placed in a private school:

> This is not unique to you…I mean I am placed in a private school but classroom spaces which were constructed for 40 students now seat 50 students …they have placed additional benches but it leaves no space for me to move around …I eventually end up doing the stuff you just mentioned…

Cramped *classroom spaces* coupled with paucity of resources lead teachers to abandon inquiry midway.

Pre-service teachers noted that private schools often have smart boards in each and every classroom with pre-installed software on different science topics. This software and internet access helped in raising curiosity among the learners, thus, paving a way to enriching classroom discussions. In such an atmosphere, it was easy for pre-service teachers to plan and execute inquiry-based science activities.

On the other hand, government schools didn’t have any *ICT based tools* in their classrooms. In some of the schools, there was one projector for the entire school. Computers did not have any internet access. In these school scenarios, pre-service teachers made charts, flannel boards, flash cards, etc. for their lessons. They observed

> Bringing materials for all the students in the class to conduct inquiry based activities is very expensive….

Eventually, in the face of these troubles, they usually abandoned inquiry-based science education.

Time was another important resource for pre-service teachers. Government schools were centrally managed by the Ministry of Human Resource and Development, Government of India. Curricular planning was done beforehand by external authorities. All the schools were made to complete a particular quantum of syllabus in specific periods of time. Any change is not permitted. Therefore, pre-service teachers were not allowed to try out different ways of teaching, rather it was expected that the teachers complete the course by reading the chapter and dictating/guiding students to do textbook questions in their notebooks. Government schools lay strong emphasis upon finishing the curriculum by making students memorise a few fact-oriented questions that had a high probability of coming up in the summative examinations. Pre-service teachers noted that anything other than textbook reading was considered fancy and irrelevant by the teachers and school administration. One of them observed

> My school principal constantly made complaints regarding my ways of teaching to my supervisor. They (referring to both school administration and regular school faculty) pressurised us to finish the syllabus and do revision instead of wasting time in inquiry based activities.

To which another pre-service teacher added:

> Regular teachers consider us as 'substitutes'…. I mea(n)… who could teach while they finish their administrative tasks. I am not left with any time to plan my lessons, gather materials from school laboratory etc. for conducting inquiry…you see…as all my periods are occupied….

However, this was not the case in private schools. A pre-service teacher placed in a private school observed:

> We (referring to her the group of 6 student interns who were placed in the same school) were given ample time to cover topics. We generally get topics, like, water, waste management, pollution….where lots of discussion could take place…there is no time boundation…we felt free to discuss and develop it in our own ways…

Time to explore a variety of pedagogical approaches helped them to evolve as science teachers.

Medium of Instruction

Pre-service teachers placed in government schools were made to teach science in Hindi. They reported:

> …it is difficult to teach science in Hindi as I tend to forget the technical terms…and its' pronunciation is like a tongue twister….

Another teacher added

> I have had all my education in English medium…now teaching science in Hindi is the toughest challenge of PD…
>
> I find it difficult to write in Hindi ….to be true…sometimes I use wrong terms….but students correct me…they can understand my difficulty….

As per classroom observations, it was found that most of the pre-service teachers taught science in English despite the fact that students had textbooks in Hindi and had opted to write their examination in Hindi. This is largely due to their own comfort levels in teaching science in English. They argued that English is the language of global discourse. One of them observed:

> In case, these students opt for Science in higher education, they will in any case have to study the subject in English language, so it is better to start right away…

Students were somehow able to manage as in-service teachers code switched from Hindi to English and vice versa. On the other hand, pre-service teachers who have had their own education of science in Hindi were found to be adept in teaching science in the Hindi language.

Resistance to Inquiry

It was observed that a few schools offered resistance to the change of their routine ways of teaching. At times, when pre-service teachers adopted scientific inquiry to which students responded positively, in-service school teachers forced them to abandon these activities for fear of these students getting a taste for inquiry, and hence, not respecting their didactic ways of teaching. In-service teachers posed problems for pre-service teachers such as: barging into the classroom in the midst of a lesson; not allowing the pre-service teacher to take the periods assigned for teaching. Cultural resistance forced pre-service teachers to shun inquiry and adopt didactic methods.

These views indicate that schools expect pre-service teachers to assimilate their routine ways of working. Anything that challenges the popular beliefs of the cultural context of school is rejected by most of the stakeholders.

Discrepancy Between Professional Development Program Orientation and School-Related Factors

The situational factors discussed in the last section led to conflicts between what was expected in the professional development program in terms of inquiry-based lesson planning and how teachers enacted their plans in the school situations. They observed that school-related factors, such as stress on summative assessments, classroom management and so on made them teach in didactic ways. One of them observed:

> My supervisor (referring to the faculty attached as mentor through PD program) insists on making an inquiry based lesson plan …she will cut my marks if I don't do that…but that plan is obsolete in the school situation…I have to rework the stuff to make it deliverable in my classroom context…And…. I do it by changing all the student-centred activities to teacher-led demonstrations….I mean….she is not coming everyday to observe me …. and, I have to teach them anyhow…they should know the content otherwise they will fail.

Another teacher added:

> I need to learn how to swim in the ocean where I am thrown….my supervisor will not come to teach here….All those fancy words taught to us in Pedagogy paper (referring to Pedagogy of Science paper taught to pre-service teachers during first year of B.Ed.) are not going to help me….In order to maintain structure, I dictate notes to them, this makes all the parties (referring to stakeholders- students, teachers, parents, and school principal) happy…

These ideas indicated that pre-service teachers were unable to execute their actual lesson plans—often based on principles of inquiry-based science teaching—in the face of situational factors emerging from the school context. To resolve this issue, they made two plans for the same content: one that was inquiry-based and that served the requirements of the teacher education program; and the second which was based on didactic transmission of information to fit into the school context.

Pre-service teachers suggested that they tried to communicate and convince their supervisors (faculty from teacher education program associated with them as mentors) regarding the situational factors but to no avail. Supervisors did not appreciate their problems and insisted upon inquiry-based lesson plans using a variety of methodologies. One of the pre-service teachers noted:

> I tried to tell her many times that the inquiry based science projects you want me to do are simply irrational for schools like this…but she is not ready to accept it…and all her ideas of doing low-cost no-cost science is very difficult to execute….umnnn…. I won't be able to do it with such large numbers…hmm…but in 'ideal' conditions…. I would love to execute my actual plans and see how scientific inquiry looks into practice.

Pre-service teachers' views constantly alluded to the importance of mentor support in development of their pedagogical orientations. Further probing in this direction suggested that they preferred mentors who could suggest ways of doing inquiry rather than simply writing comments about their didactic pedagogical approaches.

Teachers' Belief About Science and Pedagogy

Apart from situational factors, it was apparent that teachers did not have a clear understanding about the various ways in which scientific inquiry could be practiced.

Skewed Version of Scientific Inquiry

Pre-service teachers used a variety of teaching-learning materials to develop scientific concepts. They noted

> I, at least, show them charts, models, or at times, videos… you can see my students are so happy …whenever I take material for demos (referring to demonstrations)…they are excited, they don't make noise and all of them behave well so that they get to see it…

Another teacher teaching in another government school added,

> I invite few representative students to do it….they all want to touch stuff…work on things….but I can't afford all of them to be a part of it…so I do it on rotation basis …

These viewpoints suggest that teachers considered the transmission of scientific information through varied teaching-learning materials to be the same as scientific inquiry. There was an inherent understanding that showing videos, charts, or models is equivalent to scientific inquiry. Pre-service teachers placed in government schools complained that their counterparts, who are teaching in private schools, have easy access to ICT based tools and had smart boards with pre-loaded lessons installed in it. According to them, having smart boards is a great help as it enables making links between the content and world outside. While this sounds true, how the use of these tools relates to scientific inquiry remained a question which was unanswered.

Belief About Students

It emerged that many of the teachers who opted for didactic pedagogy did it consistently across a number of POSTT items. Upon further probing, it was observed that their reasons behind these choices were that they had an intrinsic belief that students belonging to low socio-economic class are inherently incompetent in pursuing scientific inquiry, thus, flagging a nativist view of human intelligence. They thus considered it imperative to 'tell' the scientific content to students belonging to low socio-economic groups. When asked whether they were taught such a view in their teacher education programs, pre-service teachers during focussed group discussions observed,

> …..fancy stuff told in B.Ed. does not work in reality…

Another dimension of pre-service teachers' belief systems that seemingly influenced their pedagogical choices was the relationship between inquiry-based science education and student academic achievement. They noted that often high achieving students possess high cognitive abilities, hence, they adopted didactic pedagogy for *Nishtha* (group of low-achievers), and inquiry-based science instruction for *Pratibha* (group of high-achievers).

Teachers' Competence in Handling Inquiry

Almost all the teachers agreed that science teaching through inquiry was very challenging. They were scared of students' questions which they were unable to answer instantly. One of the teachers noted:

> Unnn…they will stop respecting me if I say 'I don't know'.

To which other teachers added:

> In our scenario, things are even more challenging. Students have access to large reservoirs of information through tuitions, internet….their parents are also educated…they ask questions to trouble us…if I say I don't know they will mock at me…I will be gone…

> Ya right…I can't answer everything spontaneously…they are always full of questions because we give them space… unlike their regular teachers…. where it is simply impossible to speak…

These ideas suggest that teachers are not adequately prepared to handle inquiry. Their position as a 'trainee teacher' made them even more vulnerable. In another focussed group discussion, a teacher who had taught in a private school observed:

> It takes time to win the trust of students… once they start accepting you then they will listen to you, appreciate your humility when you say "I don't know, let's find together"…It took me time but somehow my consistency, may be…I am not sure, helped me in establishing a culture of inquiry in my classroom.

They felt incompetent to answer queries and felt the need to update their content knowledge.

Success Stories

It emerged that in spite of discrepancies between what was taught in the B.Ed. program and what was being practiced in schools, there were cases where a few motivated teachers adopted scientific inquiry in their respective contexts. One of the teachers teaching in a government school observed:

> India has got a tradition of low-cost science, see what is being done by our Toymaker, ….I mean…Arvind Gupta…, for long now…I am also placed in a government school which has large class size of 50, no functional lab (referring to laboratories) for me to conduct experiments …but that doesn't mean that they should be marooned from the experience of scientific inquiry…Umnn…open inquiry is I feel impossible but doing some guided inquiry could certainly happen. Ok, what I do is… I have given them an inquiry-based science project to be conducted through my period of work here…They will have to choose a topic for the same, inform me rather (emphasis in voice) consult me, we devise a plan of action and …. they will have to perform it themselves…..It is important for me to make it workable, that is, the apparatus should not be fancy enough…I mean things which are around …could somehow be used… we could find an alternative…. It is not necessary that inquiry based tasks always belong to the content that I am teaching but my intention is to develop scientific processes in them…

This view indicates that scientific inquiry is not always content-specific. Rather, a few motivated teachers deployed inquiry-based pedagogical approaches irrespective of the content they were teaching.

Teachers observed that initially students used to find fault with their ways of teaching, in fact, they reported it to school authorities that they were doing bad teaching. But later things changed. This observation was corroborated by other teachers as well. They stated that

> it happened with all of us but gradually students found our ways of teaching exciting. They did the work we designated with great enthusiasm. It was so invigorating for me as a teacher.

One of them noted

> I had asked them to collect leaves of different shapes and sizes from in and around their community. Next day, everyone had brought it. They were eager to know how we are going to use it. When I assigned them the task of classification of leaves, they did it earnestly, I was so happy…they were able to make connections between different types of venation taught to them in the theory class…

Conclusion

It emerges that teachers began their internship journeys enthusiastically, armed with inquiry-based pedagogical approaches. However, situational constraints led to amendments in their practice. Similar to Nargund-Joshi, Rogers, and Akerson's study (2011), it was found that situational factors, such as, availability of ICT based tools, science laboratories, time for pedagogic planning, classroom space, teacher-student ratios, medium of instruction and resistance to inquiry acted as filters which, at times, facilitated the inquiry-based science teaching approaches while in other cases acted as barriers making them adopt didactic ways of science teaching. Pre-service teachers devised their own unique ways to handle the tensions and discrepancies between what was taught to them and expected of them by their teacher education programs and what was feasible in the school context. They made dual lesson plans: one as per the requirements of PD program and other suiting the school context.

School culture created a figured world which subtly influenced teachers' belief systems—about science as a discipline, about children's cognitive abilities, and about scientific inquiry. Mostly, it was found that in private schools curricular and pedagogic practices supported scientific inquiry while in government schools didactic instruction worked best. However, this is not the uniform case and variations occurred across the spectrum.

Teachers' pedagogical orientations were also influenced by their personality attributes, as a few teachers persisted in practicing scientific inquiry despite situational constraints. These pre-service teachers not only placed high value on scientific inquiry but also possessed the competencies necessary to conduct scientific inquiry in its true spirit, unlike others who abandoned inquiry-based science instruction owing to their skewed understanding of scientific inquiry.

Teacher education can only work towards expansion of teachers' skill repertoire but it cannot guarantee the same in practice. Teachers' pedagogical orientations are strongly dependent upon the school type that they are placed in as interns and how these situational factors engage with their belief systems, as well as the degree to which they possess competencies to conduct scientific inquiry. Therefore, it can be suggested that pre-service teachers' pedagogical orientations were an amalgamation of science teaching philosophies taught in professional development, their own experiences of science learning as a student, and what seemed to work best in varying school situations where they were placed as interns during their professional development programs.

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