# Transacting inquiry in middle school science classrooms: A study exploring the nature of discourse and a spectrum of outcomes

A Thesis

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by

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# Declaration

This thesis is a presentation of my original research work. Wherever contributions of others are involved, every effort has been made to indicate this clearly, with due reference to the literature, and acknowledgements to other researchers, peers and colleagues who helped at different levels and in different capacities in shaping and completing this work.

The work was done under the guidance of Professor Jyotsna Vijapurkar, at the Tata Institute of Fundamental Research, Mumbai.

Aisha Kawalkar

In my capacity as supervisor of the candidate's thesis, I certify that the above statements are true to the best of my knowledge.

Date: 20/1/2020

Prof. Jyotsna Vijapurkar

Thesis Supervisor

*To*

*My daughter, Urmika*

*Who was with me on this through it all*

# Abstract

Science involves reasoning about the world in particular ways that are shared by a scientific community (Lemke, 1990). Students are inducted into the practices of science through discourse in the science classroom. The teacher plays a pivotal role in guiding students into this emergent science community through the level and complexity of her questions, the environment created for questioning, and the patterns of teacher-student interactions. This study explores some of these ways in which teachers guide the discourse, activities and ways of thinking in the science classroom, how students appropriate them in their learning and how it affects not just students' understanding of science concepts but also the ways in which they engage with and perceive science and learning. For this purpose, science teaching and learning were studied in two sets of middle school science classes, one taught through inquiry and another through traditional teaching, in the context of an out-of-school science program.

The study adopted a mixed methods research approach and is aligned with the social constructivist perspective (Vygotsky, 1978) that emphasizes how personally meaningful knowledge is socially constructed through shared understandings. Accordingly, open-ended methods (classroom observations, video-records, teacher reflections, student diaries questionnaires and semi-structured interviews) were used to gather data which were analyzed qualitatively and quantitatively to build a naturalistic account (Lincoln & Guba, 1985) of the science teaching that was observed. Different methods and elements of the study together portray a composite picture, leading towards a characterization of the complex process of teaching science as an inquiry; teachers interested in moving towards more constructivist teaching practices in their classrooms may find this description helpful. This study also attempts to explore a wide array of outcomes that may help in garnering further support for the teaching of science as an inquiry.

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This is the last section of my thesis that I pick up to write. I kept it for the last as I was not quite sure, though ever hopeful that I would reach the milestone of thesis submission. This journey has gone on for so long, it seemed like one of Zeno's paradoxes (Achilles and the tortoise) where every time a set distance is covered, the goal also moves ahead. So you keep nearing the destination but you're never quite there. But here I am, writing this today!

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Aisha Kawalkar (20th January 2020)

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## In Journals

Kawalkar, A. & Vijapurkar, J. (2015).* Aspects of Teaching and Learning Science: What students' diaries reveal about inquiry and traditional modes, *International Journal of Science Education*, 37(13), 2113-2146. **(mainly Chapter 4, 5 and 6)**

Kawalkar, A. and Vijapurkar, J. (2013).* Scaffolding science talk: The role of teachers' questions in the inquiry classroom, *International Journal of Science Education,* 35 (12), 2004-2027. **(mainly Chapter 4 & 6)**

Vijapurkar, J., Kawalkar, A. & Nambiar, P. (2014). What do Cells Really Look Like? An Inquiry into Students' Difficulties in Visualising a 3-D Biological Cell and Lessons for Pedagogy, *Research in Science Education*, 44 (2), 307-333. **(Section 1.3)**

## In Conference Proceedings

Kawalkar, A. & Vijapurkar, J. (2013) Aspects of learning science in inquiry and traditional classes: what students' diaries reveal. In Nagarjuna G., Jamakhandi, A. and Sam, E. (eds.) *epiSTEME 5 International Conference to Review Research on Science, Technology and Mathematics Education,* Conference Proceedings. India: Cinnamonteal. p.220-226

Kawalkar, A. & Vijapurkar, J. (2011) Several Lines of Inquiry Into Inquiry Teaching and Learning: Exploring the Affective Outcomes of Inquiry-Oriented Science Teaching. In D. Mogari, A. Mji and U. I. Ogbonnaya (Eds.), *Proceedings of ISTE International Conference on Mathematics, Science and Technology Education*, p. 265-276. South Africa: University of South Africa. **(Section 1.4)**

Kawalkar, A. & Vijapurkar, J. (2011) Science Talk in the Inquiry Classroom: An Analysis of Teachers' Questions and Purposes. In S. Chunawala & M. Kharatmal (Eds.) Proceedings of epiSTEME 4 -- International Conference to Review Research on Science, Technology and Mathematics Education, p. 144-149. India: Macmillan.

Kawalkar, A. and Vijapurkar J. (2009) What do cells really look like? Confronting children's resistance to accepting a 3-D model. In K. Subramaniam and Majumdar, A. (Eds.), Proceedings of epiSTEME 3 - International Conference to Review Research on Science, Technology and Mathematics, Education, p.187-193. India: Macmillan.

**Note:** Material from accepted manuscripts of the publications marked (*) forms a substantial portion of the text in this thesis. The sections which mainly contain this material, reporting the results and discussion of results from these articles, are indicated above. However, some of the text is strewn throughout the thesis, appearing in other parts too (namely, the Introduction, Literature review and Methods chapters). The publisher of these articles recognises the right to include them in the dissertation. (https://authorservices.taylorandfrancis.com/copyright-and-you/)

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# Introduction

*Inquiry is in part a state of mind, and in part*
*a skill that must be learned from experience.*

Bruce Alberts (2000, p.7)

The state of mind that Alberts refers to is that of being inquisitive, and luckily for us educators, young children are naturally curious. However, if they are regularly 'explained to' rather than having opportunities to explore phenomena, if their curiosities are constantly ignored, if they are expected to mostly answer rather than ask questions, they may slowly lose interest in their pursuit of finding things out and eventually develop a passive and unquestioning attitude. Sustaining and building on the initial curiosity in the pedagogic space, and even evoking it, requires that teachers attend to crucial design features that are often left tacit, features that teachers need to "orchestrate to help children build a chain of inquiry rather than a succession of fleeting interests" (Lehrer, Carpenter, Schauble & Putz, 2000).

The teacher's decisions about how a concept would be introduced, the activities that would be used and how much and what type of guidance is needed while transacting the lesson affect how students engage with their science learning. As the teacher goes about creating and shaping the classroom dynamics, the nature of interactions between the teacher and students is crucial in the process (Alexander, 2006). This study intends to understand such dynamics in the science classroom, exploring the ways in which teachers guide the discourse, activities and ways of thinking in the science classroom, how students appropriate them in their learning and how it affects students' understanding, views, participation and engagement with science in classes taught through inquiry vis-a-vis those involving conventional, expository science teaching.

Before delving into the research background, context and motivation of the study, the research questions that it aims to address and the theoretical assumptions underpinning it, we find it necessary to engage in a prologue on what we, as a science education community, want students to learn in science at the school level. The intent, in the next section, is not to draw up a comprehensive list of goals of science education but to highlight the broad spectrum of goals deemed important by different researchers in science education. As Biesta (2008, p. 33) argues,

> there is a need to reconnect with the question of purpose in education in general and science education in particular, especially in light of a recent tendency to focus discussions about education almost exclusively on the measurement of educational outcomes.

He asserts that instead of merely making a case for an effective way of teaching, we need to also ask 'effective for what?' and 'effective for whom?', otherwise there is a danger that we would end up valuing what is measured, rather than engaging in examining ways to measure what we value.

## 1.1 Revisiting the Goals of Science Education:

### Towards a more complete picture of teaching and learning of science

It is well accepted that an educated citizen of the contemporary, scientific and technological society needs a foundation of interest in and facility with the ideas and practices of science (Falk et al., 2016). Some students go on to build on this foundation to take up a career in science or a related discipline (in the commonly assumed sense as an employed professional). This original purpose of including science in schooling - putting students in the 'pipeline' for a career in science - has traditionally remained a predominant role of science education (Aikenhead, 2006; Duschl, 2008; Fensham, 2008; NRC, 2007; Sarukkai, 2014).

Science teaching at school does need to ensure a thorough preparation in content, reasoning and skills, and an illustration of what doing science is like, to enable and inspire students to take up advanced studies in science. Osborne, Simon & Collin (2003) point out that there is a mounting concern in many countries about the 'swing away from science', a continuing decline in interest in young people taking up post-compulsory science courses and careers in science, and that the literature identifies quality of teaching as one of the most crucial factors contributing to negative attitudes towards science; therefore they argue for a greater need for science education research to identify those aspects of science teaching that students find engaging.

There is also a general lament (Lyons, 2006; Sarukkai, 2014; Tytler, 2007) that students who do come to pick a career in science, or an adjunct field, are ill-prepared in terms of the knowledge, attitudes and skills needed for expertise in their chosen fields of work, due to the kind of teaching-learning and assessment systems that are commonplace, which value rote-memorisation rather than depth of understanding, compliance over creativity and scepticism, and compartmentalised, discipline-bound perspectives instead of the broader inter-linkages within science and those between science, technology and society.

Most students, however, will not go on to become professional scientists or even pick a career related to science or technology. Why then should all students in school essentially have a basic education in science? What are the goals of teaching and learning science at the school level? A significant, widely professed rationale for teaching science is to develop a scientifically literate population (Bybee, 1997; Duschl, 2008; Fensham, 2008; Tytler, 2007). Some students might take to science-related hobbies and pursuits and perhaps connect with science through 'citizen science' and 'professional-amateur' communities dedicated to astronomy, phenology or even molecular biology (Feinstein, Allen & Jenkins, 2013; Mueller, Tippins & Bryans, 2011). However, all students will need this foundation in science in order to make informed personal and community decisions on issues at the intersection of science and society.

Scientific literacy, although a contested term with multiple meanings attributed to it (DeBoer, 2000; Hodson, 2002; Jenkins, 1999; Raveendran, 2017; Rennie, 2006), involves not only the ability to understand and critically evaluate information that is, or is purported to be, scientific but also a basic understanding and appreciation of the nature and practice of science, of how knowledge claims are arrived at, justified, debated and advanced, being skeptical and questioning of claims about scientific matters, and utilising this knowledge to solve relevant problems (Hand, Lawrence & Yore, 1999; Holbrook & Rannikmäe, 2010). Inadvertently, commonplace science teaching often portrays science as merely a body of rigid, self-justifying knowledge that has to be uncritically received; Dewey, as early as 1910 (p. 124), laments

> Science teaching has suffered because science has been so frequently presented just as so much ready-made knowledge, so much subject matter of fact and law, rather than as the effective method of inquiry into any subject matter.

Apart from the economic and democratic imperatives, educators (Alberts, 2009; Driver, Leach, Millar & Scott, 1996; Osborne, Duschl & Fairbrother, 2002) have argued for a cultural goal for science education - to enable students to appreciate science as a distinctive human endeavour that has contributed significantly to our cultural milieu, both intellectual and aesthetic. Science merits a place in schooling as part of our intellectual heritage, rather than merely technical, disciplinary training, as a set of particular ways of examining the natural world and building a shared understanding of it, with contributions from different cultures, over centuries (Sarukkai, 2014). Duschl (2008) argues that the cultural imperative also brings attention to the social and epistemic dimensions that underlie "the growth, evaluation, representation, and communication" (p. 268) of science ideas and practices and which underscore the need for a shift in teaching from 'what we know' to 'how do we know' and 'why we believe in it'.

At the individual level, learning and doing science can be an intrinsically valuable and enjoyable activity which is wholly absorbing and, as Ellwood & Abrams (2017) point out, it can immerse students in experiences of 'flow', a concept first described by Csikszentmihalyi (1990) as a state in which an individual is wholly engrossed in a task and develops "a sense that one's skills are adequate to cope with the challenges at hand… and the sense of time becomes distorted'' (p. 71). Furthermore, learning science can provide an experience of wonder (Hadzigeorgiou, 2011) and awe (Piercarlo, Shtulman & Baron, 2017). Dawkins (1998) argues against the excessive focus on the usefulness of science which overshadows and distracts from its inspirational value, pointing out that "usually even its sternest critics concede the usefulness of science, while completely missing the wonder" (p. xii).

It is unfortunate that because of the way science is often taught, many students tend to look upon learning science as dull, boring and too abstract a discipline that is disjunct from personal experience (Lyons, 2006; Tytler, 2007). Despite the many years spent in studying science, only a few students relate to it in a sense that it becomes a part of their essential world view and understanding relevant to everyday life or develop a connection with its subject matter so that it becomes a source of inspiration and occupies a formative position in their life (Witz, 2000).

Further, Lemke (1990) critiques the way, unwittingly, science education perpetuates the harmful mystique of science which portrays science as authoritarian, dogmatic and impersonal, and science learning as too difficult, further alienating many students from science. He argues for a closer analysis of talk in the science classroom to understand how harmful this mystique is, how it is maintained, and what can be done about it. Jaber and Hammer (2016) make a case for foregrounding 'epistemic affect' involving feelings and emotions experienced within science - such as feeling the excitement of having a new idea or irritation at an inconsistency, anticipating the pleasure of a new understanding, feeling driven by a question or persisting in the face of intellectual challenges - which is part of what inspires and sustains engagement in learning and doing science and is closely linked with the ways of knowing in science.

Science itself being a collaborative endeavour, educators like Reiss and White (2014) and Mueller, Tippins and Bryans (2011) have espoused another significant purpose of science education, and by projection, of schooling - that of developing a collaborative learning community involved in joint reasoning, mirroring a microcosm of liberal, participatory democracy where everybody learns from everybody else, where pecking orders are challenged and where no learner would be held back by thoughts of inability or low self-worth. This idea has roots in Dewey's (1937, p. 467) conception of democracy as a way of life and his call for "democratic habits of thought and action" to be part of the very fibre of all social relationships including, and especially, those involved in the act of education.

Thus, educators have argued for a diverse range of goals for the teaching of school science that are conceptual, epistemic, social and affective in nature. Certainly, how students engage with and perceive their classrooms, learning, and science, how they see themselves relative to science and school and how they relate to science in their everyday lives is shaped by the patterns of practice teachers pursue in their classrooms and by how they themselves experience and think about the process of teaching-learning (McLaughlin & Talbert, 2001; Varelas, Kane & Wylie, 2011). These outcomes are interlinked with various components of teaching in a complex web, and though the primary focus of a particular teaching approach may be any one of the goals, these goals are not mutually exclusive, and de facto, students would most likely be affected in multiple, interconnected ways.

Therefore, we argue that studies exploring the dynamics and effectiveness of science teaching need to consider the larger goals of science education instead of just content acquisition alone, which is often the major focus, and also to dwell on what aspects of teaching affect the different outcomes, and how, and what could be the kind of evidences of students attaining those outcomes. These are the broad considerations that underpin our study of teaching science as inquiry, exploring the kind of classroom transactions that make it possible and the multitude of ways in which it affects students, in comparison to commonplace science teaching.

## 1.2 Research Background and Rationale

Across the calls for reforms proposed in science education throughout the world, there is a common, recurring emphasis on teaching science as inquiry, which would mirror the ways science works and facilitate students' active intellectual engagement (European Commission, 2007, 2015; Haury, 1993; Minner et. al., 2010; National Council of Educational Research & Training [NCERT], 2005, 2006; National Research Council [NRC] 1996, 2012). Yet it is not commonly practised in classrooms (Alexander, 2001; Capps, 2016; Educational Initiatives & Wipro, 2011; Lebak & Tinsley, 2010) possibly because it is challenging to prepare teachers to adopt inquiry practices in their classroom.

As Bybee (2000, p. 20) points out, although teaching of science as inquiry has a long history in science education, there has been "an equally long history of confusion about what teaching as inquiry means and regardless of its definition, *its implementation* in the classroom" [emphasis added]. Furthermore, it is unclear whether the outcomes justify the effort needed for transacting inquiry in the classroom, as educational and political debates continue over its effectiveness (Anderson, 2002; Cobern et al., 2010; Zhang, 2016). Researchers in science education have been trying to address this problem in two ways. Firstly, acknowledging the difficulty of visualising inquiry in actual practice, recent studies (e.g. Gonzalez-Howard & McNeill, 2019; Kawalkar & Vijapurkar, 2013, 2015; Martinez, Borko & Stecher, 2012; Roth, 1996; van Zee et al., 2001) have attempted to characterise the complex process of inquiry in the classroom and provide real-life descriptions which would facilitate reform. Secondly, studies have aimed to probe the efficacy of inquiry-oriented teaching; see meta-analyses such as the one by Furtak et al. (2012) and review studies such as those by Colburn (2008), Hmelo-Silver, Duncan & Chinn (2007) and Zhang (2016).

This dissertation study seeks to contribute towards answering these two crucial questions that underpin the current research on inquiry-based science teaching: What does inquiry in the science classroom look like, in terms of the transactions that make it possible? And what, if any, is the comparative evidence for the effectiveness of inquiry across the conceptual, affective and epistemic domains of learning?

## 1.3 Research Context[1]

The present study was associated with the 'Middle School Science Curriculum Development Project' at the Homi Bhabha Centre for Science Education (HBCSE). The objective of this larger project was to develop an alternative, inquiry-oriented science curriculum at the middle school level, with instructional material for students and supporting material for teachers. The curriculum development and testing processes involved in this project were so combined that the curriculum

1 This section is based on (Vijapurkar, Kawalkar, & Nambiar, 2014)

took shape within the classroom setting; science classes were regularly conducted for exploring students' ideas and developing and testing instructional strategies that support conceptual change. The nature of inquiry-oriented teaching in the classes conducted for this curriculum development project is described in Vijapurkar, Kawalkar & Nambiar (2014).

The instructional approach in these classes was specifically that of guided inquiry (Magnussen & Palincsar, 1995; Samarapungavan, Mantzicopoulos & Patrick, 2008). Guided inquiry approaches are based on the belief that scaffolding from the instructional environment (such as teacher support through modelling and questioning) allows students to acquire rich domain knowledge, supports their capacities of thought in their pursuit of causal, coherent explanations (Samarapungavan, Mantzicopoulos & Patrick, 2008; Hammer, 2004).

These classes, taught by the researchers themselves, typically involved investigating a phenomenon with hands-on activities by students, mostly in small groups, or demonstrations by the teacher, followed by interactive, whole-class discussions. Discussions and activities were used to gauge students' prior knowledge and elicit their mental picture of the associated concepts. These insights aided the teacher in planning and developing the pedagogical sequences required to take students to the point where they can do a critical examination of their understanding and revisit their conceptions. Thus, the teacher not only engaged students in first-hand experiences with phenomena but offered them opportunities to develop conceptual understanding and reasoning skills through discussions with other students and with the teacher. Students were persuaded to confront their ideas and any cognitive conflict that may follow from them. As students were engaged in this process of inquiry, so was the teacher - exploring students' intuitively held ideas, probing the roots of these ideas, and designing and testing ways to address them.

An essential element of an inquiry curriculum is that it addresses students' ideas, therefore elicitation of these ideas was a significant component of the teaching in these classes. Multiple modes of expression - written worksheets, models, drawings, discussions amongst groups of students - were used to enable students to express their ideas. Participation from all the students in the class was actively sought; efforts were taken to encourage even the shy students to participate in class discussions and not allow a few vociferous ones to overshadow the rest.

The classes conducted for this curriculum development project from June, 2009 to June, 2010 were observed as inquiry-based classes as part of this dissertation study.

## 1.4 Motivation: A Precursor Study[2]

Over the several years that the classroom trials were conducted for the curriculum development project, we noticed some conspicuous affective changes in students, although the focus of teaching in these classes was on conceptual understanding. A group of students attended these classes consistently for four years since the time they had passed Grade 4 till they had passed Grade 8 (2005 - 2009)[3]. At the end of the contact period with them, we probed these outcomes using self-report questionnaires and follow-up interviews with the students. We also administered questionnaires to students' parents and peer group for triangulation of students' responses. Findings of this preliminary study included reports of some varied outcomes of learning through inquiry; we present some of these below -

**Increased interest in science:** A majority of students reported that they liked science more than they did before attending our program. They started to find studying science fun and wanted to know much more than what was given in their school science textbook. They tried out at home the experiments and also observed

2 This section is based on Kawalkar & Vijapurkar (2011)

3 This curriculum project was headed by Prof. Vijapurkar. I was part of the project staff in the research team in 2005-06 and later observed the classes for this group of students informally.

their surroundings much more often and closely than they did earlier, relating science to their daily lives. They read more science-related extracurricular books from the library and watched more science related programs on television. Students' increased engagement in science was reflected in their responses revealing that they the observed phenomena studied in these classes, for months after the topic was taught, (for example, star-gazing to identify stars and constellations or looking at flowers for different types of floral parts). Students, as well as their parents and friends, reported that the students initiated more science-related discussion and asked more questions. Students reported an increase in interest in specific subject areas in science which they did not appreciate earlier; for example, a student wrote about biology: "I now realise that biology is not just about remembering (facts), there is so much more to it."

**Change in how students viewed science and scientists:** According to many students, they started to relate science to everyday life rather than merely viewing it as a subject to be studied at school by default. They also reportedly started to appreciate the history of science. One of them interestingly said,

> I started appreciating people who contributed to science… Actually (earlier) I did not take it as a creative thing or something on which we have to concentrate. It was a formality, you're going to school, and you have to read it, but now I respect them (scientists) and I am inspired by them.

Students also reported that they earlier had a very limited idea of what scientists do. As one student put it,

> I imagined scientists as mixing two chemicals but now realise that there are different sorts of work that scientists do.

**Increased participation in their science classes at school:** Not only did students' participation in the classes in the program increase gradually but they also, reportedly, started to participate more in their science classes at school. Their interest and attentiveness increased, so did participation in terms of answering and also asking questions. Three students reported that their fear of the teacher had lessened; one student explained,

> First, I used to be really afraid to ask questions to teachers, thinking maybe teacher will scold me, but after attending these classes I ask doubts (sic).

Two students explicitly said that this increase in participation in school classes was despite the fact that their school classes remained expository and non-interactive and that their questions and ideas were not appreciated, even discouraged in some cases. Students also reported that there was an increase in their participation in extracurricular science-related activities (science quizzes, exhibitions).

**Change in the way they studied science:** All the students, irrespective of their academic grades in school, reported that they used to rote-learn or memorise for exams. However, after learning science through inquiry, each one of them said they "learn with understanding", "thought a lot more", "reasoned out", "imagine" and "visualise". A few students stated that earlier they would ignore the questions that arose in their minds, but now they have to have these "doubts" cleared. Some added that they did not accept the teacher's explanation as given but have "learned to question and ask for reasons."

**Some other interesting changes:** Students shared that from the interactions in our classes, they learned to conduct themselves better in the classroom situation even in school. For example, one student said that the habit of following the simple rules in the classes in this program made it possible for everyone to speak in class without chaos; it resulted in him respecting rules in general, and his conduct in the classroom became better.

The new-found common interest in science that students formed in these classes led them to forge friendships. One group of four students reported that whenever they learned something new or had any question in mind, they discussed it in their group. The teacher-researchers in these classes also noticed that over time, students were better able to work with others in a group. Though initially girls and boys were very resistant to working in the same group during activities/ experiments, this resistance gradually faded. The group dynamics in many groups in the class changed over time such that the shy ones also participated openly, and the overtly dominating students gave others in the group a fair chance to participate.

The teaching was not designed for particularly bringing about these concurrent changes and yet they were among the significant outcomes of a project that concentrated on conceptual learning. Notably, these changes that students reported developing in these science classes appeared to have transferred to other domains and contexts: the learning of subjects besides science, their school classrooms, extracurricular activities in school not necessarily related to science, and interactions with their family and peer group.

**Way forward:** Limitations of this preliminary study largely stemmed from it being a retrospective study of the serendipitous observation of changes in students that took place over time during inquiry science teaching. Since questionnaires were administered only after the intervention, baseline information from students was not available for comparison. Being an ex post facto study, it could not address the effect of confounding variables like positive bias, maturation and Hawthorne effect (the effect of having an intervention of any kind itself bringing about an effect) though we explicitly probed the reasons for these changes during interviews with students and they attributed these changes to the teaching in the program.

We took up further research on this issue, in the form of this dissertation study, to address these limitations and also probe the characteristics of inquiry teaching that might play a part in bringing about such outcomes. Researchers (Eccles & Wigfield, 2002; Anderson & Nielson, 2011) have pointed out the need for analysis of classroom interactions and discourse in science classrooms where students are likely to get motivated to learn science, in order to identify the factors that stimulate students' motivation.

Inputs from this preliminary study informed the design of questionnaires and interview schedules used in the doctoral study. The questionnaires and interview schedules developed and piloted in the preliminary study were used for the dissertation study with a few additions and modifications. Possible confounding factors were addressed with measures like (a) inclusion of a comparison group, (b) administration of questionnaires both before and after the instructional contact period to get a baseline for comparison, and (c) having researchers in the class exclusively assigned for class observation (unlike the earlier classes in which teachers themselves had noted some changes in students in the course of their teaching). Reports from short-term participants suggested the length of the intervention for the dissertation project. Building on the preliminary study, this dissertation study attempts to explore the array of outcomes from multiple data sources as well as detail what happens in an inquiry classroom, compared to a traditional science classroom, particularly what the teacher does in terms of scaffolding science talk.

## 1.5 Theoretical Framework

This study is aligned with the social constructivist perspective of Vygotsky (1978), which focuses on how personally meaningful knowledge is socially constructed through shared understandings. A significant factor that sets Vygotsky's theory apart from the other theories of learning and development is that it not only proposes that higher mental functions (such as processes of thinking, voluntary attention and memory), which he terms as *intermental functioning*, can occur between people but the theory claims that mental processes that occur within the individual, which constitute *intramental functioning*, are derived from intermental functioning. Thus, any mental function appears on two planes, first on the social plane and then within the child on the personal, psychological plane. The mental processes that occur on the intermental plane are mastered and internalised and thus are transformed into the processes that constitute intramental functioning which then have a different structure and function than those from which they are derived. This reasoning leads us to understand how children adopt and appropriate ideas and perspectives from social interactions and use them as a tool for thinking and learning.

We can understand this in terms of the explanation Vygotsky gives for the phenomenon of *egocentric* or autonomous speech that very young children (aged three to five years) carry out with themselves. He views this as a transition phase between external speech used for communication with others and *inner speech* or thought that is used to plan and regulate one's actions. Adults around the infant give meaning to the initial babbling by the infant who then slowly uses these verbal signs as means of social contact; thus, speech originates in the social realm. This external speech is then internalised as a means to regulate oneself, and during this transition, roughly at the age of three, egocentric speech emerges with the new function of self-regulation. However, the child during this period is not able to separate this new function from the social function of speech, and hence, it is still in an external and explicit form. It is noteworthy that Vygotsky uses the term inner speech instead of thought. The use of this term underscores his claim that individual thought has social origins, it has its foundation in intermental functioning and, in fact, it has a quasi-social nature, in the sense that it retains certain properties of speech, such as dialogic structure.

Vygotsky was especially interested in the intermental functioning between the teacher and student in the process of instruction and how intramental functioning of the student can be developed through this interaction. This is evident in his concept of 'the zone of proximal development' (ZPD)[4], in which the actual and potential levels of development correspond with intramental and intermental

4 Vygotsky (1987) describes the zone of proximal development as distance between actual and potential levels of development as determined by independent problem solving and problem solving in collaboration with an adult or a more competent peer, respectively.

functioning respectively. He posited that social interaction, especially with more experienced members of a community (teachers, usually, in the case of a classroom) provides children with ways of interpreting the world around them, and thus students become "enculturated into ways of thinking that are common practice in that specific community" (Palmer, 2005, p. 3). This position highlights the importance of the teacher's role in guiding students towards conceptual understanding through the ZPD and of using talk as a means for joint reasoning. Our empirical study and our analyses are in line with this sociocultural perspective in which discourse has various crucial functions: as a pedagogic tool which one person can use to provide intellectual guidance to another, as a cognitive tool which children learn to use to process knowledge, and as a social or cultural tool for sharing knowledge as well as values and attitudes (Mercer & Wegerif, 1999).

Also, there are constant, implicit inputs from the teacher about what counts as knowing and valid ways of knowing. These epistemic messages are conveyed to students as they try to make sense of their experiences and construct understanding for themselves through the appropriation or accommodation of ideas, ways of communication and habits of mind that are valued and nurtured in the classroom (Lidar, Lundquist & Ostman, 2006; Sampson & Walker, 2012). Yackel and Cobb (1996) argue, in the context of inquiry teaching in mathematics classrooms, that such normative understandings (of what counts as an acceptable explanation or justification) are constituted through ongoing interactions as the teacher helps students in not only participating in the explanation but also in "making the explanation itself an object of reflection" (p. 471). In the process, these norms regulate students' participation in the discussion and also lead to higher-level of cognitive activity.

Kelly (2007) points out that teachers' choices in pedagogy also send messages about the nature of science and science learning, and in recent years some studies (e.g. Berland & Hammer, 2012; Christodoulou & Osborne, 2014; Hammer & Elby, 2003 and May & Etkina, 2002) have examined the epistemological assumptions of classroom discourse. Whether they are aware or not, teachers design the learning environment by setting norms for the kinds of questions worth pursuing, the forms of arguments that are persuasive and the criteria for an acceptable explanation (Lehrer, Carpenter, Schauble & Putz, 2000). The teacher's design tools include asking questions that push students' thinking farther, calling for evidence for their arguments, focusing and fine-tuning students' explanations and engaging them in evolving chains of inquiry. Clearly, teachers' questions play a crucial role in *orchestrating and improvising* (Jurow & Creighton, 2005) the classroom discourse.

This theoretical framework underscores the importance of research on the ways in which teachers frame the classroom interactions and how students appropriate them in their learning. Scott, Asoko, and Leach (2007) note that though we have a much better grasp of the role of the teacher in making scientific knowledge available on the social plane of the classroom, the step of individual sense making, or internalisation has received far less attention. Our study is an effort to explore such individual sense making using students' writing and relate it to the teaching approach they experienced.

Drawing on Vygotsky's cognitive zone of proximal development (ZPD), Brophy (1999) developed the idea of motivational ZPD. On the affective side, Brophy contends that the features of a learning domain or activity must gear up with the learner's prior knowledge and experiences in such a way as to stimulate interest in pursuing the learning. This would occur when the domain or activity is familiar enough to the learner to be recognisable as a learning opportunity and attractive enough to interest the learner in pursuing it. Also, an optimal match is required between the difficult level of a task and the developing skills of the learner. Sociocultural theory extends this idea to include the role of the teacher in optimising this match with mediation via modelling, coaching and scaffolding.

## 1.6 Aims of the Study and Guiding Research Questions

In this study, science teaching and learning were studied in two sets of middle school science classes, one taught through inquiry and another through traditional teaching, in the context of an out-of-school science program. We started the study with two broad aims described below. As described in the section on motivation for the study (section 1.4), initially, our focus was mainly on the varied affective outcomes of inquiry. However, as the study unfolded, our interest in studying the classroom interactions that made the transaction of inquiry possible in the class became foregrounded.

As the study design was not tightly predetermined but emergent (Suter, 2011), our strategies for collecting data were open to revisions and additions (for example, asking students to write a learning diary or interviewing teachers) detailed in Chapter 3). Along with the research foci, the research questions also evolved and got sharpened during the study, even as some new ones emerged along the way. This led us to explore the following questions and sub-questions that guided our analyses.

**Aim 1.** To characterise teaching of science through inquiry and explore the classroom interactions that make it possible, in comparison with traditional science teaching, through multiple perceptions of the researchers, students and teachers

In this study, we were interested in several closely related aspects of science teaching. Specifically, we asked -

1. How does the teacher guide the discourse in the two sets of classrooms, one taught through inquiry and the other taught the traditional way?

   How are the teachers' questions and classroom interaction patterns different? What are the teachers' views and strategies that guide the framing of their questions?

2. How does the structure of lessons, nature of tasks and their usage differ in the two modes of teaching?

3. How do students perceive the instruction? What may students' writing in the form of learning diaries reveal about their characterisation, if any, of the teaching methods they have experienced?

4. What are the perspectives of the teachers, participating in this study, on the teaching-learning that happened in these classes?

**Aim 2.** To explore a range of possible outcomes of learning science through inquiry and through traditional teaching (conceptual understanding, students' conceptions of science, learning and themselves as science learners, their participation in class, and cognitive, affective and behavioural engagement) and explore methods to study them.

1. What is the difference, if any, in students' understanding of science concepts gleaned from their learning diaries?

2. How students think about what knowledge and learning entails? How do students in the two classrooms frame science learning?

3. What are students' feelings and reactions towards the teaching they experienced and their self-perceptions of their own ability to learn science?

4. What is the difference in the nature and pattern of students' classroom participation?

   Who participates and to what extent? Over time, how does students' participation evolve in their classroom community? Is there a difference in the number and kinds of questions students ask?

5. Is there any change in students' interest in science in and beyond the science classrooms in the program? Is there any change in their participation in the science classes in their school?

Note that these are not independent questions. We have chosen to focus on these aspects of science learning because we think that they are central to deepening our own and others' understanding of what it means to learn and teach science as inquiry.

## 1.7 Organisation of the Thesis

The introduction chapter attempted to give an overview of the study, outlining its purpose, context, and the theoretical perspectives framing it. The second chapter on literature review dwells on the barriers as well as dilemmas that teachers face while attempting to teach science as inquiry. It underscores the need for further characterisation of teaching as inquiry and for comparative accounts of inquiry teaching vis-a-vis traditional teaching. Chapter 3 describes the methodological approach, the settings and the methods. The results are presented in the subsequent two chapters. Chapter 4 focuses on characterisation of teaching science as inquiry, in comparison to traditional teaching while Chapter 5 presents the outcomes of teaching science through the two modes. Chapter 6, along with discussion and reflections on the findings, outlines the significance, limitations and implications of the study.

# 2

# Literature Review

## 2.1 What Does it Mean to Teach and Learn Science as an Inquiry?

Though views on what exactly is involved in inquiry-based science teaching (IBST) have varied historically (Haury, 1993), most of them converge on conceiving it as a pedagogical approach that mirrors the investigative nature and practices of science by involving students in questioning, investigation and argumentation. The assertion that students should learn science by mimicking the process of knowledge construction in science is not new. It has deep roots in educational philosophy and learning theories that can be traced to Dewey's (1916) insistence that science should be taught as a process and a way of thinking, not as a subject with facts to be memorized, to Piaget's constructivism (1926; 1964) which posits that learners construct knowledge for themselves, from their experiences through simultaneous processes of accommodation and assimilation, and to the social constructivism of Vygotsky (1962; 1978) wherein knowledge is socially and culturally constructed in the interactions between individuals. Schwab (1962) denounced the teaching of science as “a nearly unmitigated rhetoric of conclusions in which the current and temporary constructions of scientific knowledge are conveyed as empirical, literal and irrevocable truths” (p. 24) and argued for inquiry-based learning based on explorations that gave learners the opportunity to experience the processes of science.

The understanding of learning through inquiry most commonly agreed upon by current researchers in science education, is that it is an approach in which learners critically and systematically

> engage with scientifically-oriented questions regarding the world around them, formulate explanations from evidence, connect explanations to scientific knowledge, and communicate and justify explanations” providing convincing arguments. (NRC, 2000, p. 30).

Each of these ‘essential features’ can be implemented along a continuum based on the amount of direction from the teacher or the student (NRC, 2001). Further, the *Next Generation Science Standards* framework of the USA (NGSS Lead States, 2013), often cited in recent science education research as the gold standard in reform goals, recognised that reform efforts should be centered on classroom practice and, with the intention of better explaining and extending what is meant by inquiry in science teaching and learning, articulated (in addition to the disciplinary core ideas) a range of cognitive, social, and physical practices inquiry entails, namely

> (1) asking questions and defining problems
>
> (2) developing and using models,
>
> (3) planning and carrying out investigations,
>
> (4) analysing and interpreting data,
>
> (5) using mathematics and computational thinking,
>
> (6) constructing explanations and designing solutions,
>
> (7) engaging in argument from evidence,
>
> (8) obtaining, evaluating and communicating information.
>
> (p. 382)

Contemporary models of IBST (e.g., the 5E instructional sequence[1]) incorporate the Piagetian concept of cognitive dissonance as well as the Vygotskian idea of providing scaffolding; central to this form of instruction is the idea that

> the learner must have the opportunity to explore concepts before formal explanations of the phenomena are provided, thus facilitating conceptual understanding (Marshall, Smart & Alston, 2017, p. 778).

Van Booven (2015) points out that divergent interpretations of this principle have led to varying emphases in instruction: from involving students in 'hands-on' activities to provide concrete experiences (Roychoudhury, 1994) to 'minds-on' teaching to encourage higher-order thinking (Duckworth, Easley, Hawkins & Henriques, 1990) and, in recent times, on developing sustained argumentation (Abell, Anderson & Chezem, 2000; González-Howard & McNeill, 2019; Hand et al., 2016; O'Connor & Michaels, 2017).

However, what exactly inquiry might look like in practice is frequently left implicit with no precise operational definition, leading to the widely differing perspectives (Anderson, 2002; Bevins, Price & Booth, 2019; Capps, Shemwell & Young, 2016; Crawford, 2000; Wells, 2007). For some educators, it is just one among many recommended instructional genres with specific sequence of steps. For instance, the position paper on 'Teaching of Science' by the National Focus Group (NCERT, 2006), posits that a "good pedagogy must essentially be a judicious mix of approaches, with the inquiry approach being one of them" (p. 5). Many other educators adopt a broader perspective, arguing that

> when education as a whole is viewed as inquiry, it is not a method to be used on particular occasions, but a particular orientation to learning, in which the task of teaching becomes that of supporting the inquiry process (Harste, 1993 quoted in Wells, 2007, p.155).

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1 The BSCS 5E model, originally created by Karplus and Thier (1967) and further developed by Bybee et al. (2006), suggests a science teaching sequence through 5 stages: Engage, Explore, Explain, Elaborate, and Evaluate.

We are inclined towards this broader view in which inquiry is multi-faceted and subsumes the use of different strategies. As NRC (1996) puts it,

> Conducting hands-on science activities does not guarantee inquiry, nor is reading about science incompatible with inquiry (p. 23).

It would be valuable to further examine inquiry-based teaching-learning to identify its core elements (Pedaste et al., 2015).

In his review of inquiry-based science instruction, Anderson (2002) draws attention to the questions that have historically surrounded inquiry, and these questions still haunt science educators as they try to answer them:

> What does teaching science as, through or with inquiry entail? Is it an approach that can be realised in the classroom or is it an idealised approach that is more theoretical than practical? Is it something that the "average" teacher can do, or is it only possible in the hands of an exceptional teacher? What are the goals of its use? Does it result in greater or better learning? How does one prepare a teacher to utilise this approach? What dilemmas do teachers face as they move to this form of teaching? (p. 1)

## 2.2 Complexities in Teaching Through Inquiry: Need for further characterisation of classroom interactions

Driver (1995), paralleling the Vygotskian idea of scaffolding, posits that merely involving students in hands-on activities, no matter how well they are designed, is not inquiry. Teachers essentially play a crucial role in the process, such as, by asking questions to help students express and justify their ideas about the concepts involved, aiding students to build on each other's ideas, positioning students as contributors to the larger picture (Asay & Orgill, 2010; O'Connor & Michaels, 2017). Such key roles are not explicitly described in the literature; Oliviera (2008) points out that they are usually described metaphorically through ill-defined labels like teacher as 'facilitator', 'co-investigator' or 'mediator' and argues that "such simplistic and over-generalised instructional metaphors fail to convey the interactional expertise that inquiry teaching requires" (p.4). Many teachers, including those who are positively inclined towards inquiry, are still bogged down with the basic question of how inquiry works in the classroom (Fitzgerald, Danaia & McKinnon, 2019). Perhaps not surprisingly, even where the curriculum explicitly requires them to take up inquiry-based approaches, many science teachers find it difficult to implement it in their classrooms (Bansal, 2017; Choksi, 2007; Lebak & Tinsley, 2010; Pimentel &McNeil, 2013). Anderson (2002) draws attention to the dilemmas that teachers face as they attempt to adopt inquiry; he delineates them from barriers and obstacles that teachers must overcome, which are external to the teacher, arguing that "much of the difficulty is internal to the teacher, including beliefs and values related to students, teaching, and the purposes of education" (p. 7).

Some of the challenges that teachers face in teaching science through inquiry as reported in the science education literature (Anderson, 2002; Crawford, 2007; Fitzgerald, Danaia & McKinnon, 2019; Marshall, Smart & Alston, 2017; Windschitl, 2002) include: (1) personal belief structures that are counter to inquiry approach, for example, the preparation ethic, i.e., an overt commitment to coverage underlying the perceived need to prepare students for the next level of schooling (2) cultural beliefs (for instance, the idea that knowledge can be transmitted through exposition is pervasive in many oral traditions), (3) lack of confidence in teaching through inquiry (4) inadequate pedagogical content knowledge (5) insufficient curricular, professional development and administrative support (6) political issues such as lack of resources and parental resistance. In addition to these varied issues, and the pressures of teaching the set curriculum in a prescribed amount of time (Jenkins, 2000), researchers (Solomon, 1998; Martin & Hand, 2009) suggest that teachers are not familiar with the skills required to teach through inquiry and are unsure of its value. Akuma & Callaghan (2019) in their systematic literature review to characterize such intrinsic challenges, from an instructional design perspective, clarify four basic categories:

> initiation-phase challenges (such as unfavorable views regarding science and practical work), planning-phase challenges (including difficulties involved in designing inquiry-based practical work), implementation-phase challenges (e.g., persuading learners to reflect on their experiences and findings), and summative evaluation-phase challenges which include concerns linked to the grading of practical inquiry (p. 619).

In a recent work in India, Bansal, Ramnarain & Schuster (2019) report that the teachers in their study expressed that they often chose didactic practice over inquiry because they believed that it is not suited for students from low socio-economic background or for those who are low academic achievers.

Speaking particularly of classroom practice, it is messy, requiring that teachers attend to students, materials, tasks, and ideas, often simultaneously, as well as to the social context that serves to shape the overall climate of the learning environment (Bevins & Price, 2016; Harris & Rooks, 2010). A common problem reported in the literature, which resonates with our experience of working with teachers, is that even when activities are included in the instruction, oftentimes they are not weaved into the classroom conversations; more often than not, the ensuing class "discussions", if at all they are there, are simply times when teachers give away the explanations (Colley & Windschitl, 2016).

Inquiry requires that teachers choreograph the sequence and flow of activities in a manner that guides students to move towards understanding the key science ideas in an investigation. This involves building and sustaining coherence within and across lessons. Teachers may struggle to engage students in complex reasoning (Driver, Newton & Osborne, 2000); it is challenging to focus not just on students collecting data or completing procedures but more on analysing the data, generating conclusions or synthesizing new findings with students' previous ideas (Jimenez-Aleixandre, Rodriguez & Duschl, 2000).

Inquiry demands new and different roles from the teacher; instead of explaining, demonstrating, and correcting, the teacher has to place more emphasis on guiding the student's through the stages of inquiry, which requires a myriad of roles requiring a high level of expertise, for instance the "motivator, diagnostician, guide, innovator, experimenter, researcher" (Crawford, 2000, p. 931) mentor, monitor and collaborator (Zhai & Tan, 2015). Frequently, the complex activities teachers perform as facilitators and guides for inquiry-based student projects are left mysterious (Zion & Slezak, 2005). Few research studies have explicitly examined teachers' instructional practices within inquiry-based classrooms (McNeill & Krajcik, 2008). Crawford (2000, p. 917) laments,

> Details of day-to-day events in the real world of classroom life are left to the imagination and often frustration of the classroom teacher striving to use inquiry-based strategies. The gap between research and practice may contribute to the disparity between the intended curriculum of the reforms and the implemented curriculum in classrooms.

Hence, we need concrete examples from the day-to-day milieu of an inquiry science classroom (Haug, 2014; Bevins, Price & Booth, 2019). Asay & Orgill (2010) express that we need to observe these interactions, focusing on both the teacher and students, across many classes and activities to get more clarity on implementing inquiry in the classroom.

One among the many areas of science education research that has attempted to diagnose and address the challenges in implementing inquiry at the instructional level is discourse analysis. With its analytical lens zooming in and out of macro- and micro-level structures in classroom discourse, researchers have attempted to use discourse analysis in order to identify the discourse moves, conversational turns and linguistic features that could either support or constrain the teaching and learning of science (Van Booven, 2015).

Smart & Marshall (2013) explain that though discourse is

> broadly defined as the use of language in the social context… within science education research, the concept of discourse is more complex in meaning… Discourse is more than classroom talk; it is a complex interaction between

> teacher, students, and these individuals' unique perspectives manifested in verbal communications (p. 250).

As Gee (2001) defines it, discourse is an interplay between ‘‘words, acts, values, beliefs, attitudes, and social identities’’ (p. 526) among individuals who jointly attempt sense-making.

The seminal work on classroom discourse like those of Mehan (1979), Sinclair and Coulthard (1975) and Lemke (1990) highlighted the ways in which norms of communication are constructed in the typical classroom through discourse moves that the teacher makes and how these often implied rules for verbal interactions may constrict student talk. They described the ubiquitous pattern of classroom talk in which the teacher usually initiates an interaction (I) with a question, a student responds (R) and then the teacher evaluates (E) or gives feedback (F) which leads to IRE/ IRF sequences. The teacher's role in orchestrating discussions continues to be one of the salient foci of science education research, especially teacher questioning and their level, complexity, and ecology (Chen, Hand & Norton-Meier, 2016; Chin, 2006; Smart & Marshall, 2013), classroom communication patterns (Mortimer & Scott, 2003; Jin, Wei, Duan, Guo & Wang, 2016), and classroom interactions (Van Booven, 2015).

Traditional, teacher-centred discourse patterns, with expert-novice forms of social activity, are inconsistent with an inquiry-learning philosophy (Polman & Pea, 2000) wherein the function of teacher talk is to encourage student voice and dialogical argumentation. Oliviera (2008) describes the novel social roles in the inquiry classroom: teachers are required to forgo, at least partly, their expert role by giving up some interactional rights such as providing the right answers and being the exclusive one in class to respond to students' ideas; parallelly, students need to give up, at least in part, their novice roles and proactively ask questions, respond to others in the classroom and propose an argument or a counter-argument. Establishing these new roles and relationships is a demanding task and we do not prepare our teachers to effectively deal with them. Hayes (2002) and Lotter (2004) report that teachers attempting to teach through inquiry find it difficult to understand the kind of teacher authority needed in an inquiry classroom and feel uneasy over the loss of control.

Thus, orchestrating inquiry-based instruction is complex (Anderson 2002; Assay & Orgill, 2010) and takes substantial effort (Alozie et al. 2010); as Harris, Phillips and Penuel (2012) elaborate, it not only needs a good grounding in the content to be taught but also some awareness about students' difficulties with the concepts and ways to help students with them. The discussion in the inquiry classroom may still take unexpected turns; the teacher needs to be open to such uncertainty and be able to decide on the strands of the discussion to follow through and the amount of support to provide students in the process. We therefore need instructional models of inquiry-based student-teacher interaction that are more elaborate and well-grounded in the classroom context, and thick descriptions of its implementation and teachers' roles in the process (Crawford, 2000; Henderson et al., 2018; Keys & Bryan, 2001; Oliviera, 2008).

Several researchers and teacher educators report that teachers often know how to get student conversations started (with a puzzling question or demonstration), nor do they have difficulty surfacing students' resources in terms of prior knowledge and relevant experiences, however, they find it challenging to help students build on these initial ideas (Colley & Windschitl, 2016; Harris, Phillips & Penuel, 2012). Given the importance of sustained dialogue, there is clearly a need to study the ways in which whole-class dialogue in a science classroom develops over a period (Benus, 2011).

Keys and Kennedy (1999) describe teachers' struggle with refraining from giving away direct answers to students' questions, and tossing the questions back to them during inquiry discussions. Similarly, Furtak (2006) report that teachers have trouble dealing with students' expectation for getting right answers from them; teachers seemed to have this problem irrespective of the level of teaching experience, discipline or amount of professional training. Colley & Windschitl

(2016) observe that we have few accounts of teaching that is responsive to students' ideas, unfolding across lessons to outline the conditions that foster student talk. In the present study, we look closely at the various ways in which the teacher initiates dialogue as well as sustains it through her feedback in the form of questions and prompts.

McNeill and Pimentel (2010) argue that in order to understand how to bring about a shift in the nature of classroom discourse, we need to examine the roles of both the teacher and the students during these interactions. Furthermore, in order to gain further insights into scaffolding students' co-construction of conceptual knowledge and bolster their ownership of learning, we need to deepen our understanding of what ignites and sustains students' full engagement in inquiry. Narratives of inquiry in the science classroom often miss the details of the ongoing student-teacher interactions (Reinsvold & Cochran, 2012), especially the affective dimensions of these interactions (Oliviera, 2008).

Other aspects that require more attention "include the beliefs and pedagogies of teachers who appear successful in engaging students in inquiry-based lessons" (Crawford, 2000, p. 933). On the other hand, Zhai, Jocz, and Tan (2014) outline the need to investigate students' perceptions of their inquiry learning experiences and how these shape their conceptions of school science. Thus, we need voices of both the teacher and the students, as we attempt to develop a holistic understanding of inquiry in the science classroom.

Discourse in the classroom also plays a role in creating certain exclusions and inclusions in the science classroom, creating hierarchies and equally important, creating spaces of possibilities (Hanrahan, 2005; Segal, Pollak & Lefstein, 2017). Microanalyses of classroom discourse, especially how the teacher and students negotiate their roles during teaching and learning practices, may guide us to develop an in-depth understanding about how students develop their identities in science and what factors may influence and shape such a process. van Zee et al. (2001) implore the need for further studies documenting changes in students' ways of speaking during the school year, not only in their questioning but also in their ability to engage in discourse that facilitates the learning of their colleagues. Similarly, Henderson et al. (2018) while pointing out the focal issues of concern that the field of argumentation research should further pursue, posit that these issues center around understanding the hurdles in establishing a classroom culture that values dialogue, social collaboration and "epistemic shifts in the classroom mindset towards argumentation" (p. 9) and finding ways to support students and teachers in doing so.

## 2.3 Teacher Questioning

Teacher questioning has a key role in facilitating and transforming classroom discourse (Chen, Hand & Norton-Meier, 2017; Chin, 2007; Roth, 1996; Zhai & Tan, 2015). There is limited amount of literature investigating teacher questioning in constructivist learning environments such as inquiry (Erdogan & Campbell, 2008) where it is especially pivotal.

### 2.3.1 Teachers' questions and their kinds

Several categories of teachers' questions have been proposed. Well known among these are lower and higher-order questions (Bloom, Englehart, Furst, Hill & Krathwohl, 1956), and open and closed-ended questions (Graesser & Person, 1994). Lower-cognitive questions, corresponding to closed-ended questions, are those that invite brief answers and place few cognitive demands on the student while open-ended or higher-cognitive questions invite extended answers, may have several acceptable answers and place more demands on the learner. It has often been reported that traditionally teachers spend most of their time asking low-level cognitive questions (Harlen, 1999; Wilen, 1991).

Some other researchers have suggested categories of questions that move away from this typical division. For example, Watts and Alsop (1995) illustrated instructional (e.g. 'Can you see what is supposed to happen?'), conceptual ('Can you understand the difference?') and transactional questions ('Has everybody finished that piece of work?'). Elstgeest (1985) described productive questions that were: attention-focusing, exploring how and why, forging comparisons, problem solving and prompting actions. However, such broad categories may paint many aspects of teacher questioning with too broad a brush; Chin (2007) has pointed out that a fine-grained analysis is needed. Chin's work on categories of questioning-based approaches is such a study of science classes in general. She describes four approaches (namely 'Socratic questioning', 'verbal jigsaw', 'semantic tapestry' and 'framing') and several strategies within these approaches that encourage student responses and thinking. We note that though some of the strategies described by Chin are indicative of an inquiry approach, her categories do not necessarily detail the kind of questioning in the inquiry setting which is our focus in this study. Our study not only explores the details of the specific ways in which teachers' questions can elicit, support and encourage students' thinking but also describes a progression of question categories that underlies inquiry lessons.

### 2.3.2 Teachers' use of questions in inquiry

Previous studies have shown that the purpose of teacher questioning in traditional science classes is to evaluate what students know and the predominant pattern of discourse is initiation–response–evaluation (IRE) or the triadic dialogue (Lemke, 1990). However in inquiry-oriented science classrooms the role of teachers' questions is to encourage true dialogues (Lemke, 1990) aiming at conceptual understanding. With the emphasis of discourse in traditional, direct instruction being exposition and transmission of knowledge, the purpose of questioning is to evaluate what students know and have learnt and hence questions usually lead to expected answers and the teacher moves on with the lesson after accepting or correcting responses from students (Chin, 2006, 2007; Erdogan & Campbell, 2008; Lemke, 1990). The objective in the inquiry classroom is to move away from “this simple recollection of the ‘right answer’, towards coherent explanations of the phenomena in context” (Erdogan & Campbell, 2008, p. 1894).

In inquiry teaching, the discourse aims at facilitating the construction of conceptual knowledge by students and therefore, the purpose of questioning is to elicit students’ ideas, help students to articulate them, to elaborate and reflect on their own as well as their peers’ thinking, challenge them to resolve inconsistent views, construct relevant relationships and provide a setting for active student inquiry (Chin, 2007; Erdogan & Campbell, 2008; Yip, 2004; van Zee, Iwasyk, Kurose, Simpson & Wild, 2001). Thus, the inquiry teacher’s questions have to continually challenge as well as support students’ thinking and progressively build on students’ responses. We summarise the characterisation and differentiation of these two modes of teaching in Table 2.1 based on the literature (Chin, 2007; Erdogan & Campbell, 2008; Marshall, Smart & Horton, 2009; Scott, 1998) and our own observations; this table gives an overview of the inquiry and direct instruction modes of teaching observed in our study.

There are few studies such as Erdogan and Campbell (2008) and Roth (1996) which have examined teacher questioning in constructivist learning environments and have attempted to describe the complexity of these questions. Roth (1996) described a case-study where the teachers’ questioning was designed to draw out students’ knowledge and scaffold students’ discursive activity. Erdogan and Campell found, using categories of open and closed-ended questions (modified from Graesser & Person, 1994) that teachers facilitating classrooms with high levels of constructivist teaching practices not only asked a significantly greater number of questions but also more open-ended questions.

**Table 2.1** A summary of the differentiation of inquiry teaching and traditional, direct instruction based on the literature and our own observations which applies to the two teaching modes in our study.

| **Traditional teaching** | **Inquiry teaching** |
|---|---|
| Teacher explains the concepts with the help of demonstrations and hands-on verification activities. | Teacher engages and guides students through investigations, making observations and arriving at explanations. |
| Teacher's responsibility is to expound clearly. | Teachers' responsibility is to elicit, challenge and scaffold student thinking and encourage wider responses from the class. |
| Teacher engages students in questioning that does not lead to discussions; teacher goes through a sequence of questioning, accepting or correcting answers where necessary but rarely follows up with further probing. | Teacher consistently engages students in open-ended questions, often leading to discussion and debate where observations, assumptions and reasoning are challenged by the teacher or other students. |
| Students' utterances are often in response to teacher's questions and usually consist of single, detached words, many a times in chorus. | Students' utterances are not restricted to direct answers to teacher's questions, are expressed in whole phrases/ sentences and may be tentative. |

They have expressed a need for future investigations that continue to explore nuances of facilitating constructivist learning. The richer variety of open-ended questions in the classroom we observed led us to study and categorise both the kinds and the levels of teachers' questions. Lustick (2010) points out that question typologies that examine the role of questions are significant to classroom practice and the more the science teacher educators understand about questions for inquiry, the more likely such questions will be used to foster learning.

Discourse in the inquiry classroom necessitates certain distinctive types of questions, including open-ended or divergent questions which can be answered in multiple ways (Colburn, 2000; Chen, Hand & Norton-Meier, 2016; Kaya, Kablan & Rice, 2014; McNeill & Pimentel, 2010; Zhai & Tan, 2015). Teachers' questioning in the inquiry classroom serves diverse discursive purposes (Oliviera, 2010b; Soysal, 2019). Common query types include probing questions (van Booven, 2015), those that generate ideas (Crawford, 2000), diagnose student understanding (Ruiz-Primo & Furtak, 2007), those that help students draw from their everyday experiences (Cavagnetto & Hand, 2012), and challenge students' ideas (McMahon, 2012). While asking questions in inquiry, teachers also typically use personal pronouns such 'you' or 'we', for example "why do *you* think this happened" instead of "why did this happen?" in order to encourage students to express what they think rather than focusing on getting the answer correct (Oliviera, 2010, p.423).

### 2.3.3 How scaffolding supports classroom discourse

During class discussions in inquiry, the teacher needs to avoid giving immediate evaluation of students' responses, and instead, try to understand and extend students' answers by rephrasing them, further prompt students to clarify and justify their position (Oliviera, 2008). Therefore, the need for initiation–response-feedback (IRF) pattern of discourse, instead of the typical IRE, wherein the feedback step is truly crucial for providing such support and can be in the form of a question. As Wells (1993) points out, when used effectively, it initiates the next cycle of the learning-and-teaching spiral. Mortimer and Scott (2003) described how elaborative feedback from the teacher during hands-on activities led to discussions that were more dialogic in the form of initiation–response–feedback–response–feedback (IRFRF) chains.

Ruiz-Primo and Furtak (2007) outline the questioning strategies that teachers use in inquiry classrooms for informal formative assessment in the form of 'eliciting, recognising and using information' on students' learning. They flag the vital step of using the gathered information to inform instruction as an especially challenging task, for it needs both preparedness and improvisation. Chin (2006) remarks that when the teacher asks follow-up questions instead of making an evaluative move, she not only extends students' responses but helps them in reasoning beyond mere recall, thus easing them into more cognitively active roles. Recent studies such as by Howe et al. (2019), McNeill & Pimentel (2010) and Soysal (2019) provide further evidence that teacher questioning is linked with the cognitive level of students' contributions in class discussions and also leads to positive attitudes.

The distinctive repertoire of the inquiry teachers' response moves (including accepting students' ideas without judgment and presenting them to the whole class by revoicing or rephrasing them (eg. "did you mean…?") and extending/ applying students' ideas to further the central arguments, thus essentially valuing students' contributions to the discussion plays an additional key role of establishing more symmetric interactional roles (O'Connor & Michaels, 1996, 2017; Oliviera, 2010a). Our study looks closely at the various ways in which the teacher initiates dialogue as well as sustains it through her feedback in the form of questions.

Successful scaffolding strategies used in IBST that are reported in the literature include providing suggestions and prompts for reasoning, cognitive structuring of difficult tasks and parsing them into manageable steps, modeling scientific thinking and making its features explicit, appropriately introducing and mindfully using terminology, and connecting the discussions with previous learning and the practical work done (Colley and Windschitl, 2016; Hmelo-Silver, Duncan & Chinn, 2007; White & Frederiksen, 1998).

## 2.4 Effects and Potential of Teaching Science as Inquiry and the Need for Comparative Studies

While much research has been done, for some decades now, on the effectiveness of inquiry-based science teaching, the results are not definitive; see meta-analyses such as the ones by Furtak et al., (2012), Lazonder & Harmsen, (2016) and Shymansky, Hedges & Woodworth (1990) and review studies such as those by Anderson (2002), Colburn (2008), Hmelo-Silver, Duncan & Chinn (2007), Minner, Levy & Century, 2010 and Zhang (2016). A number of studies of inquiry science teaching and learning (for example, Cuevas, Lee, Hart & Deaktor, 2005; Slavich & Zimbardo, 2012) have explored how IBST affects a range of learning outcomes, for example achievement and content retention over time, skills in problem solving, critical thinking and conducting scientific investigations, creativity and vocabulary (NRC, 1996, 2012).

In general, the evidence from studies on outcomes of inquiry teaching suggest that the support for it is well grounded (Sadeh & Zion, 2009), although this evidence is not unequivocal and conclusive (Hodson, 1990; Zhang, 2016). While some have reported negative results (Areepattamannil, 2012; Lavonen & Laaksonen, 2009; Kaya & Rice, 2010) and some others have claimed that if both the modes of teaching are well designed, there is no difference between inquiry-oriented and direct instruction in terms of science achievement (Cobern et al., 2010) or even process skills (Pine et al., 2006). The researchers who have reported negative results have interpreted these findings as possibly being a consequence of inquiry instruction not being implemented effectively or appropriately. This again points to the importance of characterising the day-to-day transaction involved in inquiry-based instruction. It can also be argued that these studies used achievement on standardized tests as a marker of effectiveness of teaching through inquiry and, we believe that we need some other measures which will more discernibly examine students' learning of science through inquiry.

Supporters claim positive effects of IBST on cognitive and attitudinal outcomes as well as on students' process skills like drawing conclusions from data (Cheng, Wang, Lin, Lawrenz & Hong, 2014; Marshall, Smart & Alston, 2017; Wilson et al. 2010). Development of argumentation skills has also been reported as a result of engaging in inquiry (Sampson & Walker, 2013). Another noteworthy outcome reported is that it can lead to narrowing the gap in science achievement of students from diverse backgrounds (Cuevas, Lee, Hart & Deaktor, 2005; Geier et al., 2008; Marshall & Alston, 2014) suggesting that it has a potential to make science accessible for all learners.

However, there are also critics (Kirschner, Sweller & Clark, 2006; Klahr & Nigam, 2004, Settlage, 2007) who have questioned the effectiveness of inquiry, looking at minimally-led inquiry approaches like the open-inquiry or discovery method. Researchers have responded to this argument by detailing the kind of guidance and support involved in inquiry-based science teaching (Hmelo-Silver, Duncan & Chinn, 2007). However, what kind of guidance is adequate, and for whom? These questions need further investigation (Lazonder & Harmsen, 2016). There are also doubts whether the outcomes justify the time and effort (Jenkins, 2000).

Minner, Levy & Century (2010), in their synthesis of research on the effectiveness of IBST point out the need for investigating a wider range of outcomes of inquiry teaching. On similar lines, Cobern et al. (2010) argue that analyses of outcomes other than content learning alone would greatly add to the collective understanding of the full effect of inquiry teaching on students. There is a paucity of research, involving classroom situations, assessing and comparing the impact of learner-centred teaching with more traditional ones, on students' perceptions of learning, actual content learned and depth of thinking about (and understanding of) the conceptual underpinnings of science (Wohlfarth et al., 2008; Villanueva et al., 2019). Anderson (2002) eloquently points out that the more interesting result of his synthesis of research on the outcomes of inquiry-based science teaching "is not simply that it is possible to foster inquiry teaching but that doing so is difficult. It is important to understand the difficulties encountered in doing so" (p. 7). We thus need to focus more on understanding the dynamics of teaching through inquiry and how it can be brought about.

## 2.5 Considering Students' and Teachers' Perspective on the Teaching-Learning they Engage in

The evidence of students' conceptual understanding comes largely from pre- and post-testing; Sugrue, Webb & Schlackman (1998) suggest that in case of complex concepts, open-ended responses can reveal more misconceptions than tests with multiple choice items. Further, studies looking at the practice and conceptions of inquiry usually involve either classroom observation by researchers or self-report from teachers. By analysing diaries written by students, we provide another perspective, that of the students, through descriptions of their science learning experience in their own words. Studies investigating how students conceptualise the constructivist perspective are rare though constructivism represents an influential view of learning (Loyens, Rikers & Schmidt 2006). Knowing what students think they know and how their learning is changing is important and in line with constructivist thinking which is at the core of inquiry teaching.

There have been many studies on the usefulness of students' writing in science notebooks. It is acknowledged that writing in science notebooks promotes learning and serves as a tool for formative assessment (e.g. Baxter, Bass & Glaser, 2000; Bernacki, Nokes-Malach, Richey & Belenky, 2014; Keys, Prain, Hand & Collins, 1999). A few studies (Klentschy & Molina-De La Torre, 2004; Minogue et al., 2010 and Ruiz-Primo, Li & Shavelson, 2002) exploring how such writing can provide evidences of practices in the classroom have been reported. In these studies, the focus has been on structured, systematic accounts of laboratory investigations by students, not open-ended reflective writing about the overall learning experience. Wiebe et al.(2009) used open-ended writings of second graders in their science notebooks as a tool to examine inquiry practices in the classroom. More recently, Madden and Wiebe (2013) used notebook entries to examine how teachers' instructional practice was interpreted by students.

Engaging in reflective writing (as in diaries, journals or learning logs) can take students to deeper levels of reflection and help identify the significance and meaning of a given learning experience for them (Fink, 2003). By recreating the processes that go on inside the writers' minds, and conveying it to the reader, such writing opens up fields that are not normally accessible to researchers. In science education research, while there have been some studies on reflective writing by teachers (e.g. Harwood, Hansen & Lotter, 2006), there have been few studies on students' reflections on their learning experience, especially at the school level. Studies at the college and graduate school levels on students' perceptions of their experience using interviews, weekly reports and course evaluation questionnaires have been reported by Hsu and Roth (2010), May and Etkina (2002) and Wohlfarth et al. (2008). In his review of studies in three different countries, Lyons (2006) found that high school students across these countries perceived traditional school science as passive, unengaging and difficult. He notes the need for more studies on students' reflections on their experience, especially in contexts which engender more positive attitudes towards science.

In order to gain further insights into scaffolding students' co-construction of conceptual knowledge and bolster their ownership of learning, we need to deepen our understanding of what ignites and sustains students' full engagement in inquiry. An interesting study at the school level by Hadzigeorgiou (2011) illustrates the usefulness of optional journal entries in investigating students' involvement as well as content learning. He used such entries, of Grade 9 students, to provide evidence that compared to teaching in a traditional way, invoking a sense of wonder while teaching science makes a positive contribution to learning of content as well as involvement with it.

## 2.6 Summary and Conclusions of the Review

It is surprising that though inquiry has been a consistent theme in the reform advocated worldwide in science education, the research and advocacy efforts have not satisfactorily translated into changes in science instruction. Wilson et al. (2010, p. 276) note that "the paradox of educational reform without change is not exclusive to science education… but it is nevertheless intriguing that such a sustained and largely consistent drive for reform has had such little impact on classroom practices".

The practices associated with inquiry teaching involve complex experiences and interactions for both the teacher and the student with materials and language (NRC, 2000), and as Oliviera (2008) points out, the literature does not describe in enough detail the the various kinds of expertise that is needed in teaching science through inquiry. Few research studies have explicitly examined the struggles and strategies of teachers' striving to teach science through inquiry. This may have contributed to the gap between research and practice. Hence, we need concrete examples to better understand how inquiry science is enacted in the day-to-day milieu of the classroom (Haug, 2014; Bevins, Price & Booth, 2019), especially in terms of the discursive moves that that teachers use to guide the lesson (Henderson et al., 2018; Oliviera, 2008).

Also, we need to include the voices of the teacher and also the students, as we attempt to develop a holistic understanding transacting inquiry in the classroom. Further, we need to look across the conceptual, affective, epistemic and social domains of learning, as we compare the outcomes of inquiry vis-a-vis traditional science teaching.

# 3

# Methods

This chapter presents a description of the methodological approach used and provides background information of the participants in the study. Further, it details the nature of the two modes of teaching involved and the instructional units. Next, the chapter illustrates the data collection and analysis procedures. Finally, the measures taken to raise trustworthiness of the study are described.

## 3.1 Research Design and Methodological Approach

This study has a mixed methods design (Creswell, Plano Clark, Gutmann, & Hanson, 2003; Cresswell, 2014; Yin, 2006) with a quantitative strand nested within a predominantly qualitative study. The qualitative approach guided the study, in the sense that not only qualitative research methods were predominantly used for collecting data but the theoretical framework and the philosophical assumptions (grounded in socio-cultural theory) that shaped the kind of research questions, methods and the nature of claims made in the study are more aligned with the naturalistic, qualitative paradigm (Lincoln & Guba, 1985).

In a seminal article, Greene, Caracelli, and Graham (1989) map out the intents in which mixed methods could be used to inform one another. Out of the reasons they describe, we find that, in our study, the mixing of methods served purposes of *triangulation* (seeking corroboration of results from two or more methods), *complementarity* (exploring different but overlapping facets of the same phenomena) and *expansion* (increasing the scope of inquiry by using several methods for different components of inquiry). These aspects would be clearer in section 3.6, while discussing methods of data analysis.

The conceptually and operationally ill-defined and innately complex nature of inquiry in the classroom (as described in the previous two chapters) warranted such a research design. As Ponce and Pagán-Mal-donado (2015) point out, the integration of qualitative and quantitative methods is well-suited to capture the complexity of the context and the impact of an educational phenomena. Further, in a recent review article, Rapanta and Felton (2019) argue that research on inquiry-based instruction, especially that which looks at social processes (such as discourse) and complex, subtle and qualitative aspects of learning outcomes, "offers a perfect example of the ways in which a paradigm and its research questions call for mixed-methods designs" (p. 289).

The qualitative component of the study adopts a 'comparative qualitative research' approach (Silverman, 2004) which involves accessing multiple data sources in looking for patterns within and across cases, providing means to understand, explain and interpret the diverse processes and outcomes. In doing so, it draws from:

(a) **Ethnographic case studies**[1] - attempting to provide detailed, in-depth description of everyday classroom life and practice (Hammersley, 2006; Parker-Jenkins, 2018),

1 We understand ethnography as defined by (Hammersley 2006, p.4): "A form of social and educational research that emphasises the importance of studying at first-hand what people do and say in particular contexts. This usually involves fairly lengthy contact, through participant observation in relevant settings, and/or through relatively open-ended interviews designed to understand people's perspectives, perhaps complemented by the study of various sorts of documents - official, publicly available, or personal."

(b) **Discourse analysis** - examining who said what to whom, when, where, how, and why and looking for patterns in ways of speaking among members of a *speech community* (Gee, 1999), and

(c) **Phenomenography** - exploring *lived experiences* of the participants, to understand the essence of the experience and its significance for the participants of the study, i.e, the students and the teachers (Marton, 1981).

Thus, the qualitative component of this research involves exploring how the participants make sense of events and what meaning and value they assign to them (Costa, 1995). It attempts to understand *what it is like* to experience particular conditions and how the participants manage a specific situation. Hence, it is concerned with the quality and texture of the experience (Willig, 2001); rather than establishing a cause-effect relationship, the objective of this study is to describe and possibly explain.

For this purpose, science teaching and learning was studied in two sets of middle school science classrooms, one taught through inquiry and another through commonplace, expository or direct teaching. Open-ended research methods were used (classroom observations, students' learning diaries, formal and informal interviews and discussions with teachers and students, video and audio recordings, class summaries and reflections by teachers and researcher's field notes) to build a naturalistic account (Lincoln & Guba, 1985). This was augmented by questionnaires administered to students at various junctures during the study, which included some survey questions as well as open-ended questions that elicited more elaborate responses. From these multiple sources of data representing perspectives of the researchers, teachers, and students, the study attempted to analyse processes of day-to-day science instruction, to elucidate key aspects of inquiry-based instruction as compared to traditional science teaching.

The methods were also mixed at the analysis level; results of the qualitative analysis were augmented by a comparative, quantitative analysis of the findings. Our choice of tools for data collection and methods of analyses (exploring what is salient in the experience for the students and teachers, inductively coding them often in their own words) are consistent with the qualitative research approaches we identify with. For example, the learner diaries in our study contain indications of students' efforts in making sense of events, and serve as a window into their conceptual and emotional engagement with the teaching they underwent.

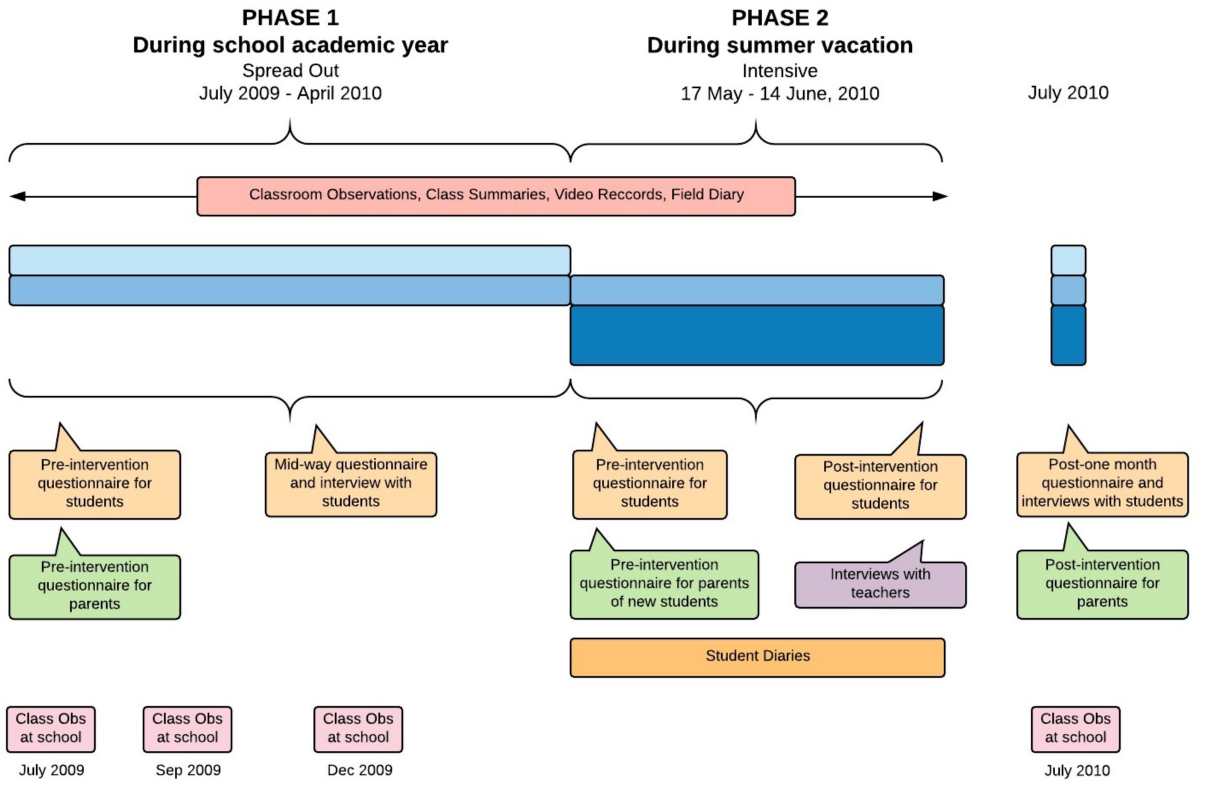
Comparison of the teaching across the two groups in the study (observed over a total of 171 hours) involved studying (a) the kinds of questions asked by the teacher and feedback provided to students, (b) lesson structure and activities used, (c) classroom environment that was set (d) cognitive and affective scaffolding of students' responses and (e) turn-taking[2]/ interaction patterns. The learning outcomes studied were content acquisition, students' conceptions of science and learning, student participation in class (and change over time), students' engagement levels and interest towards science learning within the class and in out-of-school science-related activities, student questioning and observation and the kind of classroom culture that was established within which the students related and reacted to each other and the teacher.

## 3.2 Data Collection

Data collection was conducted in two phases. Figure 3.1 summarises the details of data collection.

2 In any conversation, there are implicit rules, particular to a context and the people involved, regarding who talks, and then who talks next, how much and when. This process is called turn-taking; turn-taking patterns in the classroom were discussed in Chapter 2 (section 2.2)

**Figure 3.1** A snapshot of the study design and its timeline




| | | Inquiry group | Comparison group |
|---|---|---|---|
| Phase 1 | One hour classes, twice a week, in school, along two week-long camps at HBCSE which were for two hours each day | 58 hours | 43 hours |
| Phase 2 | Two hour classes each day, days a week for a month, at HBCSE | 37 hours | 33 hours |

| | Inquiry group | Comparison group |
|---|---|---|
| Students who participated only in Phase I (more than 20 hours) | 7 | 10 |
| Students who participated both in Phase I and Phase II | 10 | 9 |
| Students who participated only in Phase II (more than 20 hours) | 24 | 21 |

Phase I involved after-school classes, spread over an academic school year (from July 07, 2009 to April 27, 2010), in the students' school. This included week-long intensive 'camps' conducted twice during short-term school vacations students had in October and December. During these camps, students came to the centre for a two-hour class daily. In Phase II, during the summer vacation (from May 17, 2010 to July 14, 2010), classes were held at the centre for two hours a day, five days a week.

## 3.3 Participants in the Study

**Phase I:** Students of Grade 7 (average age 11.8 years[3]) were invited to attend voluntary, after-school science classes held within their school premises. The classes were mainly held in English, but sometimes the students and teachers switched to Hindi. The students belonged to an urban school in a cosmopolitan setting of Mumbai. The school had English as the medium of instruction and followed the national curriculum in India, brought out by the National Council of Educational Research and Training (NCERT). Students came from varied linguistic and socioeconomic backgrounds but mainly from lower to middle-income groups.

This school was chosen for its varied student profile and because of its ease of access and proximity to the centre. Students who were interested in joining were randomly divided into two groups, each of about 25 students. The analysis confirmed that there was no significant difference between the two groups in terms of their academic performance at school (Figure 3.2) or socioeconomic status (gauged from family income and parents' education levels) (Table E3 and Figure E1 in Appendix E).

3 Age as on 13/ 07/19

There was a slight difference between the two groups, in parents' reports on students' level of interest in academics and particularly science (Figure E2 and E3 in Appendix E). Students in the comparison group seemed to discuss more about school in general and about science in particular (compared to other subjects taught at school).

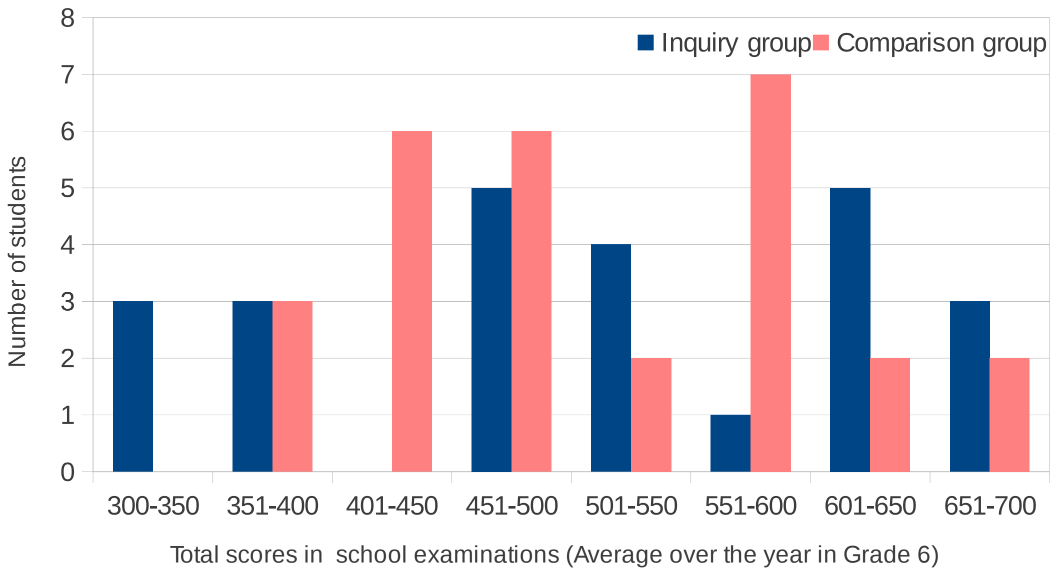



**Figure 3.2** Academic performance of the two groups in Phase I

Two teachers from the research group taught (individually, not together) a group of students through inquiry. Both the teachers (referred to as Teacher IJ and Teacher IK) had at least a Masters degree in science but were not formally trained teachers. One of the teachers had over ten years of experience in research and in teaching science in the inquiry way. She coached and supported the other teacher, who had a couple of years of experience in lecturing at the college level but was a relative novice in inquiry teaching. This became necessary because, given how extremely rare inquiry teaching is in this region, we could not find a second teacher who had this experience.

Two teachers (referred to as Teacher TN and Teacher TP) from nearby schools, nominated as among their best science teachers by the school authority, taught the comparison group. Although they taught in the traditional way, they reported that they could do fuller justice to their teaching in these classes as they were not constrained by time limits for transacting material as demanded by the school schedules, nor were they limited to the content of prescribed textbooks. They also put in considerable effort to prepare for these classes and make them more interactive than their usual school classes. Both these teachers had a Masters degree in science and were formally trained teachers with four to five years of teaching experience.

There was a drop in the number of students over the year from both groups. From an average of 21 students in the inquiry group and 26 students in the comparison group in July 2019, the number went down to 12 and 17 students respectively in December. Therefore, for Phase II enrollment was opened to other students to get enough number of students for the two groups, especially since it would be conducted during vacation time.

**Phase II:** In addition to students from the school in Phase I, students from three other nearby schools from the same school system were invited to attend a science summer camp at our centre. Students were now in Grade 8 with average age of about 12.50 years[4]. The new students who volunteered to participate were randomly assigned to the two groups so that each of them had around 30 students each. The average number of students over Phase II remained 30 for the inquiry group and 29 for the comparison group.

Records of students' academic performance at school indicated that there was no significant difference between the two groups either for overall scores (Figure 3.3) or for science (inquiry group: 79.24 ± 13.80, comparison group: 80.34 ± 15.18).

4 Age calculated on 17/05/2010

Similarly, there were no significant differences in the socioeconomic backgrounds of the two groups inferred from data on monthly family income and education of the parents (Table E5 and Figure E4 in Appendix E) or in their reports related to interest in science (Appendix F). However, there was clearly a difference in the academic profile and the socioeconomic status of the incoming students and the students continuing from Phase I, and this was true for both the groups (Table E15 in Appendix E).

The same two teachers from the research group, who taught the inquiry classes in Phase I, taught in this phase too. However, the school teachers who taught the comparison group in Phase I, were unavailable in the summer. Hence, two other teachers (referred to as TS and TA), each with a formal degree in teaching and at least a Masters' degree in science taught the comparison group in Phase II. One of them had over four years of experience in teaching in middle school; the other was a relative novice.

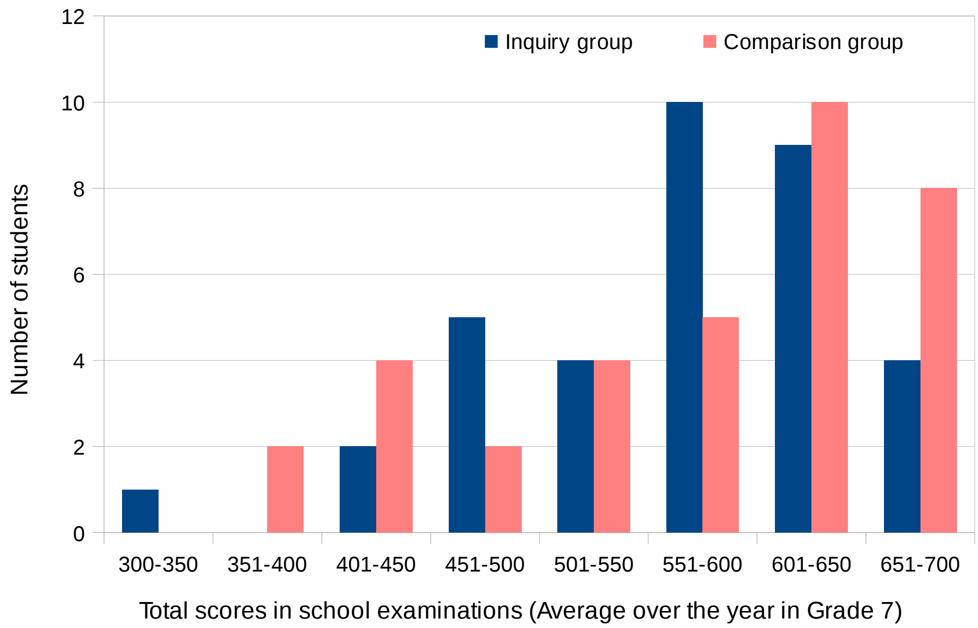



**Figure 3.3** Academic performance of the two groups in Phase II

**Teacher support:** The primary support given to teachers of the comparison group was to provide them with content material, access to computers, lab equipment, library. Teachers of both the groups were provided with support in their lesson planning, including the collection of material needed for activities/ experiments and literature. Discussion during the planning phase included students' difficulties and common misconceptions related to the lesson, reported in the literature and in our own experience.

Research assistants were present in the classrooms of both groups for purposes of videotaping and could be asked for help in conducting activities if needed. There was often an informal debriefing immediately after the class during which teachers reflected on how the class had proceeded. Sometimes, members from the research team, including the observers, provided feedback during these debriefings meetings, regarding the content or class dynamics, especially in the initial classes for Teachers IK, TP and TA.

Specifically for supporting Teacher IK in teaching through inquiry, classroom coaching was used as a form of teacher professional development, specially in Phase I. Coaching refers to learning that occurs as the novice teacher engages in her daily work activities along with a more experienced colleague, learning "in and from practice" (Ball & Cohen, 1999). Teacher IJ supported Teacher IK by helping her with her lesson plans, modelling instructional strategies through her own teaching, observing IK's lessons and discussing them during debriefings.

## 3.4 Data Sources

### 3.4.1 Classroom observations of teacher-student interactions

The researcher observed the classes along with a research associate (referred to as AF in Table 3.1). The observations mainly centred on the discourse, noted using an observation sheet that was developed to record the classroom interactions in detail

(Appendix A). We mainly noted teachers' questions and subsequent student-teacher interactions (verbatim or summarised) – the core features of inquiry-based science (Brandon et al., 2008). In addition to the two sets of classrooms in the study, some science classes at students' school were observed over the year. The intent was to understand the nature of experience that students have had in their science classes at school and secondly to note changes, if any, in the way students participated in their science classes at school after attending classes in this study.

**Table 3.1** Details of the number of classroom observations

| | | **Total no. of classes (hours)** | **Observed by** | | | |
|---|---|---|---|---|---|---|
| | | | **Only AK** | **Only AF** | **Both** | **None** |
| **Phase I** | Inquiry group | 58 | 50 | 3 | 4 | 1 |
| | Comparison group | 43 | 28 | 8 | 3 | 4 |
| **Phase II** | Inquiry group | 37 | 24 | 5 | 7 | 1 |
| | Comparison group | 33 | 17 | 10 | 5 | 1 |
| **Overall** | School Science classes | 33 | 24 | 9 | - | - |

In case of class observations in classes conducted as part of the program (but not those that were observed in school), data in the observation sheets were cross-checked with the help of video records (which were used to fill in any gaps in real-time observations). Almost all the lessons throughout the intervention were observed by at least one observer (Table 3.1). The researcher closely followed the teaching-learning in these classes, by being present for most of the classes conducted, even when not formally noting down observations. Ellwood & Abrams (2018, p.398) note that -

> very few research studies have embedded researchers in the classrooms to study the entire student experience, or focused on student social interactions and their influence on IBSE (inquiry-based science education) outcomes.

**Trials and retreats in the process:** In November 2008 and February-March 2009, classes conducted as part of the curriculum development project, with two groups of students (from two of the schools from the same school system as the students in the study) were observed as pilot studies for the researchers to figure out what to focus on during class observations and how to note down the details of the classroom transactions.

These class observations led to the development of the classroom observation sheet given in Appendix A. There was another part of the observation protocol (reported in Appendix B) developed and used for some initial classes in the study. However, the researcher was unable to fill this part of the protocol consistently after the initial few classes, and therefore it was left out of the analyses. The questions though that were of interest in this part of the protocol (for example, how many students participated in class? How did the teacher respond to unexpected answers from students? Did any student disagree with other students or the teacher?) guided the broader analyses of classroom data.

Another mode of data collection that was planned but later abandoned was case studies of individual students; it was planned to closely observe and follow the development of engagement and participation of eight students each from the two groups in Phase I (planned to be noted in the second part of the observation protocol, reported in Appendix B). However, the researcher did not find it feasible in terms of time and effort.

### 3.4.2 Field notes

**Field notes** were written during and soon after class observations within the observation sheet. They were used to note any critical events, interactions and impressions of the class. The field notes were used to note relevant developments, suggest tentative assertions, raise questions for subsequent reflection and discussion within the research team, and identify particular students or groups of students who might be observed more closely and to summarise the observers' understandings and reflections on the classroom events.

While the field notes were about individual classes, a **field diary** (some excerpts in Appendix C) was also maintained which was a running note about the research study as it progressed - to note any significant interactions with teachers outside the class, researcher's overall reflections and trends across the groups and the choices made along the way.

### 3.4.3 Video records

Video recording of the classes involving two groups in the study were used to examine the content and structure of the lessons and details of classroom interactions, as well as details such as the exact instructions for diary writing and contexts of particular diary entries. Longitudinal, videotaped records enabled an analysis of students' verbal participation as they engaged in science learning in moment-to-moment interaction and over extended periods.

The classes were video recorded with two cameras, one focusing on a specific event/ the teacher or student holding a speaking turn and the other, with a wide-angle lens, to capture the whole class continuously. Also, patterns of instructional practice in the two modes were identified using these video data and field notes and compared across groups. We decided not to video record the classes observed in school as perhaps teachers would not be comfortable with it and it would disrupt the normal proceedings of the class.

### 3.4.4 Teachers' reflections

Discussions with the teachers before and after class as well as their written lesson plans and class summaries served as valuable data sources for making explicit the teachers' intent, for example through the details of how a lesson was planned or their reasons for departures from their lesson plans. Additionally, self-reports by teachers on their motivations and purposes for questioning were obtained which helped us better understand teachers' beliefs and practices related to questioning and informed the categorisation of questions. Further, semi-structured interviews (Appendix K) with them were done after the program to get their reflections and to capture teachers' vision of instruction. The interviews were audio recorded and transcribed.

### 3.4.5 Students' diaries

In both the phases of the study, notebooks were given to students to write down class notes and homework, if any. In Phase II, Teacher IK (one of the teachers in inquiry and member of the curriculum development project) suggested that we ask students to write in these notebooks what they had learned in each class, specifically, in case of students in the comparison batch most of whom hardly spoke in class. We thank her for this ingenious idea that shaped this study substantially; our analysis of students' diaries brought to light many more aspects of the teaching and learning in these classes than we had anticipated.

Students were requested to note down, as a reflective diary entry, what they had learned, how they felt about the class and anything interesting that they came across. Instructions for making the diary entries given to both the groups by their teachers were essentially identical and students were explicitly told that they would not be graded or evaluated individually for their writing and that they could be frank in their diary entries.

The diary entries were optional, although they were encouraged (however, at the end of some classes in the comparison group, one of the teachers gave students time to summarise in their diaries what they had just learned). The teachers never read or discussed any of the diary entries in class. They accessed the diaries only rarely because they were planned for research purposes and not for formative assessment. These measures were taken to obtain spontaneous, voluntary and candid writing from students.

Students' diary entries served several purposes: (a) the amount of voluntary diary writing gave an indication of students' engagement level with their learning experience (Hadzigeorgiou, 2011) (b) candid feedback could be obtained from students (c) it became possible to capture students' emerging understanding of the content after the teaching in each class. Thus, we essentially used the diaries to explore the effect of the instruction and how students perceived it rather than to evaluate individual students.

At the end of the intervention, notebooks from each group were obtained and photocopied before returning them to the students; 19 students from inquiry and 18 from the comparison group turned in their notebooks. Details such as the exact instructions for diary writing and the context of particular entries were obtained from video records of classes, field notes by observers and class summaries written by teachers. Chapter 5 contains the analyses of students' diary entries to examine the outcomes of inquiry and traditional teaching modes while characterisation of these two modes of teaching, from students' perspectives, is presented in Chapter 4.

### 3.4.6 Questionnaires and interviews for students and survey for parents

An overview of aspects explored through questionnaires and interviews is given in Appendix D. The questionnaires administered at the outset of the program helped us understand the characteristics of the two groups as they entered the program

(Appendix E and F) and served as a baseline for changes, if any, reported by students and parents in the post-intervention questionnaires (Appendix G and H). Students' questionnaires were in English, interviews were bilingual, in Hindi and English while surveys to parents were given in both Hindi and English.

Open-ended questionnaires, followed up by semi-structured interviews (Miles & Huberman, 1994) contributed to an understanding of students' perceptions on the impact of the instruction and to understand their personal, subjective experience of the teaching-learning they underwent. All the interviews were conducted by the researcher (AK).

The questionnaire and interview questions administered to students and their parents were mostly those that were developed and piloted in the preliminary study (described in section 1.4), with a few additions and modifications. Reframing of questions was done, for instance, (a) to ensure more extended responses rather than mere yes or no answers (for example, by asking for an example or to explain their response) and (b) to increase comprehensibility according to students' context (for instance, when students' were asked if they commented on what the teacher or their classmates said in class and to what extent, we realised that students understood "commenting" in a negative sense as mocking and vehemently denied it, with most choosing the option "never"; so the question was revised to "Do you add to what the teacher/ other students say (like – I agree, I don't think so… etc.)".

The pilot interviews similarly helped the researcher to reflect on the process and better probe students' responses in a more neutral way, give them enough time to open up and speak, and rephrase the questions in multiple ways and switch to Hindi, as and when needed. The classroom observation sheet, the revised questionnaires and interview probes were shared with an external expert in science education for feedback and validation.

Mid-way interviews were conducted with all students after the winter camp in Phase I. A subset of students were also interviewed while following up the delayed post-instruction questionnaires (administered one month after the end of the summer camp). This questionnaire (Appendix I) was administered to 78 students from both the groups and 27 of these were interviewed further (Appendix J) to explore changes students may have experienced as a result of participating in it. The one-month gap was expected to give them some time to notice any changes, especially in their participation in the science classes at school.

## 3.5 Data Analysis

The analyses are multifocal, centering on different aspects of teacher-student interaction - discourse structures, questioning strategies, directives and personal pronouns (how teachers address students, tone of teacher's address) and involvement-oriented strategies. Mainly two qualitative methods of analysis of were used:

(1) **A microethnographic analysis** (Garcez, 2008) for data from classroom observation sheets and video-recordings enabled us to describe and illustrate patterns in classroom discourse and how teachers guide the discourse. Bogdan and Biklen (2003) describe microethnographies as case studies of very specific activities (e.g., teacher questioning) within small units of time (e.g., inquiry science lessons). They aid in investigating in detail what participants do in real-time as they co-construct talk-in-interaction. Ethnographic microanalysis of interaction or microethnography aims at descriptions of how interaction is socially and culturally organised in particular situational settings.

Microethnographers typically work with audio-visual data from naturally occurring social encounters to investigate in minute detail what interactions happen in real time. The analyses are then combined with other kinds of information, such as ethnographic data gathered through observations and interviews, to provide a variety of macro- and micro-views of how teachers and students interactively create and sustain the social realities in the classroom (Oliviera, 2010).

(2) **An emergent or bottom-up approach** (Thomas, 2006) was used for qualitative, thematic analysis of data from the student diaries, the questionnaires and interviews, that is, instead of pre-established codes, tentative categories emerged and were gradually grouped, regrouped and refined based on close examination of meanings and patterns in the data. The results of the qualitative analysis then enabled us to proceed to a comparative, quantitative analysis which mainly consisted of descriptive statistics; further tests of significance of differences were used where required.

After we analysed individual data sources, we realised that there were common themes and trends across and within a data set. For example, indications of students' level of engagement with their science learning were evident from their diary writing, class participation as well as from reports from students themselves (in responses to different questions in questionnaires and interviews) and reports from their parents, peer, teachers and the observers. We did a cross-comparison of the data sources and collated the evidence according to the themes that emerged. Such a triangulation, helped us arrive at a more robust picture of the outcomes and differences in them across the two groups in the study. Suter (2012) describes such a process of qualitative data analysis with the cogent metaphor of a kaleidoscope – grouping similar pieces of coloured glass (bits of raw data) and then comparing the pieces within piles and sub-piles which connect together to bring out the larger pattern.

We present the details of how particular forms of data were analysed in the succeeding sections.

### 3.5.1 Analysis of teachers' questions

Our analysis of teachers' questions was based on 12 classes from Phase I; it was a random selection of three classes of an hour each per teacher. However, the results reported in Chapter 4, are informed by observations from all the classes conducted throughout the year. The topics taught in these particular classes included units on environmental science, plant reproduction and human circulatory system.

A plethora of subtle cues from the classroom may guide a teacher to ask a particular question. The exact motivation the teacher has for asking a question at the moment it is asked is clearly not available to the observer. Therefore, using multiple sources of data (classroom observations, video recordings and teacher reflections), we attributed a category to the questions, taking into account the context in which they were asked i.e., the classroom interactions that preceded and followed the questions. In doing so, we have taken into consideration the three dimensions of teachers' questioning suggested by Carlsen (1991): the context of questions, the content of questions and the responses and reactions to questions.

Utterances with either the structure or intonation of an interrogation were taken to be questions. Each question was examined and coded for its intended purpose as well as its effect in the teaching episode (such as stimulating interest, invoking reasoning, directing attention). When there were more than one possible purposes, all of them were noted; the categories of questions are thus, we wish to emphasise, overlapping. Such polythetic classification schemes (which allow an observation to be assigned to multiple categories) are appropriate in handling the complexity of human discourse (Graesser & Person, 1994; Roth, 1996).

Tentative codes were initially developed by the researcher; the categories of questions that emerged from the coding and teachers' reports were then sequenced and grouped/ regrouped according to relatedness. Further the sequences of questions were analysed for emerging patterns. Discussions with the teachers and researchers led to refinement of the codes and the categories. All the questions were also coded as open or closed-ended questions to see their proportion in classes of each of the teachers. The definitions of open and closed-ended questions were adopted from Graesser and Person (1994) which are described in the literature review.

The categories of questions, their descriptions and examples (as reported in Chapter 4) were shared with another researcher who then independently coded the questions after viewing the video records of the classes, using data in the observation sheets. There was around 90% agreement in coding by the two researchers. The differences were reviewed, revisited in the context of the episode of teaching (aided by an overview of the teaching unit) and easily resolved through discussions among the research group.

### 3.5.2 Analysis of students' diaries

We examined students' written descriptions of the teaching as well as of what they had learned from it, in order to add another perspective to our characterisation of the teaching-learning in the two modes in the study, as well as to explore any differences in their outcomes that could be gleaned from the diaries.

Reflective text written on each day was counted as one diary entry. The date of the entry (from the dates that had been recorded by students) and the tone of the diary writing helped locate and demarcate diary entries from class notes and homework in the notebooks. A quantitative analysis of the entries - the total number of diary entries per group, the average number of words that a student wrote in an entry and the distribution of entries over the course of the intervention - served to discern the engagement levels in the two groups. A non-parametric statistical test, the Mann-Whitney U test, was used to check if there was any significant difference in the distribution of average number of words per student for the two groups. Descriptive statistics for rest of quantitative data showed large differences so that the use of further tests for significance of differences was rendered unnecessary.

Qualitative analysis involved inductively and recursively examining each entry to see what aspects of the class interactions were recorded and how. The initial three main categories that persistently emerged in the entries were "describing what was done", "summarising what was learned" and "expressing what was felt". We found these coding categories that emerged from our data to be very similar to those used by Audet, Hickman and Dobrynina (1996) ("storytelling", "knowledge claims" and "affective categories") to analyse undergraduate students' computerised group learning logs. These authors in turn had found that their preliminary coding categories resembled the method of discourse analysis by Newman, Morrison & Torz (1993) which they then adapted and extended to include affective features of learning logs. May and Etkina (2002) also analysed college students weekly reports in terms of what they learned ("formula", "vocabulary", "concept" and "skills") and how they say they learned it ("observed", "constructed from observation", "reasoned", "learned by doing" and "from authority"). It is interesting that different researchers, working with different sets of data, independently arrived at similar categories, indicating that this is a reliable way of characterising students' reflective writing.

Iterative reading and further coding of these categories led to the coding scheme that is summarised along with representative examples in the results chapters. Further details of the coding, the categories and their frequencies are provided along with the results. We note that this coding scheme has a high degree of objectivity; it is not very interpretative and therefore less prone to biases.

Students' summaries of what happened in class were coded according to the form - as either declarative sentences or as questions. The instances of "what was learned" were coded for their conceptual understanding, manner of describing ("personalised" in their own words or repetition of facts, definitions and principles given by the teacher) and source of the knowledge claims (from what was told or explained by the teacher or students' own reasoning). The latter two categories brought out the differences in students' conceptions of learning science. The coding was done by the researcher. In order to check the inter-rater reliability of the coding scheme, a research associate who had earlier been a teacher (but with no prior participation in this study) coded 15% of the data independently for these two categories and there was 86% agreement between the two researchers. This agreement is fairly high considering that she was not present during the teaching; she explained that what informed her coding decisions was whether formal definitions or principles seemed reproduced in students' writing or seemed reasoned out in students' own words. Students' knowledge claims were also examined for explicit statement of a sense of shared epistemic authority with the teacher, and instances providing tentative solutions to the question at hand.

The conceptual correctness of the entries related to content learning were analysed first by the researcher. Then the statements showing incorrect understanding from both the groups were collated together, along with some correct statements, divided into three parts and evaluated by three other researchers, each of whom looked at statements in the area of his/her content expertise. There were only a few differences among the researchers; these differences were easily sorted out through discussion. Statements that were judged to be even partially correct were taken as correct.

The affective responses to the teaching were analysed to find which aspects of teaching-learning were liked or disliked by the students in the two groups. We also found indications of affective outcomes, namely, a feeling of self-efficacy and students' engagement with learning. Evidence for students' engagement levels was additionally backed by data from other components of students' notebooks such as students' spontaneous notes and questions written during class. In the Chapter 4 and 5, we illustrate our findings with quotes from students' diaries. It is likely that a quote given to support a particular claim implies several other aspects; we have used it to highlight the most prominent aspect.

### 3.5.3 Analysis of responses in questionnaires and interviews

The responses were closely read and significant categories or themes, often incorporating actual phrases from the responses, were noted. After iterative reading and coding, the categories were compared quantitatively to look for any difference across the inquiry and comparison groups.

### 3.5.4 Analysis of students' participation

Quantitative data on students who participated spontaneously in whole-class discussions in Phase II was collated from the classroom observation sheets. This was analysed quantitatively to discern the patterns of participation over time in the two sets of classes and also to explore which are the students that participate more in them.

## 3.6 Content of the Instructional Units

A few topics, being developed for the curriculum project (for example, units on immediate environment and taxonomy refered to in the results section) were novel and had no direct parallel to the standard textbook for the particular grade the students were in. Other topics (for example, human circulatory system and reproductive system in plants) were chosen from the standard, central board textbook, for which parallel units were being developed or refined for the curriculum project; these topics were not necessarily dealt with in the same manner as in the text and were taught in the program before they were taught at school. In both groups, each teacher taught the units which fell in her area of training - physical science or biology.

**Phase I:** Six units were taught in this phase, transactional details of which are given in the Table 3.2. Except for the first unit on environment education, all the other topics were from within the existing curriculum for the grade.

Components of the unit on ‘Our Immediate Environment’ are described here as an example of the make-up of the units (1) Discussions around what is environment? Who should save the environment and from whom? (2) Aesthetics - paying more attention to the surroundings and thinking what one likes or does not like about their surrounding areas (3) Brainstorming on problems like open drains, garbage, disease spreading vectors like mosquitoes and flies; discussion about specific areas around their residence, for example, where do mosquitoes breed (4) Mosquito as a disease vector – life cycle, observation of the different development stages, discussion and activities around students’ questions, diseases transmitted by mosquitoes (5) Rain measurement and (5) Reasons for urban flooding.

**Table 3.2**. Content of lessons taught in Phase I

| | **Inquiry group** | | **Comparison group** | |
|---|---|---|---|---|
| **Instructional unit** | **No. of lessons** | **Teacher** | **No. of lessons** | **Teacher** |
| Our immediate Environment | 18 | IJ, 1 by IK, 2 by AK | 10 | TN, 2 classes by SM |
| Human circulatory system | 12 | IK | 7 | TP, 1 class by AK |
| Internal transport in plants | 5 | IK | 4 | TP |
| Reproduction in plants | 10 | IK | 6 | TP, 1 by AK |
| Introductory chemistry and biogeochemical cycles | 9 | IJ | 10 | TP |
| Volume and density | 4 | IK | 6 | TA |
| **Total** | **58** | | **43** | |

**Logistical issues:** Teacher TN (one of the teachers for the comparison group in Phase I) canceled a lot of classes due to health and other personal problems. Due to this, seven classes of the comparison group, were canceled at short notice between 15/07/09 to 09/09/09. Meanwhile we looked for another teacher and asked TN as well as the school principal, some other teachers and colleagues to help us find a teacher for this purpose. This was one of the reasons for the comparison group having lesser contact period than the inquiry group in Phase I, especially for the unit of ‘Our immediate environment’.

**Phase II:** Two units, one on the concept of density and the other related to fish were taught in both the classes. In both groups, each teacher taught the units which fell in her area of training - physical science or biology. The unit on density basically consisted of teaching (a) prerequisite concepts of volume and mass and the inverse relation between these two (b) density as the property of a substance and relative densities of different substances (c) floating and sinking of objects and (d) the Archimedes’ principle. The unit on fish (with the larger aim of teaching classification) consisted of (a) Fish as a unique group of animals different from others i.e. ‘What makes a fish a fish?’ (b) similarities and differences between different taxonomic groups of fish (c) internal structure of fishes with special attention to gills and the swim-bladder and (d) respiratory and circulatory systems of fish in comparison to corresponding human systems.

Students had very little or no prior exposure to these topics in the school curriculum they had undergone before participation in the study: The topic on fish is not covered at all in their school curriculum; the concept of volume is cursorily treated in the mathematics curriculum as Volume = length × breadth × height. We note that both topics offered rich opportunities for exploration (whether hands-on or otherwise), experiments and demonstrations, and for helping students arrive at conclusions through analysis and reasoning based on their observations.

The time taken for teaching the units was different in the two modes (Table 3.3). The teachers in the comparison groups took less time for common units, and used the extra time they had to teach additional units (cells, electricity and magnetism). The difference was pronounced in the unit on density which is a difficult concept for middle school students to grasp. Its in-depth exploration requires a considerable investment of time and planning on part of the teacher, and involves many prerequisite concepts and students' mathematical as well as hands-on skills. Notably, in the discussions prior to the intervention period, teachers of both groups had gone over, in detail, the difficulties students may have with this concept.

**Table 3.3.** Number of classes taken by teachers of the two groups for the different units in Phase II

| | **Units** | **Number of classes** | |
|---|---|---|---|
| | | **Inquiry group** | **Comparison group** |
| **Biology Units** | Fish | 7 | 10 |
| | Circulatory and respiratory system + Cell biology | 8 | 4+3* |
| | **Total** | **15** | **17** |
| **Physics Units** | Density | 22 | 9 |
| | (Volume) | (3) | (1) |
| | Electricity and magnetism | - | 7 |
| | **Total** | **22** | **16** |

* Teaching about cells was an integral part of the unit in inquiry; in the comparison group since teachers completed the unit on circulatory and respiratory systems, they taught further on the internal structure of cells.

## 3.7 Methological Considerations

### 3.7.1 Out-of-school context of the study

The study could not be conducted within the school settings for logistical constraints (for instance, schools would not allow for the long intervention required by the design of the study). Hence we needed to conduct an after school/ summer program. This had advantages in terms of random assignment of students to the two groups, which is difficult to do in a regular school setting, and flexibility over time-on-task, being free from prescribed obligations of government-prescribed curricula. As a voluntary summer program, however, it had limitations, stemming from its difference from the formal, school settings. It was conducted outside of traditional school setting, free from obligations of prescribed school programs, possibly limiting transferalibity of the findings (we further discuss this limitation and the measures we took to address it in section 6.3), Also, there were no grade incentives for students like those in formal settings, to foster students' involvement. Nevertheless, as the program drew on voluntary participation, students could be expected to have rather high interest/ intrinsic motivation towards learning science, which would also be different from usual school classroom which would have a range of students with differing levels of interest in science. Inclusion of a comparison group in the study, would address some of these confounding issues, for example, if students in both the groups attended the classes voluntarily, out of high level of interest, then any differences in their level of participation in the class could be likely due to the differences in instruction.

### 3.7.2 Conundrums involved in having different teachers for the two groups

A methodological issue that is a concern in comparative studies such as ours is whether both groups in the study should be taught by the same or different teachers. On one hand, it may be argued that aspects of a teacher's personality may well affect outcomes in the classroom, and therefore comparison of outcomes between groups taught by different teachers is not advisable. On the other hand, it could it argued that teachers would have a proclivity to teach through a particular teaching mode and therefore may be biased against the other.

Both approaches have been taken by researchers; in the study by Wilson, Taylor, Kowalski and Carlson (2009) the same teacher taught through commonplace and inquiry methods while in the study by Cobern et al. (2010) different teachers taught the two groups that were being compared. Our stance is that the same teacher cannot do justice to teaching in both the modes, and outcomes will be affected by the bias due to the teacher's preference. Indeed, teachers in this project who were trained to teach through inquiry reported that they cannot switch to traditional teaching even if needed. We have focused in our study on what the teacher does in class; after all, the often intangible qualities of a teachers' personality mediate outcomes through the way they are manifested in the teaching practice.

Having two different teachers in each of the modes takes care of the influence of the teacher's individual personality to some extent. Also, as reported in Chapter 5, teachers in both the groups were perceived by their students to be good at teaching, friendly and were well liked by them.

### 3.7.3 Difference in the two teaching modes in the study

Teachers of both the groups in the study had the same starting point in terms of content and the teaching time available. They had access to the same resource material and shared ideas for conducting activities. They had the same support in preparing for and conducting hands-on activities in class. However, transaction of the material was entirely left to them. Teachers had the freedom to change the sequence and add to or omit parts of the lesson planned. The essential difference between the two modes of teaching for us was, as Cobern et al. (2010) put it, 'how students come to the concept', that is whether students grapple with and develop the concepts from exploration, with the teachers' guidance and support or whether the concepts are explained to them by the teacher.

Going further in the study, we explored how these two different modes of teaching were transacted in our study. We illustrated this with a sketch of the teaching-learning sequence for the topic of 'What makes a fish a fish?' (Figure 4.1 and 4.2 in Chapter 4). This sequence depicts how in traditional teaching, students were engaged in activities and questioning before receiving explanations while in the inquiry mode there was a constant dialogue and the teacher tried to stretch students' thinking through questions and counter-examples, encouraging students to come up with criteria for "What is a fish?" and helping them refine these criteria.

Teaching through inquiry is often associated with first-hand exploration by students. However, there were many demonstrations too by the teacher in the inquiry. One reason for some activities being conducted as demonstrations, instead of student investigations, was being pressed for time especially in the summer camp. Secondly, they could be easily inserted, to capture and hold interest, in between whole-class discussions which were used a lot. Whole-class discussions are considered a powerful teaching strategy, especially when students are being introduced to the inquiry mode of teaching-learning (DeBoer, 2006). Similarly, science demonstrations also have the potential to provide a beginning point for experiencing science, talking about experiences, proposing questions, suggesting patterns and testing these questions and patterns (Milne & Otieno, 2007).

## 3.8 Trustworthiness of the study

Efforts were also made to gather enough data to provide thick descriptions (Lincoln and Guba, 1985) and to preserve an audit trail in the form of a field diary by the researcher. Other techniques that allowed the researchers to work towards improving the trustworthiness of claims made in the study involved prolonged engagement/ immersion in the field (observation over a long period), observation by two researchers, collecting multiple sources of data, debriefing with the participants (informal and formal lesson conversations with teachers helped the researchers better understand what the teacher did during the class and why) and providing detailed description of the data analysis including measures taken to establish inter-rater reliability and expert validation.

# 4

# Characterising Science Teaching through Inquiry and Traditional Teaching Modes

## 4.1 An Overview of the Teaching Modes Observed

As part of this research, science teaching was observed in three settings: (a) science classes in the study that were taught through inquiry (b) those of the comparison group in the study and (c) science classes in the school attended by students of Phase I.

We start this chapter with a descriptive account of the science teaching at the school; the rationale to observe these classes at school (and include an account here) was twofold: to closely understand the nature of school science that the students in the study have experienced and secondly to note any changes in the way students participated in their school science classes after attending the classes in this study. Subsequently, the two modes of teaching transacted in our study are illustrated with sketches of the teaching-learning sequences for a unit titled 'What makes a fish a fish?' (Figures 4.1 and 4.2). These were derived from video records and transcripts of the classes.

### 4.1.1 Traditional science teaching at school

This account is based on 24 classes observed over a year, in three different divisions of Grade 7 of the school to which students of Phase I belonged. It was an urban school affiliated to the Central Board of Secondary Education. It had good infrastructure in terms of classrooms and laboratories. There were around 35 students in a class. The teachers were qualified with a Bachelors degree in Education and a Masters in Science; two of the teachers were permanent while one of them was on ad-hoc basis.

The teaching in these classes was typical of the classes the researcher has experienced in her own schooling and in the class observations over the years. It was also similar to accounts of mainstream schooling and science teaching in India, reported in the literature (Bansal, 2014; Choksi, 2007; Chunawala & Natarajan, 2011; Kumar, 2005; Sarangpani, 2003; Singh, Shaikh & Haydock, 2019; Thapan, 2014; Vijaysimha, 2013).

The teaching was highly structured around the study of prescribed textbooks and examinations conducted on the basis of these textbooks. Each chapter from the science textbook took five to six classes, of 35 minutes each, to be transacted. Teaching a chapter involved three activities: the teacher or one of the students read the chapters (for two to three classes), a few paragraphs or sentences at a time. The teacher explained some parts wherever she felt the need to and asked some questions to check students' comprehension. Then questions given at the end of the chapter were answered and written in the notebooks (for around three classes). The students tried to answer the questions from what they had understood but finally the teacher dictated the answers (or sometimes, wrote them on the blackboard) and students noted them neatly in their notebooks. This was followed by a revision of the questions and answers as exams approached. The whole focus of teaching was establishing and endorsing the right answers which should be written in the examination.

Notably, there were many activities and experiments in the textbook. At times they were merely read out along with the rest of the chapter. When they were conducted, many a times they were done at a different time in the lesson sequence, disjunct from, and much later than, the activity of reading out and understanding the related text. They were conducted either in the school laboratory or in the class, generally as demonstrations with a few students helping out the teacher in conducting them. The nature of most of these activities, and the way they were framed, did not necessitate active student investigation and involvement, often reducing students to mere spectators, observing for instance, dough rising up with the addition of yeast or slides under the microscope or burning of magnesium wire or displacement of copper from copper sulphate after addition of iron.

Students seemed to enjoy the revision sessions conducted after completion of a chapter and again in the classes just before the examinations. When a question was asked, usually several children knew the answer and there was always a lot of excitement in the class, with each child being eager to be called on to answer.

Students would begin to repeatedly call out: "Teacher! Teacher!" until someone was nominated to answer. It was somewhat intriguing that they were so excited to answer even questions that involved very mundane knowledge or asked for repetition of something that was just told by the teacher. This was perhaps because it gave them opportunities to *show-that-they-know* (Sarangpani, 2003) since that is what the teacher seemed to be looking for. Those who did not know the correct answer were chastised, and sometimes kept standing for some time as a punishment, and told to pay more attention next time.

Students hardly had choice in any of the matters related to the teaching-learning that went on. Nevertheless, they generally seemed very accepting and compliant, and the class processes ran like clockwork, with the teachers hardly having any difficulty to manage the class. The exercise of authority was palpable for all teacher-student interactions; the teacher asked the questions, almost all of the time and nominated which student will talk (irrespective of whether they volunteered for answering by raising their hand or not) and evaluate the answers as right or wrong.

Here is a small episode from a class on the chapter 'Reproduction in plants' followed by a brief interactional analysis of the episode that draws out the features of commonplace science teaching that we observed.

**Episode 4.1** During a lesson on 'Reproduction in plants', the teacher reminds the students that in an earlier lesson they had seen bread mold growing on a moist slice of bread kept for days.

| Teacher's initiation | Who responded? | Student's response | Teacher's feedback |
|---|---|---|---|
| How did it come there? | Ss | Spores form | Spores come there, they are not formed. They fall on the bread and if they get a favourable environment, they grow. (The teacher then describes what are spores and sporangia) |
| What is the other name for bread mold? | S1 | Sporangia | No, Rhizobium |
| You remember, I had brought some small plants last time? | Ss | Fern | They had spores, no flowers. |
| They reproduce by ...? | Ss | Spores! | ... whenever conditions are favourable. This is an asexual form of reproduction without formation of seed, only one plant involved. |

The interaction was made of typical Initiation-Response-Evaluation (IRE) sequences, mostly disconnected from each other, or what Lemke (1990) calls, the triadic dialogue. The questions were factual, closed-ended, rarely challenging students above the remembering level. In case students did not give the correct answer, the teacher gave it promptly and moved forward. There was hardly any attempt to probe students' answers or convince them with any warrants as in the case of students' answer that spores form on the bread; the truth value of the statement that the teacher made (that spores come there and are not formed there) came from the teacher as the epistemic authority. Over the lesson, students' attention seemed to decrease with time but they continued to respond in unison. The conversation exchanges in the classroom seemed to preserve the social structure of 'the authoritarian teacher-compliant students' relationship (Hanrahan, 2006; Sarangpani, 2003).

The interactions in these classes involved little meta-talk, not even in the context of classroom management - there was no checking that students were ready to move on to the next stage of the lesson, or checking if students had understood the concept, except the occasional "Is it clear?" from the teacher after which she moved on even without any response from students, within seconds, to the next sequence of teaching. Students mostly spoke in a chorus and were rarely addressed by the teacher individually.

**Descriptions of science teaching at school from students: From responses to a question in the post-instruction questionnaire:**

We give here a gist of students' descriptions and views as a window into their experience of school science, that added to and corroborated our observations. Responses from the two groups of students in the study are clubbed, in this section, for this purpose.[1]

In a post-instruction questionnaire, administered at the end of Phase II, we asked students:

1 There were some differences in the aspects of teaching reported and the kind of changes that students in the different groups wanted; these are discussed in the next chapter (Section 5.6.2)

> The following questions are about the science classes at your school: a) What *changes* would you like to happen in your school science classes? b) What things would you like to be *added* to your school science classes? c) What would you like to be the same in your school science classes (not changed)?

Students reported that they disliked "teaching from the textbook" and complained, "In our science classes, teachers read the chapter and do not show us experiments." They suggested "Not to teach us everything by explanation but by experiments" and "… want the discussions on subjects indirectly related to the chapter."

There were a lot of changes that students said they would like to see in their regular science classes at school and they were very vocal about their concerns. Some responses, best represented in direct speech: "The classes should be interesting and the number of students should be less", "They should reduce study burden and frequent tests", "give less notes", "teach more interesting topics", "teachers should explain the topics nicely", "In school, there is only writing and studying as if we have to win a race." "They should not only try to complete the portion but try to increase the interest & knowledge of students", "They should be more interesting, teaching pattern should change."

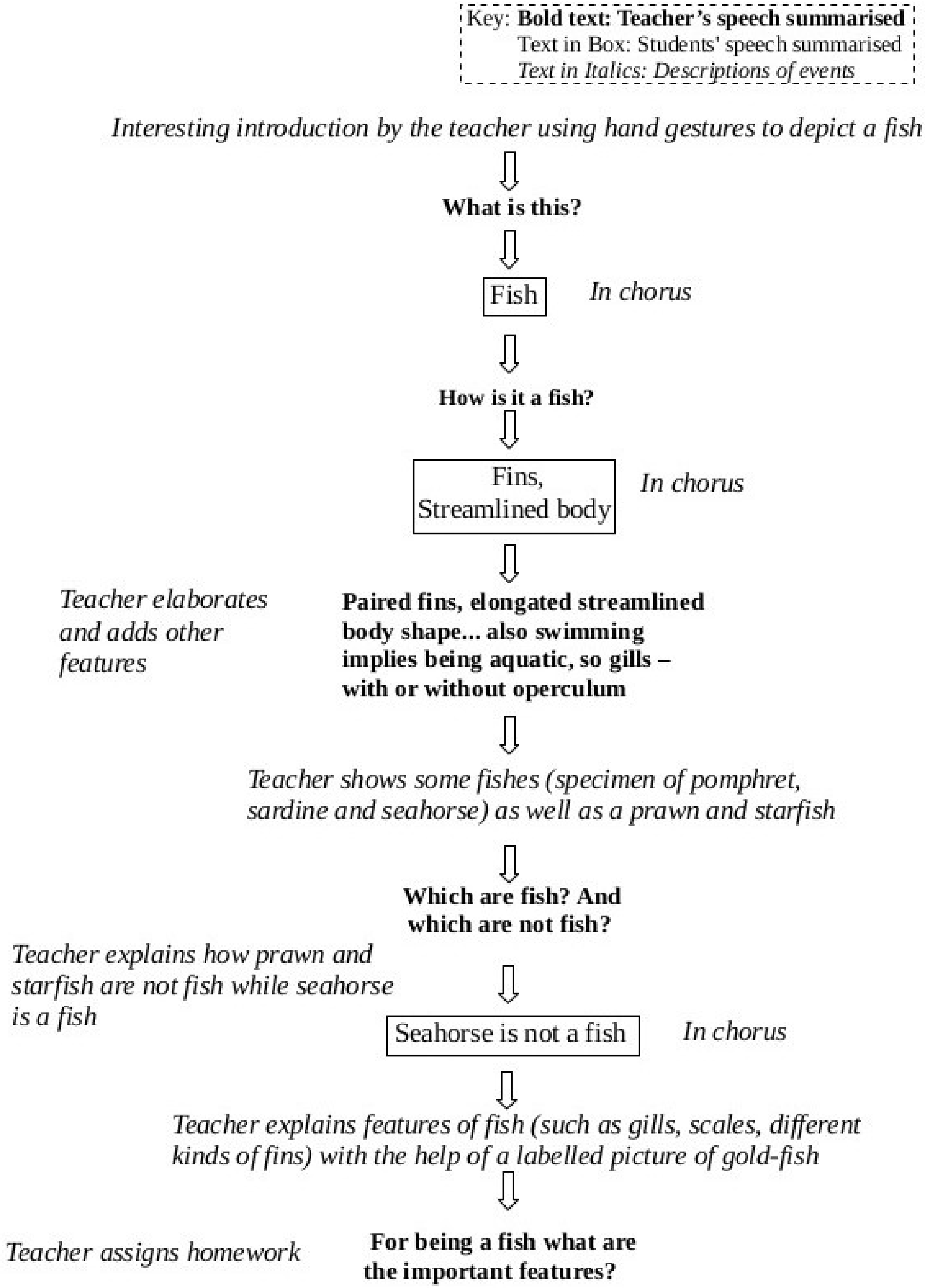
Students also noted aspects of teacher-students relationships that bothered them: "Teachers should pay attention to each child", "School science classes are also good but teachers pay more attention only towards the first benchers & the class toppers not on the weak students (some teachers only)"; "Teachers should have interest in teaching science but till now in my experience teachers only like punishing students. They pay no attention on teaching". Students asked for more activities, experiments, use of visuals/ diagrams, and more active participation: "We should do experiments in the lab ourself." Interestingly, some of them specifically mentioned that they did not want their teachers to be changed since they liked them. So, they seem to be able to separate the teacher's personality from the pitfalls of the teaching method.

### 4.1.2 Traditional science teaching in the study

In the comparison group, the teacher usually began the lesson with an interesting question, setting the stage for the instructional sequence and getting students' attention. She kept the class interactive with a lot of question-answer exchanges and included hands-on activities and demonstrations. For example, in the vignette depicted in Figure 4.1 she made the effort to bring actual specimens of various animals and used them as an aid while explaining about the features of a fish. However, though the teacher asked the driving question, she gave away the explanation herself very soon.

The activities remained as add-on with hardly any discussion taking off from them. The level of interaction and student participation was illusory since the rights, roles and responsibilities of students were limited. There were very brief answers, mostly in unison, from students. The teacher seemed to be playing the 'guess the answer in my head' game (Amos, 2002) - she asked the questions and as soon as she got the answer she expected, she moved on; in case, she got an incorrect response, she promptly corrected them. This was also evident in the teacher's ample use of questions of the 'fill in the blank' format (eg. "It's not a fish because it does not have...?") and rhetorical questions (e.g. "It is not a fish, ok?"). She tightly controlled the discussion and was the sole authority to ask questions and to respond to what students said. Thus, though it was interactive and included activities, the teaching in this group was essentially authoritative (Mortimer & Scott, 2003) and transmissive.

**Figure 4.1:** Flowchart of teaching sequence for "What makes a fish a fish?" in traditional mode: Explaining the concept with the help of activities



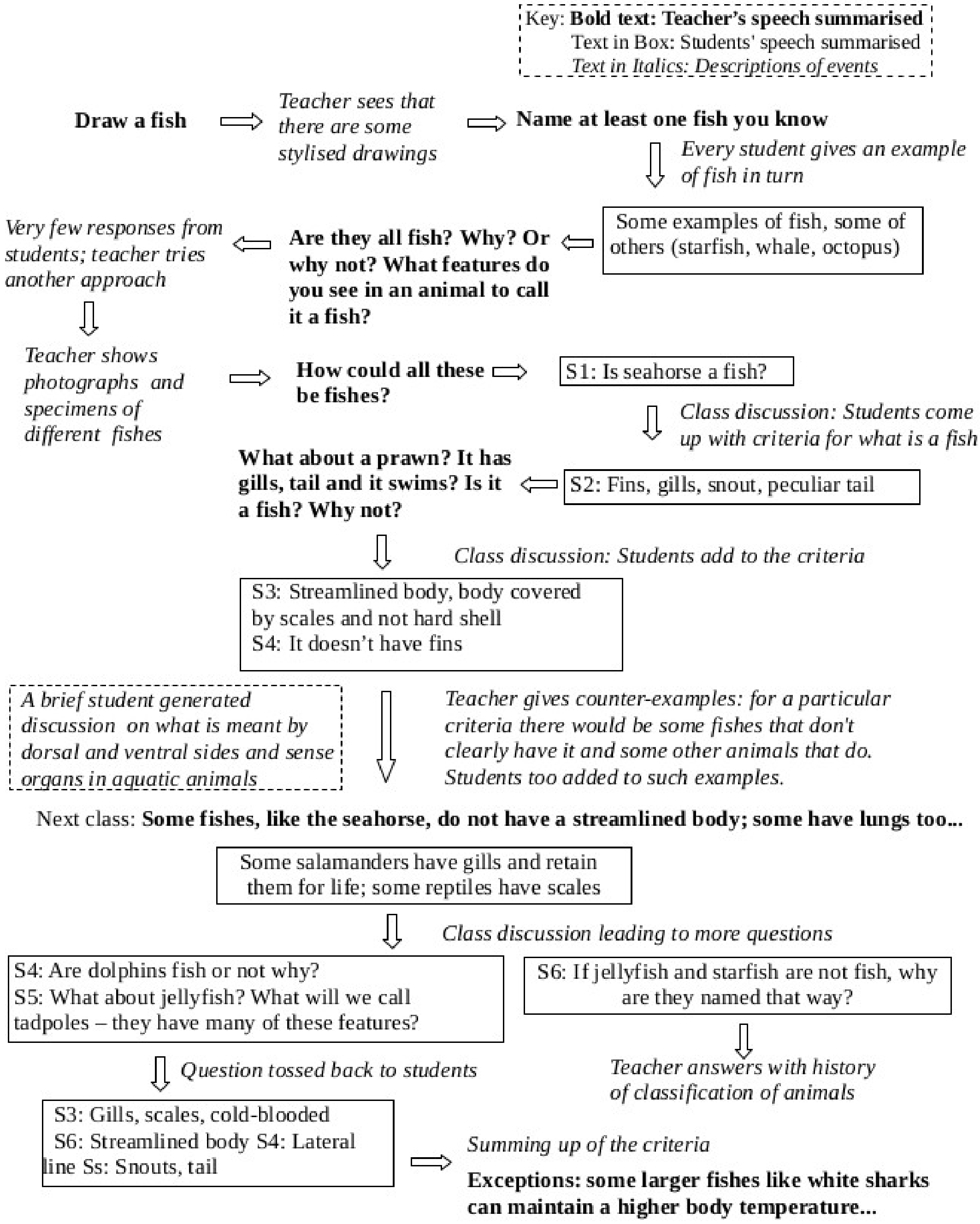
### 4.1.3 Science teaching in the inquiry classroom

Here, the explanations were essentially co-constructed by the students, guided and supported by their teacher, as illustrated in the teaching-learning sequence in Figure 4.2. The teacher consistently explored students' thinking on the topic, asked them to elaborate and justify their responses, helped them to articulate and reflect on their own and their peers' thinking and drew their attention to aspects they had missed. The observations from the activities served as anchor points for the class discussion and this in turn led to the students making far richer observations when they went back looking for more observations to back their propositions.

Even when there were incorrect responses initially (like whales and starfish being considered as fish in the illustrated sequence), the teacher did not rush to correct them but posed further questions to make students think ("Are they all fish? Why or why not?"). On getting correct but brief answers, she reframed her question in an alternate way to get reasoned responses. Even better, she responded to answers like "it (seahorse) is not a fish" by guiding students to observe and gave them time to think and discuss about it amongst themselves before resuming the whole class discussion. Thus, rather than quizzing, the teacher's questions in this class continually explored, challenged as well as supported students' thinking and progressively built on students' responses. This resulted not just in multiple individual student voices in the class but the direction and pace of the lesson was contingent on students' ideas and questions.

In our class observations, teachers' questions in each of the two modes of teaching seemed to manifestly serve different roles and the pattern of questioning brought about a difference in how the lesson progressed. Considering the significance of teachers' questions, we attempted a characterisation of inquiry teaching that focused on them.

**Figure 4.2:** A flow chart of the teaching sequence for “What makes a fish a fish?” in inquiry mode: guiding students to arrive at explanations using activities and discussion. Note: Sn indicates student ‘n’, Ss indicates multiple student responses.



## 4.2 Teachers' Questions and their Purposes

Inquiry can be conceptualised as question-driven learning; it is a complex process which includes investigating a problem or phenomenon with initial questions, thinking of ways to answer them, looking for evidence, coming up with explanations, evaluating and communicating them and going back to the original question which could lead to several other questions. Carrying out scientific inquiry needs not only the recall of requisite background knowledge but also critical thinking skills which are only in their early stages of development in students of the middle grades (Flick, 2000). Teachers have a key role in supporting and developing these skills in the classroom. They provide the necessary *cognitive scaffolding* - helping students "to solve a problem, carry out a task or achieve a goal which would be beyond their unassisted efforts" (Wood, Bruner & Ross, 1976, p. 90). Questions and prompts that teachers use to structure classroom interactions are significant forms of such scaffolding. The kind of questions teachers ask and the way in which they are asked can, to a large extent, influence the nature of students' thinking as they engage in the process of constructing scientific knowledge (Chin, 2007) and therefore can become indices of the quality of teaching (Carlsen, 1991; Smith, Blakesee & Anderson, 1993).

The analysis here is based on 12 classes (from which the examples in Table 4.1 are drawn) - a random selection of three classes of an hour each per teacher. However, observations from all classes conducted throughout the year have informed the analysis of teachers' questions in this study. The topics taught in these particular classes included units on environmental science, plant reproduction and human circulatory system.

**Table 4.1** Progression of teachers' questions in inquiry classrooms

| Kinds of Questions and their codes | Examples |
|---|---|
| **1. Exploring pre-requisites/setting the stage** | |
| Ft - Factual recall (from what was taught) | How many milliseconds make a second? |
| Fw - Factual recall (from child's observation) | What do water drops look like? |
| Exp - Eliciting students' experience | Where do you go on picnics? |
| Pre-gauging understanding of pre-requisites | Suppose I tell you to go and find how parts of the school ground is covered by concrete, will you be able to do it? |
| Er - Encouraging wider response | Each of you think of an example of stagnant water. |
| **2. Generating ideas and explanations** | |
| A - Directing attention | Did you see anything different when a drop broke up? |
| Ex - Asking for explanation | How does water enter the wells? |
| G - Asking for reasoned guesses | Which, do you think, are the youngest [larvae]? |
| O - Drawing on what has been observed | How many kinds [of larvae] did you see? |
| Ob - Calling for further observation | Do the pupae move in the same way [as larvae]? |
| Op - Asking for an opinion or stance | Suppose we have to rank these places from 1 to 10, what rank would you give the place you selected? |
| Er – Encouraging wider response | Now each of you ask a question about mosquito larvae. |
| **3. Probing further (initial student responses)** | |
| C – Clarificatory | How can that be? What kind of cells? |
| El - Asking for elaboration | So, what would happen? |
| J - Asking for justification | You said raindrop sizes are different. How do you know? |
| Con - Pointing out contradictions | When they are larvae, they are not [C-shaped], right? |
| H – Hinting | We have to think what we mean by "dirty water". |

| | |
|---|---|
| **4. Refining conceptions and explanations** | |
| T - Asking for a way to test or find out | How can we find out? |
| Rs – Calling for reasoning | Will the level in the both containers be the same? |
| I - Asking for inference | Why did we do this experiment? |
| Cor - Helping to make connections | Both pulse and heart rate increase? Are they related? |
| As - Presenting aspects missed by students | If we have a cold, we can't smell things; then is it ok to have garbage around? (Smell is not the only reason to avoid having heaps of garbage around) |
| Me - Invoking reflective thinking | What kinds of places you like for picnics? Why? |
| Fl – Pointing out flaws in the argument | Will only some organs get de-oxygenated blood? |
| P - Driving towards the focal point | So, what was the difference in shower and rain? |
| Qt - Quantitative thinking | More than double or less than double? |
| L - Focusing on language | Do you know any words starting with 'cent'? |
| Vs - Aiding in visualisation | What if we cut it? How will the vein look from here? |
| **5. Guiding the entire class towards the scientific concepts** | |
| Er - Encouraging wider response | That's what S1 thinks. I want everyone to answer. |
| Vp - Urging to consider a variety of viewpoints | S8 and S7 wrote that stigma is sticky. How do we know? We don't feel that when we touch it. |
| S - Encouraging students to take up a side | Do you agree with S7? |
| Ts - Taking stock | How many of you rated it as 10? |
| Re - Rephrasing students' questions | S1 is asking - do all flowers turn into fruits? |
| **6. M - classroom management** | Do you need a minute to think about it? |

A plethora of subtle cues from the classroom may guide a teacher to ask a particular question. The exact motivation the teacher has for asking a question at the moment it is asked is clearly not available to the observer. Therefore, by using these multiple sources of data we attributed a category to the questions in the context in which they were asked i.e., the classroom interactions that preceded and followed the questions. In doing so, we have taken into consideration the three dimensions of teachers' questioning suggested by Carlsen (1991): the context of questions, the content of questions and the responses and reactions to questions.

Each question was examined and coded for its intended purpose as well as its effect in the teaching episode (such as stimulating interest, invoking reasoning, directing attention). When there were more than one possible purposes, all of them were noted; the categories of questions are thus, we wish to emphasise, overlapping. Such polythetic classification schemes (which allow an observation to be assigned to multiple categories) are appropriate in handling the complexity of human discourse (Graesser & Person, 1994; Roth, 1996). Tentative codes were initially developed by the researcher; the categories of questions that emerged from the coding and teachers' reports were then sequenced and grouped/ regrouped according to relatedness. Further the sequences of questions were analysed for emerging patterns. Discussions with the teachers and between the researchers led to refinement of the codes and the categories.

All the questions were also coded as open or closed-ended questions to see their proportion in classes of each of the teachers. The definitions of open and closed-ended questions were adopted from Graesser and Person (1994) which are described in our literature review.

The categories of questions, their descriptions and examples (as reported in the paper) were shared with another researcher who then independently coded the questions after viewing the video records of the classes, using data in the observation sheets. There was around 90% agreement in coding by the two researchers. The differences were reviewed, revisited in the context of the episode of teaching aided by an overview of the teaching unit and easily resolved through discussions among the research group.

### 4.2.1 Teachers' questions in inquiry classrooms

Our analysis of teachers' questions led to five broad categories, apart from management questions, as given below. The sub-categories within the categories and their examples are given in Table 4.1. For clarity in illustrating and explaining these questioning strategies, the purpose most prominent for each question has been noted in the table although one question can and many times does serve more than one purpose.

***Exploring pre-requisites/ setting the stage:*** These questions basically gave feedback to the teacher about the familiarity and difficulty level of the topic. While this category of questions included closed-ended questions, there were also open-ended questions eliciting students' personal experiences, setting the stage for the class. Teachers (more often in the inquiry classes) used these questions as wonderment questions - as starters for discussions. For instance, Teacher IJ asked "How many milliseconds make one second?" after students were shown a video of falling raindrops in slow motion spanning seconds, to draw attention to how short a millisecond is, inspiring awe.

Also, the teachers asked a series of questions, especially in classes in which a new concept was being introduced, to gauge understanding of the pre-requisites needed for teaching the intended concept. For example, for a unit related with rain measurement for which children needed a grasp of the concept of area and volume, the teacher found she needed to teach about areas; after this was done through a series of activities and exercises, the teacher drew a series of shapes with different fractions of each marked out (in increasing level of difficulty) and asked "...[which fraction] has more area? How many times? Explain how?", then went on to ask "If I tell you to go and find what fraction of the school ground is covered by concrete, will you be able to do it?" Interestingly, many students responded with a "no" which led the teacher to further dwell on this concept until it was understood.

***Generating ideas and explanations:*** These questions further stimulated interest and provoked thought. They were usually in the context of activities, immediately preceding or immediately following them; they helped students to articulate their observations and make further close observations. They solicited initial attempts at explanations from students. This is crucial for the teacher to gain further insights into students' pre-conceptions and decide at what level to pitch her questions and the amount of guidance needed. In inquiry classes, asking for an opinion or a stance on the issue at hand also helped to generate ideas for discussion. This category of questions also included those through which teachers encouraged wider participation asking for guesses, examples and questions from everyone in the class. Note that this sub-category features in various forms across our five major categories. It is of particular importance in the last category, and is possible then only because this culture of engaging the whole class had been inculcated from the beginning.

***Probing further (initial student responses):*** These questions probed students' initial ideas. In the discussions that followed, often there were questions from students. More often than not, the teacher responded to these questions with a question - a 'reflective toss' (van Zee & Minstrell, 1997). We found such reflective tosses serving a variety of purposes - asking for clarification, elaboration and justification of their comments, pointing out contradictions with what has been observed or discussed in class, providing a hint to guide the student towards the answer and, in the true spirit of inquiry, asking the student if the student can think of a way to find out the answer. We have put these questions under this category since they probe students' ideas as they are forming. Thus, questions in this category begin with eliciting students ideas and seamlessly lead to the following category; however the emphasis in this category is on students' initial ideas.

***Refining conceptions and explanations:*** There was a rich variety of ways in which the teachers provided scaffolding to extend students' thinking and refine their thoughts. We illustrate this with the following episode in a class taught by Teacher IJ. The context was a unit on the measurement of rain - how odd that it should be measured in units of length! Does the cross-sectional area of the rain gauge matter? Does its shape matter? In an earlier class, a homework task had been given - place cylindrical containers of different cross-sectional diameters at two points under the shower and see if the height of water was the same in both.

Prior to this episode, one student (S7) had said that identical containers placed close to each other in rain would collect different amounts of water because rain drops may not all be of the same size. Although another student (S8) had argued against this by pointing out that sometimes the bigger drops fall in one container, sometimes in the other, he was the only one who had grasped this. So, the teacher addressed this student's (S7) conjecture in a subsequent class, presented here, with a new experiment: Artificial 'rain' was made by each child by sprinkling water on his/ her absorbent brown sheet, resulting in drops of different sizes. These were traced on a transparent sheet and in the end all the sheets stacked together (essentially, averaging over time) - the amount of water in two different quadrants of the total was about the same despite variations in individual sheets.

The teacher tried to relate this experiment to the child's observation about varying raindrop sizes affecting measurements. Understanding that varying raindrop sizes are not a problem in measurement of rain requires a grasp of difficult and abstract concepts of randomness (here, randomness of raindrop sizes over space and time) and averaging. To achieve this the teacher asked nested questions which provided scaffolding in various ways like providing hints, making connections with earlier observations and directing attention towards aspects missed by students. Note that when there was no response or an incorrect response from students, the teacher lowered the cognitive demand, gathered the prerequisites and then built up the discussion.

**Episode 4.2:** S1, S2 etc. refer to students; codes for questions are given in parenthesis as indicated in Table 1

| | |
|---|---|
| Teacher: | Why did we do this experiment? (Rs) |
| S1: | To see shape of raindrops |
| Teacher: | We already know that. (An experiment to see this had been done earlier)<br>I want others too to answer... (Only three students had raised their hands.) What did S11 observe in the shower experiment? (H, Cor) (S11 had erroneously used identical containers) |
| S2: | She got different levels of water in containers of same size. |
| Teacher: | (Repeated answer from S3) Why? (Ex) |
| S3: | Small holes on one side. |

The teacher reminded students of another experiment where rain-gauges were placed in "rain" created using a plant sprayer and the level of water was found to be the same in different gauges.

| | |
|---|---|
| Teacher: | But in the shower... why was it different? (Ex, Con) |
| S2: | Because she did not change the place. |
| S4: | She kept it in the centre of the shower where there was no hole. |
| S5: | Holes in the middle are small. |
| Teacher: | There were different-sized drops... but in the rain too we find that. So...? (As) |

There was a small digression here. S6, S7 and the teacher discussed if how long the beakers are kept in the rain or shower will matter.

| | |
|---|---|
| S8: | In rain, sometimes small drops fall here, sometimes big drops. In shower small drops always fall in the same place (the crux of the argument!). |
| Teacher: | That's what S8 thinks. I want everyone to answer. (Er, S) |

Teacher recalled another experiment where actual raindrop sizes were clearly seen on a cloth that was briefly exposed to rain for this purpose. Now students wanted to see the drops from the sprayer on the blackboard which the teacher showed them.

| | |
|---|---|
| Teacher: | Now tell me why we did this experiment? (Rs, I) Take a minute to think about it. (M) |
| S1: | Raindrops are coming from a height. |
| Teacher: | So...? (C, El) |
| S2: | In the video that you showed, raindrops split. |
| Teacher: | That's the reason for different raindrop sizes. |
| S9: | Rain is slanting. |
| Teacher: | Shower is also slanting. (As) |
| S2: | Sometimes rain drops combine. |
| S8: | Small drops in shower fall in the same place, it will not change. |
| Teacher: | So if we keep a transparency, each time it would look the same? (A, H) |

Some students nod. The teacher again stacks the transparencies made by students together.

| | |
|---|---|
| Teacher: | What happened now? Suppose I have four beakers like this... (A, Ex, Rs) |
| S2: | Same amount of water (in the four different quadrants) |
| S1: | In rain, the same thing happens. |
| Teacher: | Now tell me what is different in shower and rain? (Rs, I, P) |

Some students answered.

| | |
|---|---|
| Teacher: | So tell me why we did this experiment? (I, P) |
| S10: | To check if different beakers (gauges) kept at different places get same amount of water. (Some other students gave similar answers.) |

***Guiding the entire class towards the scientific concept:*** In an inquiry classroom, where students express their own opinions and come up with their own explanations which could be different from the canonical scientific knowledge, conclusion of the discussion is a very significant phase. The teacher has to steer the course of the discussion and direct it to the goal of reaching the scientific conceptions. This is a most important phase of classroom talk, and disabuses the general notion of inquiry teaching as ‘freedom to come to any conclusion’ or ‘no conclusion having a privileged epistemic position’.

Unlike in the traditional classrooms where the teacher moved on with even one student giving the correct answer, teachers in the inquiry classrooms made attempts throughout to involve the entire class in the discussions (evident in Episode 4.2). At times, especially at turning points of conceptual change, a show of hands was invited - “How many of you agree/ disagree/ are unsure…?”, “How many think…?” which not only served to take stock of how prevalent a particular conception was but also nudged students who had not already taken a side to weigh the pros and cons of the options in order to do so. Sometimes such questions also helped to point out patterns of results during activities. For instance, Teacher IK asked, “How many of you got the heart-rate and pulse rate the same?” to point out that most students had found them to be the same and that there is a connection between the two.

***Classroom management questions:*** These were questions for class management like asking if students want more time to think or want to discuss among themselves before answering, questions monitoring their progress during activities or cajoling students to respond to each other or gauging their readiness to do a task. The teachers also used such questions in the form of invitations instead of commands to direct student actions for example, “Would you like to do it?” or “Can you answer?” or to create a positive emotional climate “Did you enjoy the debate yesterday?”.

### 4.2.2 Teachers' questions in traditional science classrooms

Contrary to reports in the literature, and perhaps our expectations, there were as many teachers' questions in the traditional science classes as in the inquiry classes (see Table 4.2), perhaps because the teachers made extra efforts to make classes more interactive than their normal classes; questions initiated by the teacher were a way to increase interactions. However, there was a stark difference in the kind of questions (see Tables 4.2 and 4.3 and Figure 4.3). Most of the questions that appeared were for factual recall. A huge number of revision questions (based on what was just taught in the same class) and rhetorical questions (where the teacher asked and herself answered the questions, apparently assuming students have the same answer or experiences or opinions) led to a large number of questions in these classes.

**Table 4.2** Total number of questions and percentage of open-ended questions for each teacher

| | **Teacher** | **Total (of three classes)** | **Average (questions per class)** | **Open-ended questions (%)** |
|---|---|---|---|---|
| Inquiry | Teacher IJ | 93 | 28 | 92.00 |
| | Teacher IK | 79 | 26 | 86.00 |
| Traditional | Teacher TN | 80 | 23 | 15.00 |
| | Teacher TP | 56 | 17 | 19.00 |

**Table 4.3** A comparison of the number of questions in each category of the progression in teaching

| Kinds of Questions and their codes | IJ | IK | TN | TP |
|---|---|---|---|---|
| Exploring pre-requisites/ Setting the stage | 19+2[a] | 13+3[a] | 32+11[a] | 29+9[a] |
| Generating ideas | 28 | 12 | 4 | 4 |
| Probing further | 7 | 10 | 7 | 0 |
| Refining conceptions | 20 | 10 | 1 | 0 |
| Guiding the entire class | 13 | 28 | 3+19[b] | 4+7[b] |
| Classroom management | 4 | 3 | 3 | 3 |
| Total | 93 | 79 | 80 | 56 |

[a]Rhetorical questions [b]Revision questions

Another typical kind of closed-ended question in these classes was that of asking for sentence completion which was usually answered in chorus by the class. Such questions were rarely, if at all seen in the inquiry classes. Other questions included managerial questions, those asking for pre-requisites and a smaller proportion of open-ended questions eliciting experiences and asking for elaboration, instances and rarely, explanations. The management questions were limited in scope and helped retain the teacher's authority with questions like "Are you paying attention?", or "Who is ready to read out the answer?" There were a few classes taught by Teacher TN, which had a wider variety of questions but these were only the introductory classes. Thus, as seen in distribution of the question types in Figure 4.3 and Table 4.3, the traditional teachers started a unit or even each class interactively with a variety of questions but soon after easily slipped into the transmission mode and then used questions mainly to evaluate what students have learnt and keep the class attentive.

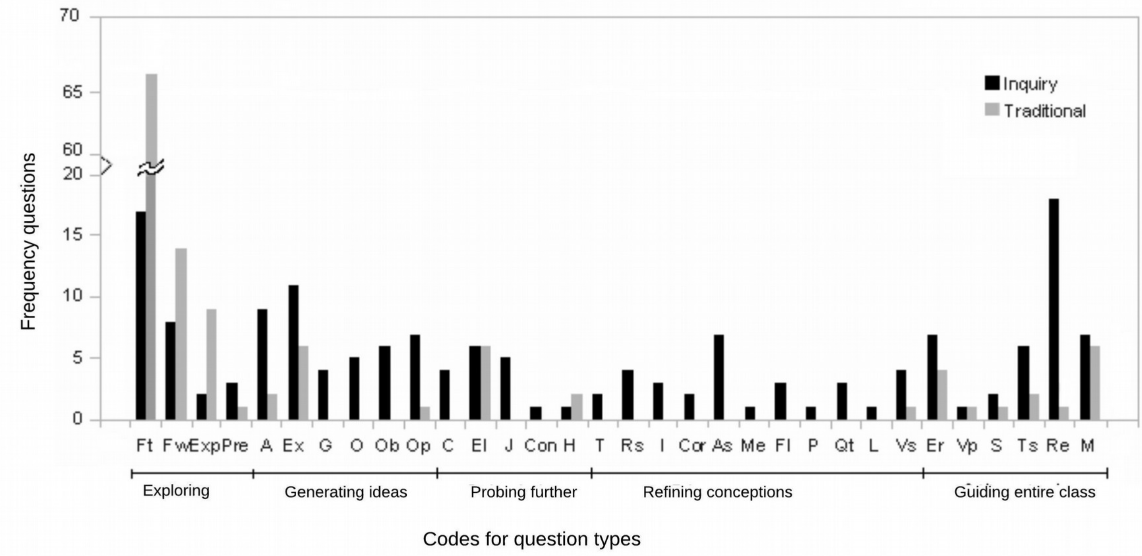



**Figure 4.3** Frequency of different questions: a comparison of inquiry and traditional classes

### 4.2.3 Teachers' reflections on their questioning

When asked to explicitly deliberate on what purposes questions serve in their classrooms, what was common in all the teachers' responses was the need to know what pre-requisites students had for the topic to be taught. Consistent with the oft-reported findings in literature (Chin, 2007), the traditional teachers in this study too said that they "ask questions to test students' knowledge" and "if they (students) have learnt the material". They also said they asked questions "to find out the level of the children since each class is different."

Both the inquiry teachers reported that their further teaching plan would be dependent on students' responses (which is corroborated by the higher number of follow-up questions in Table 4.4). They wanted to understand not only where the students were but also whether the level of difficulty of the topic they had planned suits the students. Both of them reported that they actively tried to stretch students thinking to draw out answers from them whenever it was possible and thought that additionally this would also increase student engagement and curiosity. One of them, Teacher IJ articulated a much more nuanced understanding and awareness of her questioning practices and the many crucial roles they play in inquiry - ranging from directing students' thought to the topic at hand to probing difficulties students have in understanding the topic and tracing the roots of these difficulties. She also pointed out an important purpose of questions that of involving the entire class in an exercise of genuine inquiry in the classroom:

> Questions allow a topic to be thrown into the 'public' arena (of the entire classroom) for discussion, and provide opportunities for evaluating their own and others' answers... This exercise allows for tentative explanations and possible ways to check whether a solution is acceptable... Further, children develop a culture of listening to and respecting others' views, learn that theirs and others' views matter to the teacher.

Indeed, this led us to create a new category of questions - 'Guiding the entire class towards the scientific conception'.

**Table 4.4** Percentage of questions asked as a direct follow-up of students' responses

| | **Teacher** | **Percentage of questions as a direct follow-up** |
|---|---|---|
| Inquiry | Teacher IJ | 50 |
| | Teacher IK | 30 |
| Traditional | Teacher TN | 11 |
| | Teacher TP | 9 |

## 4.3 Discourse Patterns

The feedback from the teachers to students' answers and questions, in the inquiry classes, came in various ways which resulted in discourse patterns other than the typical IRE or IRF sequence. The discussions often involved IRFRF chains, with several students (about 4-5) responding to a given question, which is typical of discourse that supports a dialogic interaction (Mortimer & Scott, 2003). Also, in addition to the student-teacher-student pattern of interaction, over time, we observed a variation of this pattern: student-teacher-other students. Though it was rare in the initial part of the teaching-learning, towards the end of the program students themselves responded to each other, leading to a dialogue among the students rather than merely with the teacher (for instance, at the end of the teaching sequence in Figure 4.2).

Out of the ways of speaking during science instruction described by van Zee, Iwasyk, Kurose, Simpson and Wild (2001), we found in this study that lectures and recitations were more common in the traditional classes while guided discussions as well as student-generated discussions were characteristic of inquiry classes.

## 4.4 Comparing the Nature of Tasks and Use of Activities

The nature of the learning activities and sequencing of events by the teacher determine the opportunities for participation, and the kind of participation which can occur. The different approaches used by the teachers of the two groups were associated with different patterns of activity and engagement by the students.

Apart from whole class discussions and demonstrations, in the inquiry classes, there were a variety of activity structures such as individual hands-on activities (e.g. making a cartesian diver), small group investigations (e.g. experiment to investigate whether water displaced by an immersed object depends on its weight or volume), facts inspiring awe and wonder (e.g. comparing the surface area of human lungs with the area of the classroom floor), modelling (e.g. modelling the distance between the nucleus and an electron in an atom), visualisation (e.g. Imagine if you could go inside the lungs, what would it look like?), games (e.g. modelled after double circulation system of blood in the human body), stories from history of science related to the topics under study (how the metric system was developed, how Archimedes solved 'the crown problem', how ideas about the human circulatory system evolved), creative writing (story of a pollen grain, poems on fish), class debates (advantages and disadvantages of cemented/ concretised areas in cities), language exercises - discussion of terms relating them in different contexts (e.g. Density - dense clouds, densely populated areas, dense forests etc. It is likely that situational interest may have been continually triggered and maintained by the variety of teaching activities that were interspersed throughout the course.)

However, since a considerable fraction of class time was spent in individual student activities such as drawings and observations (which were sparse in the comparison group), it turned out to be another factor contributing to the difference in time taken to cover the units in these two modes of teaching (described in Chapter 3, Fig. 3.1 and section 3.6).

Furthermore, in the inquiry classes, activities and experiments were an integral part of the teaching and were investigative in nature, with students' observations leading to classroom discussions; further development of the lesson depended on what students concluded from the experiment. In traditional teaching, they were most often verificatory in nature. This is evident in the episodes depicted in Figure 4.1 and 4.2. Thus, what differed in the two groups was how the demonstrations or activities were located within the discourse - whether they were directly addressing a student concern and used to build the lesson or were done as verificatory experiments.

So far in this chapter, we presented the aspects of the two teaching modes that we found salient. We examined the differences across groups in teachers' questions, the kinds of scaffolding they provided to students, the discourse patterns that the different teacher talk moves led to, the nature and variety of activities that were used for science teaching and how they were differently incorporated in the teaching sequence.

In the next section, we present an analysis of how students in the two groups viewed the teaching, what aspects they found significant. We first present the descriptions that were implicit in their diary entries and then dwell on the perceptions of how they viewed the teaching they underwent, which they explicitly verbalised in response to the questionnaire administered at the end of Phase II. This is in line with the call from Osborne, Simon, and Collins (2003, p. 1067) for more research on "what makes for effective teaching of science in the eyes of the pupil." This also aligns with the assumption underpinning much of the learning environment research which posits that "defining the classroom or school environment in terms of the shared perception of the pupils and the teachers has the dual advantage of characterizing the setting through the eyes of participants themselves and of capturing data, which an external observer could miss or consider unimportant" (Fraser, 1998, p. 528).

## 4.5 Characterisation of the Two Modes of Teaching from Students' Perspective

### 4.5.1 Characterisation implicit in students' diaries

Students' written descriptions of the teaching (Table 4.5 and 4.6) as well as of what they had learned from it were compared across the two groups to arrive at a characterisation of teaching in the inquiry and traditional modes through students' perspective.

***Traditional teaching (Comparison group):*** Diary entries of students in this group provide evidence that the instruction here was different from the commonplace science teaching in their schools in that there were many activities, the class was kept interactive through teachers' questions, and audio-visual material was used: "Teacher showed us many experiments and examples. She asked us many questions". "This is the reason I like the camp because the same topics of school taught with experiments and practicals seem more interesting". "Our teacher showed us parts of fish and about fish on LCD screen. She also showed us real fishes". "Then teacher asked everybody to give one example that [sic] how magnets are fun to play".

However, it is also evident through students' descriptions that though interactive and activity-rich, the teaching in the comparison group was in the transmissive mode where concepts were explained directly and there was an emphasis on definitions and formulae: "We studied about buoyancy and wrote laws of floating", "Teacher taught us about volume and gave definition",

> The definition of density is the space occupied by the mass in a unit volume is called density [sic]. The unit of density is gram/cm $^3$ or gram/cc. The density of water is 1 gm /cm $^3$. The formula to find density is mass/volume.

The class was kept interactive (typically using questions that placed a low cognitive demand on the students) but for interaction per se, not to develop the lesson: "Then teacher asked everybody to give one example that [sic] how magnets are fun to play". The way students wrote about the activities is indicative of these being verificatory and not investigative in nature.

"We learnt about density and did some activities **to clear the concept**"[2], "We learnt that thicker the wire in size, the lesser the resistance it has and the longer the wire, the more the resistance it has. We did an experiment **to see the difference**".

2 The emphasis in students' quotes are added by the researcher.

The teachers were perceived as friendly and many students said that they "explained nicely".

**Table 4.5** Coding scheme for analysing content of the diaries for the category 'Summaries of what was done'

| Coding categories | Instances from students' diaries |
|---|---|
| Descriptions of the events in class (what was done and how) | Today we went to the lab [sic] and did an experiment there. Both the thermocol and wood blocks floated on water.<br>We had to find out how much (what fraction) did float in water. |
| Descriptions of the lesson or activity framed as a question | Today we studied about heart. How does it pump? How it works? [sic] How does the blood flow? |
| Descriptions of class events as debates/ arguments/ discussion | What decides amount of water displaced (1) Mass (2) Size? This question started a hot debate.<br>We also had an argument on whether sea horse is a fish or not [sic].<br>We discussed about the experiments and the doubts[sic]. |
| Descriptions of the teacher's action as 'told'/ 'taught'/ 'explained' with details | She told us the different names of fish.<br>She taught us how SI units are derived.<br>She explained how oxygen goes from alveoli to haemoglobin of blood. |
| Descriptions of the teacher's action as 'told'/ 'taught'/ 'explained' without any detail | She told us about density.<br>She taught us about fish.<br>She explained about buoyancy and density. |

***Inquiry teaching:*** Students' entries in this group prominently reflect the focus on inquiry. It is interesting to note that many a times (Table 4.5) students wrote about a lesson or activity as a question to be pursued "Is that the seahorse is a fish? We were asked to reason why it is fish [sic].", "Why 1gm of gold is denser than 1gm of silver?", "How did people in the past consider the circulatory system to be in human beings?"

Learning through inquiry involved higher-level cognitive demands as described by students and was contingent upon observations and discussions in class: "**We did an experiment to find out if** the water fell out [overflowed] because of the mass or size [of the object]", "The crown battle had started … **we were thinking** how Archimedes had decided which crown is of gold and which is of silver." "After we said [sic] our guesses, **our teacher would find the answer** by …", "Teacher asked us what would happen if there were no alveoli in lungs or all the alveoli were somehow fastened to lung walls, what would happen due to this. I enjoyed the discussion very much. I also gave good answers.", "All gave good answers but some didn't manage to do it."

The teacher helped them meet these high cognitive demands by being responsive to their ideas and difficulties and providing the necessary scaffolding. There was an explicit, gradual building of the lessons - subsequent activities and discussions were based on the earlier one and teacher elicited the answer from students through a series of questions and counter-examples to students' statements. This scaffolding is illustrated in the teaching-learning sequence given in Figure 4.2, where the teacher elicits the answer from students through a series of questions and counter-examples to students' statements. This aspect is also reflected in students' entries: "She asked a question which in the end almost all could answer."

> I liked today's class taken by her. She revised all the experiments and things that she told us about sinking and floating objects. She told us and we also saw that things which have air, it is not necessary that they float.

"It was a superb class - we discussed about [sic] the experiments and our doubts [sic]", "Teacher asked some questions which were not easy … By this method [1000cc = 1 litre] it was easier to answer the questions and the concept was clear", "She asked a question which in the end almost all could answer." We note the absence of definitions reproduced verbatim in the diaries of the inquiry group, a reflection of the teaching not being centred on factual information and its reproduction.

**Table 4.6** Quantitative comparison of students' descriptions of 'what happened in class' in the diary entries of the two groups

| **Sub-categories of diary entries coded as 'Summaries of what was done'** | **No. of instances in inquiry group** | **No. of instances in comparison group** |
|---|---|---|
| 1. a) Descriptions of the events in class (what was done and how) | 140 | 53 |
| b) Descriptions of the lesson or activity as a question | 31 | 6 |
| c) Descriptions of class events as debates/ argument/ discussion | 52 | 1 + 6 [a] |
| **Total** | 223 | 66 |
| 2. a) Descriptions of the teacher's action as 'told'/ 'taught'/'explained' with details | 96 | 3 |
| b) Descriptions of the teacher's action as 'told'/ 'taught'/'explained' without detail | 15 | 28 |

[a] Six of these instances were contributed by one student.

### 4.5.2 Characterisation reflected in students' responses to questionnaires

In one of the items in the questionnaire administered at the end of Phase II, students were asked to place science from easy to difficult on a semantic differential scale. Their responses (Table 4.7) indicate that students in inquiry recognised the high cognitive demand placed on them but also found it manageable - not very easy but not very difficult either. Thus instruction in inquiry seemed to provide an optimum level of challenge. These self-reports from students corroborate what they tacitly indicated in their diaries about challenging yet manageable level of cognitive demands in inquiry. There was no difference between the groups in other dimensions that students were asked to reflect, namely how important, interesting and related to daily life students found science to be.

**Table 4.7** Students' response to how easy or difficult they found learning science on a 5-point Likert scale

| Score | Percentage of Response in Inquiry group (N=30) | Percentage of Response in Comparison group (N=32) |
|---|---|---|
| 1 (Easy) | 20.00 | 40.63 |
| 2 | 46.67 | 43.75 |
| 3* | 33.33 | 9.38 |
| 4 | 0.00 | 3.13 |
| 5 (Difficult) | 0.00 | 3.13 |

In another question, we asked students to "Compare your regular science classes with HBCSE science classes. In what ways are they the same? In what ways are they different?" This was a direct way for asking students for characteristics of the two modes of teaching that they found significant. There were fewer responses from both groups stating similarities between science teaching at school and in the program than those pointing out the differences (Table 4.8 and 4.9). Similarities were seen at the broader level - both sets of science classes included experiments to some extent, were interesting and teachers were good-natured, as perceived by the students. A girl student in the inquiry group commented that in both classes, at school and in the program, "Children make fun of others' answers".

**Table 4.8** In what ways are the science classes at HBCSE and your school same?

| **Responses from Inquiry group** (N=32) | **n** | **Responses from Comparison group** (N=34) | **n** |
|---|---|---|---|
| In both classes we learn science, they are not same in any other way | 1 | - | - |
| Experiments in both classes but less experiments in school | 1 | Experiments in both classes | 2 |
| Both are interesting/ good in their own way | 5 | Both are interesting, good | 3 |
| Children make fun of others' answers | 1 | - | - |
| - | - | In both classes, teachers teach in good way, solve our doubts | 2 |
| - | - | Teachers are kind and friendly, supportive | 1 |
| - | - | In both some topics are boring | 1 |
| - | - | If we do not understand they repeat again and again | 1 |

### Feedback and suggestions for the classes in the intervention:

We asked students, “Suppose we invite you for another set of these classes,

i) what things would you like us to change?

ii) what things would you like us to add?

iii) what would you like us to do in the same ways we have been doing so far (not change)?”

**Table 4.9** In what ways are the science classes at HBCSE and your school different?

| **Responses from Inquiry group** (N=32) | **n** | **Responses from Comparison group** (N=34) | **n** |
|---|---|---|---|
| More experiments; Here we like doing experiments | 13 | More experiments | 16 |
| Topics are taught with examples, videos, pictures | 4 | Videos, slide shows, interesting things like fish and its parts (dissection) are shown | 12 |
| More interesting (4), I have more fun in HBCSE classes (3), I am not that excited in my science class at school as in HBCSE | 8 | Interest is created, more interesting 4, Classes are fun, we enjoy here 2 | 7 |
| Way of teaching is good (2), Way of explaining, how topics are explained nicely and many times, Answering questions with proper explanation | 8 | - | - |
| Do not follow textbook | 1 | Topics taught are different, out of the textbook, Don't use textbook, topics out of textbooks 3 | 5 |
| - | - | In school we study many things in less time and here we study less things in many days (3) Teach science in more detail (3), Extended time of 2 hours, so many things are taught and experiments done | 7 |
| Teachers are more understanding, are very nice, very friendly, never scold (3), teachers talk very politely*, listen to everything*, Listening to questions patiently* | 5 | Teachers are more friendly, teach nicely | 4 |
| We study by playing, We understand more by enjoying | 2 | General knowledge increased | 1 |
| We get full chance to answer questions*, teachers answer all our questions, our doubts (sic) are cleared | 3 | Teacher has more interaction with children, We can ask our doubts | 2 |
| Here it's much more free | 1 | No punishment | 1 |
| Less hours of study | 1 | Not much homework | 3 |
| No exams | 1 | No exams | 2 |

Students' responses reflect how they perceived the instruction against the backdrop of how they would prefer it to be.

**Students' suggestions for improvement in the inquiry classes:**

In response to the question asking for feedback and suggestions on the teaching in the program, students from the inquiry group asked for more autonomy in the selection of content and in doing the hands-on activities themselves with less of demonstrations. One of them raised a concern not to "take a topic for many weeks"; a few of them had made this request in person too with the teacher. What many students did not like (but which was not part of the intervention itself) was answering the questionnaires for this study; while writing itself students complained that it was difficult to be so reflective and they were not used to it.

Students suggested adding topics that they found fascinating like astronomy/ electricity/ chemistry and also including more videos. Students did not want a change in - "The teachers", "the excitement in the class", "talking politely & teaching us the way you teach us", "The method of teaching & involving with each & every student." These responses are indicative of students appreciating the efforts teacher made to establish a supportive classroom culture – though there were some problems due to students'/ boys' behaviour. This is also reflected in students' responses, reported earlier in Table 4.9, marked (*).

Some illustrative responses: "Students should select what they want to study", "We should able to do activities ourself in class", "fewer worksheets", "Change the timings, in the afternoon I feel sleepy."

**Suggestions from students' in the comparison group for improvement in the teaching in the program**:

i) The only change demanded from this group was not to give a lot of these questionnaires that asked for reflection on the program.

ii) Students suggested including more experiments and those that they could do themselves. They also wanted the popular domains of science like robotics, forensics, astronomy and chemistry to be included, going as much away from the textbook as possible - “things should not be taught from the textbook”.

iii) Aspects that students did not to want changed were inclusion of experiments and audio-visual materials; “giving extra information”, “being kind with us” and the style of teaching.

## 4.6 Insights into the Teaching from Teachers’ Interviews

The interviews intended to get teachers’ reflections on their implicit strategies for teaching, their views that inform their teaching practice and get them to explicate moments salient to them in a narrative form (e.g., high points and low points, turning points, what they found interesting or challenging). Details of the interview questions are given in Appendix K. Broadly, we intended to probe teachers’ ideas on -

- Their purposes of questioning in their science classes (reported in section 4.2.3)
- Nature and amount of active student participation in their class (how and how much did students participate, need for student talk and teachers’ strategies to promote it)
- Pedagogy of science (orientation towards science teaching, perceived role of activities and experiments in the science class)
- Reflections on their teaching in the classes in this study in general and overall on their self-efficacy
- Any change they perceived in the class or in particular students

### 4.6.1 Reports from inquiry teachers

**Reflection on students' participation in their class:** Both the teachers in inquiry said that many (though not all) students vocally participated in the whole class interactions. The teachers reported that they tried to encourage all students to answer by gently coaxing them to attempt an answer, by waiting for more students to volunteer to speak, asking every student to ask a question to get them to talk about the topic at hand, giving students time to think if needed for coming up with questions or answers, encouraging them to talk amongst themselves before answering, and creating a space where the shy ones can come and interact with the teacher or the materials (during break, the teacher stayed back at the desk many a times). Teachers noted that eventually the class participation went up although a few hardly spoke up much in class even towards the end, especially girls. However, they did come to the teacher's desk during break time or after class to tinker around with the materials kept on the desk for activities and to ask questions or to discuss their observations.

For the teachers teaching through inquiry, teaching was contingent on student talk. They said that it was absolutely necessary for them to see how ideas were received by students (whether students were interested or were understanding the content) without which they could not move on with the lesson. Further, Teacher IK added that different ideas from students made it a richer experience for everyone. Both the teacher believed that opening the floor for everyone to speak was important in order to provide equal learning experience to all students and reported working towards correcting class dynamics towards this end.

**Reflections on their own teaching:** Teacher IJ saw her strength in teaching in diagnosing students' conceptual difficulties and lacking pre-requisites and then finally leading students to the concept of density despite these difficulties. She also felt confident in her class management skills and also explicitly working towards the classroom culture fostering inquiry. Teacher IK, although she had excellent subject matter knowledge, said that she could foresee students' difficulties recalling her own difficulties as a student and therefore being an "average student" helped her in her teaching. While reflecting on the challenges she faced in teaching through inquiry, she reported that she had difficulty when to give away an answer and when to let children grapple with it and judging the the cognitive difficulty of a concept for her students. She also added that she often reflected on the way she had framed questions in the class, often thinking that it would have been better phrased in a certain way.

**Difficulties/ challenges reported by teachers in inquiry:**

- Not all students actively participated in class discussions even when the teacher encouraged them to do so and consciously tried to create a safe environment for them to speak. There were some "eager beavers" who would aggressively volunteer to speak and would get disappointed if not always called upon.
- Some students found persisting or grappling with the same topic difficult and boring.
- Trying new activities – sometimes they did not work out the way it was expected, some experiments needed tweaking.
- Some fundamental concepts and skills were not in place, it took time to even realise that this was the problem and then going back and building them – students would get dejected or bored.
- There were some concepts which were intellectually challenging for students (like the inverse relationships involved in density).

**Specifically for Teacher IK, as a novice:**

- Knowing when to give the explanation and when, and how much, to let students grapple with it – making the dialogic-authoritative switch so to say. (Even Teacher IJ, lamented in a class summary on (28th May 2010) "I gave answers in some cases – I do that when I feel pressed for time").

- Interactional difficulty – taking stock – how much to take in students' responses – cannot ask each student every time.

- Class management: Paricularly during class discussions, Teacher IK found it difficult to handle the different pace of learning of different students – some would get the concepts easily, she struggled with keeping them engaged while supporting the others: "... sometimes I found it difficult to control the class. And… *jin bacchon ko jaldi samajh mein aata hai*, they start getting distracted, *baki bacchon ko disturb karne lagte hain.* [The children who understand/ get the concept being discussed start to distract the others]. Then it becomes difficult to get their attention."

**Strategies that teachers reported working towards:**

- Fine-tuning to adjust difficulty level of teaching according to students' response

- Taking another route into the line of inquiry, a detour leading back, to maintain interest

- Grasping their attention in the beginning of a lesson, for example with a story

- Sensing that students are not understanding something and diagnosing the difficulty

- Opening the floor to all students: encouraging students to discuss amongst themselves before answering, sometimes getting every student to ask a question to get them to talk about the topic at hand, give students time to think if needed for coming up with questions or answers, creating a space where the shy ones can come and interact with the teacher or the materials (during the break, the teacher was at the desk many a times as noted earlier)

- Saving face for students - Talked to students individually about their problem behaviour after class or in the break, not in front of anyone

### 4.6.2 Reports from teachers in the comparison group

**Reflection on students' participation in their class:** Teachers of this group noted that all the students in their class were attentive but only a few participated actively. Here too, the teachers tried to get a wider participation. They asked questions "to keep students alert". They reported that they had no problem managing the class since most students were attentive and interested: "even small definitions, they would note down", "Especially questions related to revisions – they answered all of them."

Their purpose for asking questions was clearly for testing attention (catching students off-guard so that they begin to pay more attention) and check if they are "following" what is being taught. This, along with the kind of parameters they used to note if students were engaged in their classes point to their views of teaching as transmission. While also talking about their strengths in teaching, Teacher TS said, "I can explain, in any case, *koi bhi baccha leke aa jao* [bring any kid to me], I can explain". Similarly, Teacher TA responded, "I think I can draw the attention of each student, each and every student was attentive in my class."

Both the teachers however reported themselves getting into a spirit of inquiry. TS shared that she tried a lot of experiments at home along with her family to be able to do them in the classes in the program

> I liked doing experiments in front of them [students]... and at home also. I was full time busy with this, either density or magnetism. It was good, even my kids also started getting interested… *ki cell hai toh kya..? yeh aisa kyun hai?* [What is a cell? Why is it like this?] If we have a battery cell, can we…? Means my home atmosphere was like that *ki kuch bhi try kar rahe hain* [we were trying everything/ tinkering].

TA also enjoyed doing the dissections with students. She was also happy that she could prepare her own teaching material and felt confident that she had prepared good quality material. However, the teachers lamented that they were not able to transfer this active engagement to the students. TS felt that “I should have made groups of students and let them do experiments on their own: whataever we have shown or whatever we want they could have done by themselves.” TA also commented that, “I should have included related topics interesting to students (like sea stars and octopus when teaching about fish).”

## 4.7 Summary of the Findings in this Chapter

This chapter explored the ways in which teachers guided the discourse, activities and ways of thinking in the science classroom and how students implicitly appropriated them in their learning.

Considering questions and prompts that teachers use to structure classroom interactions as significant forms of scaffolding, we attempted a characterisation of science teaching that focuses on them. A fine-grained analysis of the teachers' questions revealed a rich variety of their roles in the inquiry science classroom. From a sequential typology of questions, emerged a progression in the inquiry lesson from eliciting, diagnosing and probing students' ideas to refining them and guiding the entire class towards accepted scientific knowledge. It is this progression which places increasingly higher cognitive demands on students, that truly characterises the inquiry classes, and differentiates it from the traditional ones.

To further our attempt to make explicit teachers' tacit strategies employed in inquiry teaching, we examined, through teachers' self-reports, their motivations for questioning, the need for student talk in their classes, their strategies to promote it, their views on the nature and amount of student participation and engagement in their class and their views related to their orientation towards science teaching.

Students' reflections about the teaching they experienced, depicted implicitly in their diaries and expressed explicitly in response to questionnaires and interviews added another perspective to our attempt to characterise the two modes of teaching, corroborating and adding to the researchers' perspectives.

# 5

# Exploring learning along different axes

In this chapter, we present the gamut of learning outcomes that we gleaned from multiple data sources. We present them as overarching themes from the data, themes that are interconnected and overlapping, which entails that some of the data indicate more than one outcomes and therefore would be discussed under more than one theme.

## 5.1 Comparison of Content Learning Difference Gleaned from Students' Diaries

A large number of instances of *'what was learned'* written by the comparison group (47 as compared to 11 in the inquiry group) indicated a lack of conceptual clarity and several instances of a misunderstanding of the concepts (Table 5.1 and 5.2). This was particularly stark in situations when there were inverse relations or more than two variables involved in understanding a concept such as density (21 of these 47 incorrect instances written by students in the comparison group, were related to the concept of density); some examples:

> Objects which are not heavy will float, heavy objects will sink.
>
> If the volume of an object is **greater than the mass**[1] then the density is less as the molecules are loosely packed
>
> We learned that the object which has **more mass and volume** has less density and the object which has less mass and volume has more density. So density is related to mass and volume.
>
> Density is the property of matter … [within the same entry] When there is a comparison between two objects of same material but of different sizes then, object with bigger size will have more density as it will have more weight because it is having [sic] more quantity of matter … Thus, **objects of same material but of different volume show different density**.

Notably, these common conceptual difficulties among students (such as the assumption that weight alone determines if something sinks or floats or the difficulty in understanding inverse relationships) were discussed at length with the traditional teacher during the preparation for teaching the teaching unit on density. However, these difficulties were not explicitly addressed in class, and they persisted after teaching. In inquiry teaching they were tackled head-on during investigations, for example, basing the introductory lesson on density on the question - whether the amount of displaced water depends on the weight or volume of the immersed object. Sometimes, incorrect statements in the entries of the comparison group immediately preceded or were followed by related correct statements indicating incoherence, as in the last quote above.

1 All emphases marked in students' quotes are added by the researcher

**Table 5.1** Coding scheme for analysing the content of students' diaries: 'Summaries of what was learned'

| Coding categories | Instances from students' diaries |
|---|---|
| **1. Understanding of the content** | |
| a) Instances with conceptual errors | … But I think volume of displaced water depends upon weight, size and mass of the object. (Instance 1)<br>Today we learnt that the object which has more mass and volume has less density and the object that has less mass and volume has more density. (Instance 2) |
| b) Instances showing conceptual understanding | The sinking or floating of an object doesn't depend upon the weight of the object but actually how the particles in that object are arranged. (Instance 3) |
| **2. Way of describing** | |
| a) Limited to recall of definitions of scientific terms and principles + interesting facts told by the teacher | The teacher also taught us Archimedes' principle. The Archimedes' principle states that any object which is wholly or partially immersed in a fluid is buoyed up by a force equal to the weight of the fluid displaced by the object. (Instance 4)<br>Today we learned that the object which has more mass and volume has less density and the object that has less mass and volume has more density. (Instance 2) |
| b) Personalised descriptions of what was learned in their own words | But I think volume of displaced water depends upon weight, size and mass of the object.<br>(Instance 1) |
| **3. Source of what was learned** | |
| a) What was told/explained by the teacher | Today we learned that the object which has more mass and volume has less density and the object that has less mass and volume has more density. (Instance 2)<br>The sinking or floating of an object doesn't depend upon the weight of the object but actually how the particles in that object are arranged. (Instance 3) |
| b) Students' reasoning as answer to a question or as inference from an experiment and/or class | So from this (experiment) we can understand that the thing which has more volume will float and less volume [sic] will sink in water. |

**Table 5.2** Comparison across groups of the content of diaries: 'What was learned'

| Categories to analyse 'what was learned' | No. of instances in inquiry group | No. of instances in comparison group |
|---|---|---|
| **1. Understanding of the content** | | |
| Instances with conceptual errors | 11 | 47 |
| Instances showing conceptual understanding | 79 | 64 |
| **2. Way of describing** | | |
| Limited to recall of teacher's words (definitions, scientific terms and principles+interesting facts told by teacher) | 4+16[b] | 50+5[b] |
| Personalised descriptions of what was learnt in their own words | 70 | 46 |
| **3. Source of what was learned** | | |
| What was told/ explained by the teacher | 53 | 86 |
| Students' reasoning as answer to a question or as inference from an experiment and/or class discussion | 37 | 15 |
| **Total** | **90** | **111** |

[a] Each instance coded under this category was further coded according to the three overlapping sub-categories.

[b] Number of interesting facts recalled

When conclusions of an experiment were recorded by students of the comparison group, they were often incorrect:

> Carrot sinks [while bitter gourd didn't] because it has more water molecules.
>
> I never knew that salt has such high voltage. (After an experiment to compare conduction of electricity through plain and salt water).

> Saline water has less density. This was proved by an experiment that egg or potato sinks in normal water but in salty water they float.

Also, a few entries reflected incorrect content told by the traditional teacher (e.g. "Due to their big sized body, sharks need to swim always to keep their body afloat."). This is perhaps indicative of the classroom culture in the traditional teaching mode, which is by and large uncritical and where facts and concepts are not used to build a coherent picture.

In the inquiry group too, students arrived at incorrect conclusions although as noted above, there were only a few such instances. Some examples:

> Today, teacher showed us three cubes with different number of nails pierced in them. First one floated on top, second one sink [sic] and third one sank to the bottom. **This shows the density of water**

> Then teacher asked us a question - volume [of displaced water] depends upon what? I think it depends upon its weight, size and mass.

We note that these errors of observation and argument were made in the initial stages of a sub-topic, as opposed to those by students in the comparison group which occurred throughout. As the unit progressed, building on concepts tackled through earlier activities and discussion, there were opportunities for such errors to surface in the inquiry class and were directly addressed by the teacher which might account for the fewer number of content errors in the diary entries.

## 5.2 Difference in Students' Conceptions of Science and Learning

Current science education research and policy underscore the need for students to conceptualize science not only based on a view of 'science as a body of knowledge' but also on a perspective of 'science as practice' with emphasis on its processes such as explanation, argumentation and modeling (Zhai, Jocz & Tan, 2014).

### 5.2.1 Implicit conceptions reflected in students' diaries: Frame of '*doing the lesson*' or '*doing science*'

There were instances of students' independent reasoning in the comparison group although much fewer in number (Table 5.2):

> More the volume, lesser is the density. The bitter gourd had more volume but less density so it floats in water and the carrot had less volume but more density so it sinks.

> We saw that when we put a raw egg in pure water, it sank but when we put the same egg in salty water it floats because when we put salt in water, the salt combines with water molecules and increases the density and thus, the egg is able to float.

However, more often than not the learning described in their entries was a mere recall of facts, definitions and laws covered by the teacher:

> Amount of matter in an object is called mass. When gravity pulls on the mass the object is said to have weight. The formula to find the weight of an object is kg x force (9.8 N).

> The teacher also taught us the Archimedes' principle. The Archimedes' principle states that any object which is wholly or partially immersed in a fluid is buoyed up by a force is equal to the weight of the fluid displaced by the object.

> In Biology class, the teacher explained about scales which are present on topmost layer of the fish body and our teacher told us that scales are made up of connective tissue and they are arranged like tiles of the roof.

We posit that this was the reason why there were far more instances of content errors in diaries of the comparison group. Orlin (2013) puts it quite well -

> What separates memorization from learning is a sense of meaning. When you memorize a fact, it's arbitrary, interchangeable - it makes no difference to you whether sine of $\pi/2$ is one, zero, or a million. But when you *learn* a fact, it's

> bound to others by a web of logic. It could be no other way.

Further, note that these students expressed what was learned mostly through formal, conventional statements reproducing canonical knowledge. This indicates that students in this group framed learning in their classroom as *doing the lesson* (Jimenez-Aleixandre et al., 2000) wherein the teacher has social and epistemic authority in *what is correct*, and the students are more focused on simply repeating explanations from the textbook or teacher rather than on constructing or articulating explanations. These kinds of students' epistemologies are reported to be linked to the adoption of memorisation and reproduction of information as learning strategies (Edmondson & Novak, 1993; Purdue & Hattie, 1999). Such a conception of learning as acquisition and reproduction of facts also points to a conception of science as self-evident or objective truth (Edmondson & Novak, 1993) - there is uncritical acceptance of the content under discussion even if it is at odds with students' own conceptions.

In contrast, in the inquiry group a higher number of summaries of 'what was learned' were based on experiments, demonstrations and class discussions indicating a frame of *'doing science'* (Jimenez-Aleixandre et al., 2000) wherein students assess an idea as 'true' by whether it makes sense to them and is based on evidence and arguments. Students' statements such as "**We were deciding** which kinds of objects float and which ones sink", "We convinced the teacher of our answer", "Then we raised doubts [sic] **which teacher and we answered**", reflect students' internalisation that they shared epistemic authority with the teacher. Siry (2013) discusses the importance of this shared authority in involving students in, and encouraging scientific inquiry.

Students in the inquiry group also described what they had learned in a personalised way, in their own words, pointing to internalisation and a better understanding of the content. Their endeavour to construct and articulate explanations, often in collaboration with others, is evident in the higher instances of students' own reasoning to answer a teacher's question, explain an observation, infer from an experiment or as a resolution of a class discussion:

> We had to find out the volume of the object from the water displaced. **As per my observation**, the volume depends on the size of the object, but in one case it was not true.
>
> Today teacher brought some objects, she dropped them in water and **through this experiment** we learned that there is no effect of air in making an object float or sink.
>
> We figured out the area of the room and compared it with the area inside the lungs
>
> Teacher took 3 cuboids of thermocol of different sizes—small, medium, large with the same number of nails, and she placed it in water. **So from this we can understand that** the thing which has more volume will float and less volume [sic] will sink in water.
>
> Today we discussed that [sic] why does a fish have black scales and white scales at the bottom. This is because, if a predator is at the bottom of the fish & the lower surface of a fish will be white, this will be invisible because it will match with the sunlight falling on the ocean.

Thus, a salient feature of students' learning through inquiry emerged – that they have internalised, implicitly, the inquiry approach to learning science - "we did this experiment **to find out if** ...", "after much discussion we concluded that ...". We believe this is particularly significant because these aspects were not explicitly verbalised to students but were picked up by them from the way the classes were taught: classroom discussion and argument were used as an integral part of the teaching strategy, initiated through questions; activities and experiments were designed to be investigative, with further lessons being built on students' conclusion drawn from the activity. Thus, students' diaries of the two groups reflected an epistemic difference in their conceptions of learning science - see the entries under ‘Source of what was learned’ (Table 5.1 and 5.2) and ‘Expression of own involvement’ in Table 5.3 and 5.4.

**Table 5.3** Diary entries coded under ‘Expression of own involvement’ and the illustrative examples

| Coding categories | Instances from students’ diaries |
|---|---|
| Statements explicitly showing a sense of shared epistemic authority | We had a lot of discussion on it, at last we concluded that the material which has more height will displace more water.<br>We convinced the teacher about our answer.<br>Then [we] raised doubts which the teacher and we answered. |
| Statements showing modification of conclusion/ tentative solutions | First I thought it was an ancestor of dolphin then I changed my mind. I had to change my mind again.<br>I think we should look at gills, snout and fins to look anything as a fish. If any creature has two of its factors, it is fish.<br>First I thought it was the container having more volume but I was wrong the bottle had more volume and it was because even if the height of the beaker was more but the base was less while the bottles base was more and less height. So the bottle volume was more. |

**Table 5.4** Comparison across the two groups on the content of diaries: ‘Expression of own involvement’

| Categories to analyse ‘Expression of own involvement’ | No. of instances in inquiry group | No. of instances in comparison group |
|---|---|---|
| Statements explicitly showing a sense of shared epistemic authority | 35 | - |
| Statements showing modification of conclusion/ tentative solutions | 7+6* | 1+11* |

* Responses to a question framed as ‘give your guess’ and explicitly asking why it may or may not be correct.

### 5.2.2 Students' explicit conceptions of science: 'Science as a subject' or 'Science as processes'

We set out to explore how participation in the different forms of classroom discursive practices (in traditional and inquiry science instruction) change students' epistemological ideas, not about formal science that is distant to them, but about their own experience of school science. Iii, Hand, and Prain (2002) explain that such learning occurs in two forms: explicit and more deeply held tacit conceptions. Explicit knowledge involves the understanding and knowledge that the student can immediately access while communicating with others. Tacit knowledge is described as the understandings and knowledge that is unarticulated yet demonstrable by use and/or action. Explicit knowledge is often fragmentary, dependent on one's grasp of language and is, therefore, less than a person's tacit knowledge.

More complex, tacit conceptions of science were studied through students' diaries. We sought to explore students' explicit conceptions of science with an open-ended question in the post-intervention questionnaire, followed up in the interviews: "Suppose someone who has never got a chance to go to school asks you - What is science? What would you tell them?" Although students were given adequate time to think and write the responses and explain them in the follow-up interviews, their responses were brief, simplistic and there were not many stark differences in the responses from the two groups (Table 5.5).

The following dominant themes emerged from the responses -

**Science as a school subject:** Around half of the students in both groups explicitly noted that science for them is a school subject. Some went on to include physics, chemistry and biology. Nonetheless, these students projected a positive attitude towards the subject describing it as interesting, important and "learnable" through activities and "visualising". Only three students in inquiry emphatically noted that science is not merely a subject they studied at school which is what they earlier thought before participating in the science classes in the program and now have a broader view of science as “something you deal with in everyday life” and something that involves “asking questions and understanding how things work”.

**Table 5.5** A comparison of students’ explicit conceptions of science

| Features of students’ response | Inquiry group (N=41) | Comparison group (N=40) |
|---|---|---|
| Science as a school subject | 16 | 18 |
| Catch-all expressions to characterise science as “everything” | 7 | 5 |
| Science as a body of knowledge/ amazing facts | 5 | 5 |
| Conflating science with technology | 1 | 3 |
| Science as related to daily life | 5 | 3 |
| Science as processes | 14 | 3 |

**Science as a body of knowledge or a list of facts:** This is similar to the former category where students listed discreet topics or concepts with little or no elaboration. A few students prefaced their responses with “science is the study of ...” as they then continued to list the topics like environment, the earth, human body, different kinds of plants and animals. Some students noted more straightforwardly that “science is a subject in which we can give the whole information in detail to people”, it is “full of definitions and formula” and “amazing facts”. Except this one student writing that science involves “important knowledge that can be used for good as well as bad purposes” others seem only to see the positive aspects of scientific knowledge.

**Catch-all expressions to characterise science as “everything”:** Some students took an extreme position relating everything to science, science being out there. These responses are typical of others in this group: “science is everything around you", "Day to day phenomena in our life is science". Though this category of responses may indicate an overtly positive connection or relatedness towards science that students have developed, it also depicts vagueness and a lack of explicit awareness that it is a kind of human endeavour.

**Conflating science with technology:** Not surprisingly, since the central board textbooks these students follow in their school include applied science as a part of the science textbook, a few students equated science to technology - "Science is the improving technology which has made the world shrink".

**Science as related to everyday life:** Very few students (7 in inquiry and 3 in comparison group) related science to real life, at least explicitly, writing that science is "day to day observations of our surroundings and finding reasons for it", "Science is based on our life, it is about plants and living things etc. around us".

**Science as processes, as a way of knowing:** This category of responses had many more responses from the inquiry group (14) than the comparison group (3). Here, students described science as an enquiry with a focus on processes involved like questioning, observation, experiments, providing evidence and discussing them. Some exemplars from this set of responses: "Science is trying to solve questions, find out through experiments", "Explaining how things work, how plants grow, why sun rises", "Observations of the nature around us", "Experiments to understand, to know more about like what is inside a plant", "Find out how things work, about things happening around us", "explaining everything with a proof", "Science gives us an opportunity to ask why things happen and how". Some responses were more elaborate during the interview:

> Science is looking for proof, reason, cause and effect. If we didn't have science, there would be a lot of superstitions. For example, if something boils and makes a lid shake, someone could say there is a ghost. There would be someone else who would explain why this is so (there is steam and that is why) and remove people's misunderstanding that there is a ghost. There is an explanation to it based on other observations. Other people would also make

> similar observations and believe him. Similarly, there would be some reactions and someone would have got involved to explain why did it happen this way or that way. It's about human thinking.
>
> In science, we study about things like plants, our body, what is inside, how does it work. People would definitely have got doubts[2] [sic]. To clear their doubts, they tried out things and so they got to know more. They collected information and kept studying more and more.

These responses depict students' perceptions of science as a pursuit of knowledge, as attempts at explaining natural phenomena, as a human endeavour and of scientific knowledge as empirical, evidence-based and building on itself. This is a crucial shift from viewing science as a distant subject restricted to studying at school. However, these responses are far from the informed, contemporary views on the nature of science - that scientific knowledge is "(1) tentative or subject to change and advances through legitimate skepticism, (2) empirically based, derived from or based on observations of the natural world, (3) subjective or theory-laden, i.e, theoretical, disciplinary commitments, training, and prior knowledge affect the work of scientists (4) creative, being the product of human imagination and inference, (5) socially and culturally embedded and (6) created from observations and inferences and that (7) there is a distinction between scientific theory and scientific law" (Capps & Crawford, 2013, p. 500). Also, arguably, students were not clear about what sets science apart from other ways of knowing or explaining.

Many other students still did not make this shift unlike our earlier experience in the preliminary study (Kawalkar & Vijapurkar, 2011) where most students, who had undergone inquiry teaching for at least three to four years, had abandoned the restricted view of science as merely an academic subject at school. This also contrasts with the tone of students' writing in the diaries where there was clearer evidence of most students in the inquiry group framing science as an inquiry. This

2 In India, in our experience, students often refer to questions as 'doubts' especially those asked to seek clarification or to indicate that they have not understood something.

is not surprising given the relatively short period of the study, and we argue that probably a more extended time-period was required for students to develop such an awareness explicitly and be able to verbalise it.

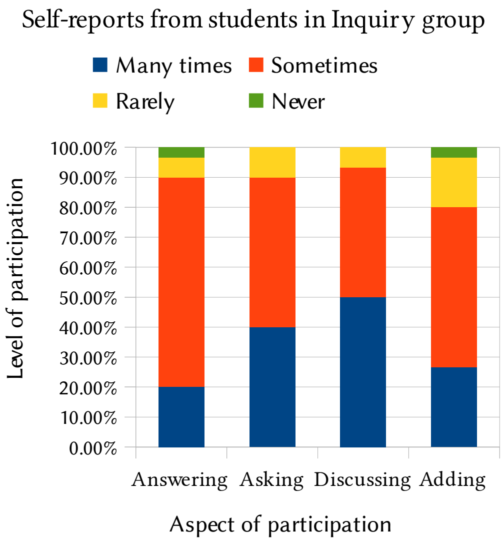
### 5.2.3 Students' reports on their participation in class: 'Asking and Discussing' or 'Answering teacher's questions'

In a post-instruction questionnaire, we asked students, "In which of the classes did you actively participate more? Classes in the program or science classes at school or equally in both?" There was a similar response from both the groups, with more students reporting that they spoke out more in the classes in the program compared to those at school. Students who attended the program longer (both phases of the study) in both the groups were more likely to report this (Table 5.6).

**Table 5.6** Students' response to the question, "In which of the classes do you actively participate more?" in a post-instruction questionnaire

| | **Option chosen by students** | **Inquiry group** | **Comparison group** |
|---|---|---|---|
| **Total students** | Classes in the program | 17 | 18 |
| | Science classes at school | 7 | 7 |
| | Equally in both classes | 5 | 5 |
| **New students** (Attending only Phase II) | Classes in the program | 9 | 12 |
| | Science classes at school | 6 | 6 |
| | Equally in both classes | 4 | 4 |
| **Continuing students** (Attending both Phases) | Classes in the program | 8 | 7 |
| | Science classes at school | 1 | 2 |
| | Equally in both classes | 1 | 1 |

However, when students were further asked to report, on a Likert scale, how much they vocally participated in class and in what ways, more students in inquiry said that they asked questions in class many a time (Figure 5.1 and 5.2).



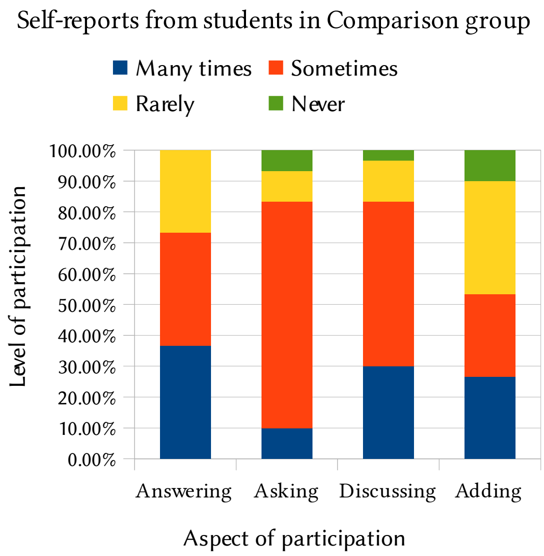




**Figure 5.1 and 5.2** Students' self-reported levels of participation (Phase II)

A substantial proportion of students from the inquiry group reported that they 'asked a question' or 'discussed the topic in class with friends' more frequently than answering in class. On the other hand, a large number of students in the comparison group reported that they rarely or never commented on or added to what others said in class. This, combined with their lower reports of 'asking questions', points to unidirectional class interactions in the traditional science classes – limited to students responding to teacher's questions which was not the case in inquiry.

### 5.2.4 Significant changes reported by students: 'Increase in interest & Questioning' or 'Answering & Knowing more'

We administered a questionnaire one-month after the summer camp (Phase II) to explore changes students may have experienced outside the classes in the program, as a result of participating in it. We surmised that the one-month gap would give them some time to notice any changes, especially in their participation in the science classes at school. Details of this questionnaire and students' responses are given in Appendix I.

When students were asked, "Have there been any changes recently in how you learned/ talked /behaved/ felt about yourself etc.? What was the change? Explain. When did this change come about? What, do you think, brought about this change? Please explain your answer", there was a similar array of responses from both the groups (Table 5.7). There was a difference however, in the most prominent outcomes reported, reflecting how students positioned themselves as learners of science.

While the most prominent changes reported by the comparison group were limited to "answering more often" in their science classes at school and "getting to know more" or having "learned many new things", from the inquiry group, in addition to these changes, they reported "increased interest in science", "asking more questions". These explicit reports of higher levels of increase in interest in science and questioning from inquiry group are consistent with the outcomes reflected in students' diaries in terms of higher engagement in learning science as well as the higher number of questions noted by them.

Since students' written responses to this question which required them to reflect on the changes in themselves were very brief, interviews were needed to probe further. Semi-structured interviews, on similar lines as the written questionnaire, were conducted with a sub-sample of students across academic scores (around one-third of the students from both groups) to probe outcomes reported in the questionnaire.

Students could elaborate and add to the changes they had reported in response to the questionnaire; details are provided in Appendix J.

**Table 5.7** Categories of outcomes reported by students of the two groups in response to a question asked in a post-intervention questionnaire

| | Interest in Science/ more attention towards Sc | Being more curious/ yearning to learn | Asking more questions in science class at school | Answer more often in science class at school | More confidence/ courage to answer/ question | Talking/ discussing more about science | Change in the way I study/ learn | Got to know more/ learnt many new things | Easier to understand what is taught in science classes | More observant | Change in the way I behave/ talk | Being more reflective | Increase in marks in science at school | No change/ not answered | Total number of students |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gp I | **12** | 3 | **7** | **11** | 2 | 2 | 1 | **7** | 3 | 0 | 3 | 2 | 0 | 4 | 41 |
| Gp C | 5 | 1 | 2 | **16** | 2 | 3 | 3 | **9** | 4 | 2 | 3 | 0 | 2 | 3 | 40 |

In response to the interviews, there was a similar pattern in the prominent narrative of changes reported by the two groups. In inquiry, students talked mainly about increased enjoyment in learning science (*"science seekhne mein mazaa aata hai"*/ I enjoy learning science*);* in the comparison group, as many students reported "knowing more" and "learning more than the textbook" as an outcome of attending the science classes as there were those who talked about increased interest in science. Eight out of the fifteen students in inquiry explicitly mentioned that their interest in science has increased while the rest mentioned a related aspect – paying more attention in science classes (4) and answering teachers' questions (4), increased curiosity (6) and discussion with friends about science (5). Compared to this, four of the fourteen students in the comparison group reported an increase in interest as an outcome for them in the interview, while six felt happy that they got to know more.

It might be argued that the kind of changes reported significant by the two groups provides another line of evidence to support the findings in the analysis of diaries that students in inquiry developed a *'doing science'* frame of learning as compared to "doing the classroom" frame adopted by the comparison group.

There is a notable difference between the groups, in the reasons students assigned for a change in their way of studying science. Students in the inquiry group said -

> Kuch sikhaya toh discuss karte hain uske baad… *pehle questions ka answer book mein doondhta tha, ab concept samajhta hoon aur khud ke mann se answer likhta hoon.* (When we are taught something, we discuss after that… earlier I used to look for answers in the textbook, now I understand the concept and write the answer in my own words.)
>
> I became [a] little observant, after class I recall what we did, if I have any questions.
>
> I saw that I was thinking more about my doubts [sic].

Students in the comparison group, said -

> *Padhai mein zyada dhyan deti hoon* (I pay more attention to studies).
>
> My concentration power is more now… only in science. I have become more faster [sic]… faster *matlab pehle answer sochna padta tha… abhi itna sochna nahi padta (*earlier I had to think more to answer but now I don't have to think that much).
>
> I find some change in my studying. I can easily 'by heart'[3] [sic] my questions and answers.

**Reasons given for finding science more accessible**

Some students from both groups (five students from inquiry and four from comparison group), especially the academically low-achieving students, reported that they found learning science easier after attending the classes in the program. There is a difference in the reason they assign for it. Students in the comparison group reported that they found it easier to understand the content and complex terms involved and were better able to answer teacher's questions when the topic

3 The term 'to by heart' is commonly used by students as verb, a misnomer of course, for 'learning by heart' or memorising.

in their science classes at school was similar to what was already taught in the HBCSE classes. For students in the inquiry group, the reason was finding science enthralling and therefore being able to engage with it more. Four students in the inquiry group who had the lowest marks/ scores in science (in their school exams) amongst the group, maintained that learning science was still difficult but because they had started finding it more appealing and tried to connect what they were learning to what they already knew from everyday life, they were able to better understand and answer in the science class. During the mid-way interviews done at the end of winter camp, two of these students had reported that they did not talk during the class discussions in the science classes at school or at HBCSE since they found it challenging. It was heartening that this developing interest in science helped them engage with it.

### 5.2.5 I want to learn science because...

More students from the comparison group, in response to a multiple-choice question in the post-intervention questionnaire, assigned reasons for wanting to learn science that indicated extrinsic motivation - scoring good marks, wanting a career in science or parents wanting them to do well in science, in addition to finding science interesting (Table 5.8).

**Table 5.8** Students' choices of options for wanting to learn science

| | I want to score good marks in science | My parents want me to do well in science | I want a career related to science | My teachers & others tell me science is an important subject | Science is interesting | It helps me understand many things in daily life |
|---|---|---|---|---|---|---|
| Inquiry group (N=30) | 20 | 6.67 | 56.67 | 6.67 | 96.67 | 60 |
| Comparison group (N=31) | 40 | 17.14 | 68.57 | 5.71 | 82.86 | 62 |

Numbers indicate percentages; students could choose more than one reason and therefore the sum for each group would not add up to 100.

### 5.2.6 Students' questions:

**Wonderment questions, based on observations and experiences or factual questions based on what is taught in science classes or read in science texts**

**Students' questions written in the notebooks:** In the notebooks (given to students in Phase II), there was a substantial number of self-generated, spontaneous questions noted down by students in the inquiry group. Analysis of these questions revealed several differences in learning between the groups. Out of the 36 questions asked by students in the inquiry group, 22 probed and built on the content taught while the rest were questions out of general curiosity and not related to content from the classes in this project.

We coded all the questions according to types described by Chin and Brown (2002). Only 9 of the 36 questions were factual or 'basic information' questions while the rest (75%) either sought comprehension, indicated anomaly detection or involved thought experimenting, all of which are types of 'wonderment' questions. Such questions are reflective of a deep approach to learning and further stimulate productive discussion and higher-order thinking (Chin & Brown, 2002). Some examples of questions from the inquiry group and the only three questions from the comparison group are given in Table 5.9. Marbach-Ad and Sokolove (2000) too found that students from 'active learning' groups were better able to pose questions and at a higher level than those taught in a traditional lecture format. Our findings further suggest that in active learning environments, students ask more wonderment questions.

**Students' questioning in class:** In addition to the large number of students' questions (Table 5.10), within the sample of six classes of inquiry teaching (for analysis on teachers' questions in section 4.2) from Phase I, three students explicitly said they did not understand a question or a statement and two students reminded the teacher that their question was not answered yet.

**Table 5.9** Students' questions in notebooks: some examples from the inquiry group, and all the questions from the comparison group

| Questions from Inquiry group | Questions from Comparison group |
|---|---|
| When we took a clay ball which was hollow from inside it sank and when we covered the ball with clay it floated. Why?* | What are lanthanide and actinide series?# |
| Can some things float *and* sink? | Does starfish also have parts like other fishes?+ |
| If we put ice in very cold water will it melt or not or will it take time to melt? | Why do we categorise sharks as fish and not as mammal though most of the sharks give birth to young ones?* + |
| How big is an atom and a nucleus?# | |
| If starfish, jellyfish are not fish, why do we call them fish?*+ | |
| Why is there no nucleus in a red blood cell?* | |
| Fishes get birth [sic] in water, they die in water but from where does air come inside the air bladder (swim bladder) inside them?* | |

*These questions probed or built on what the teacher had taught. + These questions were asked after the topic had been taught. # These questions are examples of basic information questions while the rest are instances of wonderment questions.

**Table 5.10** Number of total students' responses and questions in a sub-sample of 3 classes for each teacher in Phase I

| Teacher | IJ | IK | TN | TP |
|---|---|---|---|---|
| Total number of student responses | 150 | 180 | 96 | 77 |
| Total number student questions | 18 | 20 | 1 | 0 |

Further, at times they even questioned the teacher ("How can that happen?") or went on to point a mistake ("How can the anther fall?" when the teacher mistakenly said "anther" instead of "pollen"). Students' questions also sparked stimulating discussions in class and affected the course of the lesson, for instance in the context of measurement of rain, when the teacher got them to think – "How odd that rain is measured in units of length!" and make rain gauges, a student wondered if the size and shape of the rain gauge mattered. During the ensuing activity and discussion, another student asked if raindrops are of the same size and conjectured that if not then even identical containers, placed close to each other, would collect different amounts of water. The teacher had to develop further experiments to address these conjectures. These instances show not only that students got into the spirit of inquiry as modelled by the teachers but are indicative of students' progression in thinking.

Note that in Figure 4.2 students' questions asked in class were also wonderment questions leading to further class discussions.

In a more detailed quantitative analysis of student talk turns in Phase II, a total of 140 spontaneous questions from students were recorded during the inquiry classes (excluding the 39 questions in a class on Day 14 of the summer camp, when Teacher IJ encouraged students to ask any questions they had related to the teaching so far in the camp). In the comparison group, on the other hand, there were 35 questions asked spontaneously by students during the whole of Phase II.

**Students' questions reported in response to the questionnaires:** In the questionnaire administered one month post the program, students were asked if they had had any question since the program. Only a few students from both groups reported a question. From the inquiry group, 13 out of 37 students mentioned a question while eight out of 34 students from the comparison group reported that they had a question. Though the number of questions is small (making it difficult to compare across groups), there were some discernible differences in the kinds of questions, reflecting the general pattern found so far in students' questioning.

The questions from inquiry group (Box 5.1) seemed qualitatively distinct from those of the comparison group (Box 5.2) in that they were mainly wonderment questions focused on explanations, predictions and causes instead of facts and the source of these questions were puzzlement about personal experience (Q1), real-life observations/ events (Q4-9) and what was learned in the classes in this program (Q1-3).

**Box 5.1: Questions from Inquiry group**

1. Why do we get very much tired while running race on a running track [surface which offers less resistance compared to a tar road]?
2. i) How is [blood] circulation set in organisms? [how does blood start circulating?]
   ii) Why is that living beings respire? [what makes them to respire?]
3. Oil will float on water, in that case will egg sink in oil & water or float on it? [egg floats in saltwater and oil too, so where will the egg be when oil is on top of saltwater?]
4. The question is that I have seen some plants in my neighborhood many times, they have big pustules & warts on their surfaces, what are they?
5. Why does the grass look light green in rainy season?
6. How do the pictures come on TV or computer? If the glass breaks does the picture also break?
7. What on earth (also used as proverb) causes gravitation?
8. How iron gets the rust, why it cannot be shiny then?
9. Why does apple change colour after keeping it cut for a long time?
10. How does lightening not affect the people inside cars or buses though they are made of metals.
11. How can we get to know about climate change? [over centuries]
12. What is the difference between Physics & Chemistry? [In density lessons, we learnt about atoms and in chemistry too]
13. The first thing was what I am going to learn in science this year?

Those based on what was taught in class  (first three questions in the table) built on ideas students' had learned in the classes in the program. In the first question (Q1), which the student further elaborated in the follow-up interview, the student related what was taught in class (about increased metabolic activity and fatigue during exercise, in the unit on the circulatory system) to his experience of running on different track surfaces and wondered about it. Through Q2, another student looked for a cause for blood circulation or respiration to start in an organism in the first place. The third questions seems like a thought experiment extending the activity done in class (the student who asked this question had attended only the initial classes on density and hence was struggling with the concept of relative density but kept thinking about it). The text in square brackets at the end of some questions are clarifications given by students during the interviews.

Box 5.2 lists the questions from the comparison group. Some of them (Q1, Q2 & Q4) are wonderment questions looking for mechanism and explanation while all the rest are factual in nature and text-based. Only Q1 is related to everyday life while others are related to what was learned in class. Notably, the two questions (Q2 and 3) which are related to topics learnt in the traditional science classes during the summer camp, reflect an incomplete understanding of the concepts. Question 2 seeks to comprehend the activity done in class and depicting this student's bafflement of how the particular demonstration had worked. However, this was not brought up in class.

Among whatever few questions that were reported after the intervention, the ones by inquiry group were at a conceptually higher level. A similar trend is seen in the number and examples of students' questions reported by parents (Table 5.11 and 5.12, and Box 5.3 and 5.4).

**Box 5.2: Questions from comparison group**

1. How do gears work in cycles & bikes?
2. When we add sugar to water & dissolve, there is some other quality, how? [in the activity comparing sinking of egg in water and sugar water]
3. Is Sea horse having a brain or not? & what does it eat?
4. After the classes, in a book I read that human [being] is evolution of monkey, so I thought, why didn't all monkeys become human?
5. The question is that, what is the recent thing discovered in science?
6. I had a question on animal & plant cell.
7. What will be the reaction of copper sulphate plus zinc?
8. What is coal made of?

**Table 5.11** Parents' responses to the question "Does your child ask more questions now (after attending HBCSE classes) about events in daily life or what they see around? Or is it less or the same as before?"

| Response | Inquiry Group | Comparison group |
|---|---|---|
| Same | 11 | 9 |
| More | 15 | 17 |
| Less | 1 | 0 |

**Table 5.12** Types of students' questions reported by parents

| | Inquiry group | Comparison group |
|---|---|---|
| 1. Kind of information sought | | |
| Seeking factual information | 3 | 5 |
| Seeking explanatory information | 13 | 5 |
| Seeking methodological information | 1 | 0 |
| Seeking causal information using predictions | 2 | 0 |
| 2. Related to content taught in Summer camp | 5 | 4 |
| Total no. of examples of students' questions given | 20 | 11 |

**Box 5.3: Examples of students' questions given by parents from *Inquiry group***

*Seeking factual information -*

How is the time interval managed for all lights at traffic signal?

*Seeking explanatory information -*

He asked me about a white crow he saw, how did it get white colour?

Why does the sea get high tide especially during rainfall?

What is radiation and how does it come from Uranium?

Why does a street light going bad intermittently switch on and off?

*Seeking methodological information -*

Is there any evidence for aliens or UFO's having landed on earth?

*Describing an experiment and asking what results might be*

If we go on putting more pins on a thermacol [Styrofoam] cube it sinks, then if we remove one pin, it will sink or float?

*Seeking discrepancy -*

Is there any fish that does not have gills?

In the questionnaire administered after the program, an almost equal number of parents in both groups reported that after attending these classes, their child asked more questions about daily life/ their surroundings. However, there were more examples from the inquiry group, and these questions were more likely to be seeking explanatory rather than factual information. Also, though few, there were questions from the inquiry group that asked for methodological information (scientific ways of finding out), predictions (describing an experiment and wondering the results would be) and discrepancy in a pattern. An almost equal number of students, a few from both groups discussed questions at home from the content taught in the summer camp.

**Box 5.4: Examples of students' questions given by parents from *Comparison group***

*Seeking factual information -*

What is the function of the heart, liver, kidney? Is it the same in animals and human beings?

What is the normal number of platelets in the body?

What is the difference between motor and generator?

What is global warming?

*Seeking explanatory information -*

How does a person's height increase in space?

How does the Internet work?

Why there is a difference in pattern every time ink/ poster colour is added to a bucket of water?

Why do fish have scales?

In summary, the students' questions reported in this study portray the kind of expectations students are attuned to when they learn science in particular ways and indicate what view of science students adapt to – whether it is seen as a school subject within the confines of the typical science topics (as reflected in the questions from the comparison group) or whether it is perceived as open to questions about their observations in daily life and their personal experiences (as reflected in the questions from the inquiry group).

### 5.2.7 Students' observations beyond the science classroom

In the delayed post-intervention questionnaire, we asked students if they had made any recent observation that they found puzzling or intriguing. Only 11 students in Inquiry, reported that they made an observation recently (in the month following the camp, after they had attended the camp); these are listed in Box 5.5. Eight of these were actual observations while three were what they had noted/ what they were fascinated about when they read or learned something new. It is interesting to note that around half of them have put down their observations in a question form indicating that they are not only puzzled over them but are curious to understand them. In the instances of the white crow (Observation no. 4) and running on rubber track (Observation no. 6), the students had followed up to ask their parent or teacher about the anomalous observation as corroborated by the parent/ teacher.

Reports of spontaneous observations from the comparison group were all the more scarce (Box 5.6). Though six of them reported an observation, only two of them were actual observations (Observation nos. 1 and 2) and one of these two (Observation no. 2) was in the context of the classroom during the intervention itself. The rest of them were what these students found fascinating in their science classes at school.

**Box 5.5: Observations that students found interesting/ puzzling:**
***Inquiry group***

1. After exercise, I become a little reddish.
2. How the earthworm crawls?
3. I saw in my bathroom that salts had grown on the wall recently, why?
4. In my village, in summer holidays, I saw a white crow which was very shocking to see.
5. Recently, I have seen puzzling observation in my village when I have gone in holidays that water was coming out from the ground, there is any machine in the ground?
6. i) I saw a group of ants walking in a very different way, not after each other.
   ii) And why our energy goes fast [burns faster] while running on rubber track?
7. I watched many different types of animals.
8. How Paul, the Octopus ,is doing the predictions?
9. Between this gap, I studied about different periods of earth's age.
10. I recently observed that mercury is the only metal which is in liquid form.
11. That when wind or air blows, instead of fluttering in the opposite direction, the paper goes in that direction only. [The student came across this demonstration while working on a science project at school]

Thus, learning science through inquiry did enthuse students to observe and wonder about their surroundings and their experiences with it, though to a small extent. However, notably, both the groups, construed the term 'observation' loosely, including something that had caught their attention while reading or learning something in the science class. This was more evident in the responses from the comparison group; nevertheless, their responses indicate that they had reflected on their interests and on what they had found fascinating in school science. This set of data is yet another line of evidence indicating that students in the comparison group valued science more as a school subject whereas students in inquiry construed science in a broader, more 'personalised' way including in its purview their out-of-school observations and experiences.

**Box 5.6: Observations that students found interesting/ puzzling: *Comparison group***

1. In our class, one light bulb is broken & the switch was on. I was thinking that will the electrons & protons flow in our whole class & I laughed.
2. The interesting observation is that when water stays on the other water layer [with dissolved sugar][In the density column demonstration in traditional science class during the summer camp]
3. Coal is made up of dead organisms & not from rock.
4. Friction doesn't oppose motion, it opposes relative motion.
5. I found that many animals' cells have lysosomes which burst.
6. I found out that in a solar panel electrons are ejected which produce electricity.

There was a similar trend in the responses to the questionnaire administered to parents after the program (Table 5.13), where an equal number of parents of both groups reported that their child observed their surroundings more after the classes, however, there were slightly more examples from parents of the Inquiry group. Examples are given in Box 5.7 and 5.8.

**Table 5.13** Parents' responses to the question "After attending HBCSE classes, does your child observe his/ her surroundings more or less or is it the same. Please give a recent example."

| Response | More | Same | Less | Not answered | Examples given |
|---|---|---|---|---|---|
| Inquiry group | 19 | 6 | 0 | 1 | 10 |
| Comparison group | 19 | 7 | 0 | 0 | 6 |

**Box 5.7: Examples of students' observation reported by parents from inquiry group**

She noticed some features on leaves of some plants. She wanted to know whether they are real characteristics/ diseases/ deformities.

Nowadays he reads contents of medicine & food products & asks me what is preservative, what is sodium chloride, why it is added etc.

That rain falls straight sometimes and slanting sometimes.

Fish that we brought from the market.

I saw that he was observing the ants nearby.

She is actually watching growing plants, strange insects.

**Box 5.8: All the students' observation reported by parents from comparison group**

He has observed nest of crow and their behaviour during rainy season

He was investigating fish which I brought from market for food

He saw a fallen tree during rains and could explain the reason for it

She noticed queue of ants and told me why they go like this

Why do we park the car under the tree?

She asked me why scripts in newspapers and books black in colour, why rains only duringJuly-August months, why food served in hotels is tasty?

### 5.2.8 Difference in students' epistemologies: In summary

There is a clear pattern that emerged in how students in both groups viewed science differently and how they got involved in the learning of science. Though the difference in each of the category of evidence may not be quantitatively large in each instance, but together they consistently point to students in inquiry adopting a *'doing science'* frame of learning - they wrote what they had learnt in their own, personalised manner and based it on evidence and discussions, many of them described science as processes, participated in the science classes by asking questions and discussing with friends instead of merely answering teacher's questions; significant outcomes for them out of this program was 'increase in interest and asking questions' rather than 'answering more and getting to know more', they asked more wonderment questions based on their observations and experiences.

In contrast, students in the comparison group seem to have adopted a 'doing the lesson' frame of learning. More students in this group, wrote what they had learned in the form of mere recall of facts, definitions and laws taught by the teacher, expressed through formal statements indicating uncritical acceptance of canonical knowledge and authority. Many of these students conceived of science as merely an academic subject that they have to study at school. Their vocal participation in their science classes was mostly restricted to responding to teacher's questions rather than asking their own. The significant outcome of attending this program for them was - being able to answer more in their science classes at school since they got to know more and paid more attention. More students in this group had extrinsic motivation for learning science (like scoring good marks), asked factual questions mostly restricted to what they had read in a book or what had been taught in a science class and hardly made an observation beyond the classroom. When all the instances of students indicating a frame *'doing science'* were collated (details in Appendix M), we found that 30 out of 40 students in the inquiry group

(Table 5.25) show this frame of learning at least in one way compared to 19 out of 42 students from the comparison group (Table 5.26).

## 5.3 Students' Engagement with Science Learning

Engagement refers to the intensity and quality of children's involvement in initiating and carrying out a learning activity (Milne & Otieno, 2007). Students who are engaged may either show deep, in-the-moment or situational interest in the learning activities or involvement that is sustained over time. They tend to select tasks at the border of their competencies, initiate action whenever there is an opportunity, and invest intense effort and concentration in what they are learning. They generally show positive emotions while participating in the ongoing task, including enthusiasm, optimism, self-efficacy, self-confidence, curiosity, and interest. A collective sense of engagement in the classroom may affect other students in the class, bringing them into the fold of increasing engagement. Milne & Otieno (2007) further explain that engagement is a multidimensional concept which includes cognitive, behavioural and affective components which are interlinked:

**Cognitive criteria** include the extent to which students are attending to and expending cognitive effort in the learning tasks (e.g., efforts to integrate new material with previous knowledge and to monitor and guide task comprehension through the use of cognitive and meta-cognitive strategies), a willingness to link observation to explanation and a desire to work together to build an explanation.

**Behavioural criteria** include the extent to which students are actively responding to the learning tasks presented (e.g., number of students responding actively, asking relevant questions, solving task-related problems, and participating in discussions related to the topic with teachers/peers), and

**Affective criteria** which include the level of students' emotional investment in, and their emotional reactions to the learning (e.g., high levels of interest or positive attitudes).

We found evidence of these different aspects of students' engagement with the learning they were experiencing in the various data sources we explored.

### 5.3.1 Reflections from students' diaries

Students' diary entries in the two groups differed in both the number of entries as well as in how detailed they were. Students in the inquiry group wrote almost twice the number of entries on an average, compared to the comparison group (Table 5.14). Also, their journal entries were longer with a significantly higher number of words on an average than those of the comparison group (the means and the range of values are given in Table 5.14); the distributions in the two groups (Figure 5.3) differed significantly (Mann–Whitney U = 77, p = .0045, two-tailed).

**Table 5.14** A comparison of the quantitative aspects of diary entries of the two groups

| | **Inquiry Group** | **Comparison Group** |
|---|---|---|
| Number of diaries submitted | 19 | 18 |
| Number of days of interaction | 18 | 18 |
| Average number of diary entries per student | 15 | 7 |
| Total number of diary entries for the group | 284 | 126 |
| (Geometric) Mean number of words per entry | 86 (Range 152-48) | 55 (Range 206-23) |

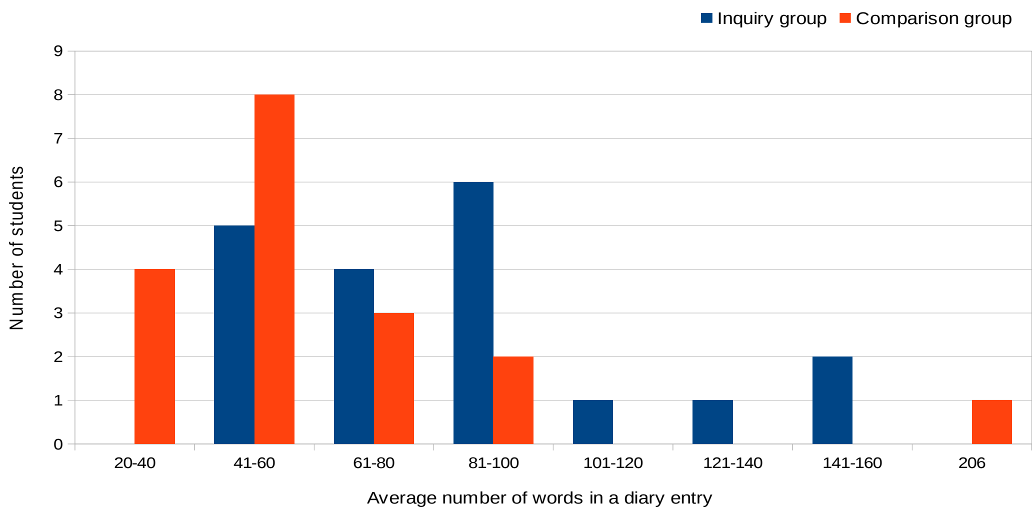



**Figure 5.3** Comparison of the length of diary entries of the two groups

Moreover, diary writing was voluntarily sustained over the four-week period of the camp in the inquiry group. Figure 5.4 shows a plot of the class total of daily dairy entries for the two groups. Note that despite a specific time allocated for making entries during the class on four occasions, the average number of entries per day is smaller for the comparison group. The students in the inquiry group clearly had more to say (and made an effort to do so) than the comparison group.

The amount of optional diary writing, and how detailed it is, is indicative of the degree of students' involvement in learning (Hadzigeorgiou, 2011). Additional evidence for the higher level of engagement in the inquiry group comes from the higher amount of spontaneous notes by students during teaching and the large number of self-generated, spontaneous students' questions written in the note-books (Table 5.15).

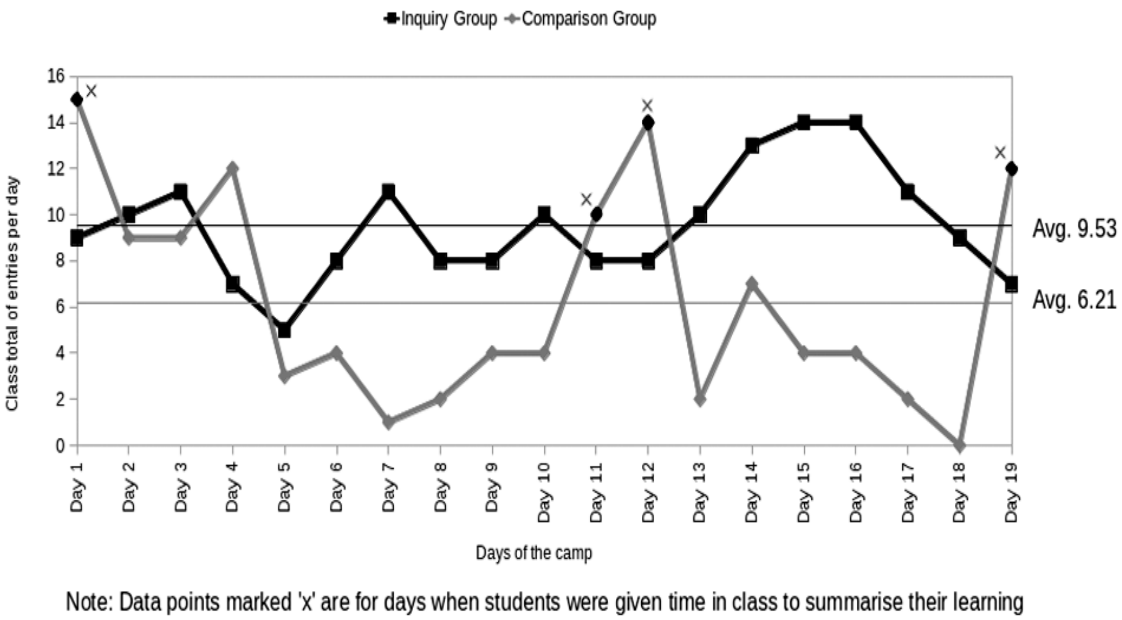



**Figure 5.4** Day-wise plot of diary entries by the two groups

**Table 5.15** Comparative data from students' notebooks indicating students' engagement levels

| | **No. of instances in inquiry group** | **No. of instances in comparison group** |
|---|---|---|
| Spontaneous notes made in class (including noting teacher's questions asked during teaching) | 29 | 8 |
| Attempt at an answer or question | 15 | 4 |
| Students' questions noted down spontaneously | 23+13[a] | 3 |

[a] One of the students asked 13 of the 36 questions

These questions were voluntary (once in each of the groups, the teacher asked students to come up with at least one question each; we excluded those questions from our analysis here; only their spontaneous questions are included).

The spontaneous notes made in class by students in inquiry consisted of (a) teachers' questions noted down to think over them (b) prerequisite facts (such as the relative sizes of proton and atom or atomic weight and size of silver and gold) which they needed to solve a problem and (c) wonderment facts, for example, "The hotter the atom, the faster it moves. It never stops" (although strictly speaking it is the material that is hot, not the atom) and the number of red blood cells (RBCs) in a drop of blood.

Students in the inquiry group wrote more in their diaries across the categories of 'what happened' in their class, 'what was learned' (Table 5.2) and instances of expressing feelings about the teaching-learning (Table 5.16 and 5.17).

**Table 5.16** Coding scheme for analysing content of diaries of the category 'Expression of what was felt'

| Coding categories | Instances from students' diaries |
|---|---|
| Positive | It was great to get a chance to present our views in the debate. Overall I enjoyed this day very much. |
| Negative | Today I did not enjoy as much as yesterday. |
| Reflective notes on teaching-learning | Teacher showed us a picture and we were guessing which animal it was ... but we all felt it was difficult. First I thought it was a dolphin then I changed my mind as its tail was moving right to left but mammals' (tails) move up and down. The most shocking thing was it was (a) reptile. |

The difference in conceptual clarity is not entirely surprising given the difference in students' engagement with the material being taught, as is seen from the quantitative analysis of diary entries. This difference in cognitive engagement is also evident in their descriptions of teacher's action as 'told', 'taught' and 'explained' - descriptions that were qualitatively very different in the two groups (Table 5.1)[4]. In the comparison group they tended to be used in a summary fashion with no detail - 'the teacher taught us density', 'taught volume' or 'she told us about different parts of fish', whereas in inquiry *what* was told or taught was specified and described, often in rich detail - 'she told us why the volume depends on the size of the object', 'she taught us how SI units are derived' or

> She taught us more about parts of fish. I saw many parts - heart (red colour) [with a small drawing], liver [with drawing], liver was covered with fats, lateral line, observed scales in which there were rings like round patterns and scientists can know their ages only by looking at scales of the fish ... there is also a swim bladder which is white in colour and is filled with gases ...

**Table 5.17** Comparison of the diary entries coded as 'Expression of what was felt'

| Categories to analyse 'Expression of what was felt' | No. of instances in inquiry group | No. of instances in comparison group |
|---|---|---|
| Positive | 68 | 57 |
| Negative | 6 | 4 |
| Reflective notes on teaching–learning | 10 | 2 |
| Total | 86 | 63 |

4 Use of the word 'told' to describe instructions such as 'she told us to ask questions' were excluded from the count

Although the number of entries expressing positive feelings was also almost the same in both groups, their frequency distribution was different (Figure 5.5). Note that 22 out of the 57 entries in the comparison group were written by a single student; a maximum of 10 entries were written by one student in inquiry. Both cohorts equally reported liking their teachers, the way of teaching in their class, hands-on activities and the audio–visual material (Table 5.18).

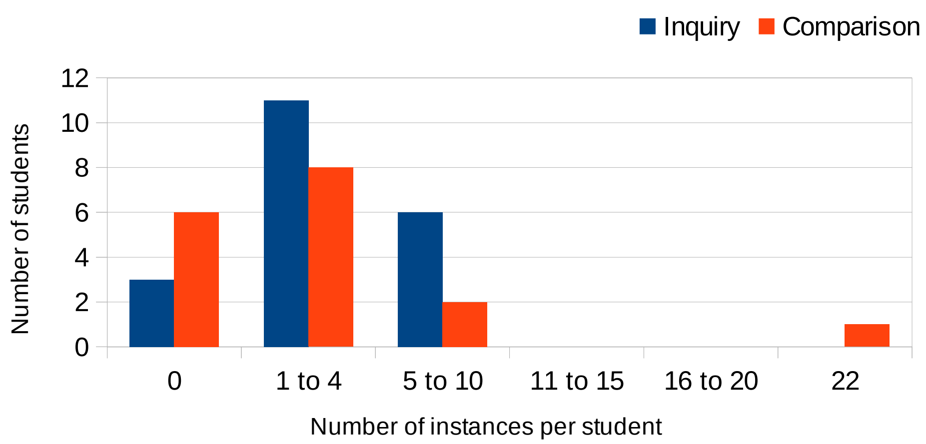



**Figure 5.5** Instances of expression of positive feelings

**Table 5.18** Comparison of the categories of positive responses from students

| Aspects that students liked | No. of instances in inquiry group | No. of instances in comparison group |
|---|---|---|
| The class in general | 15 | 28 |
| Teacher or teaching | 7 | 9 |
| Experiments and demonstrations | 24 | 14 |
| Cognitive engagement/ high cognitive demand | 12 | 1 |
| Whole class discussion | 4 | 0 |
| Videos and slide shows | 6 | 5 |

In addition, students in inquiry reported that they enjoyed the classroom discussions:

> It was great to get a chance to present our views in the debate.
>
> This question started a hot debate. We said [sic] and convinced the teacher of our answer.
>
> This whole day [one class period] went in asking questions and giving/finding answers. I was a little bored and also happy listening to everybody's questions and answers.
>
> We asked our yesterday's [sic] unanswered questions and doubts [sic].

These students also noted that they appreciated the component of history of science built into the teaching:

> We were back in the past with some great people of that time - Aristotle, Galen and William Harvey... She told us about the experiments done by Harvey to find out about circulation
>
> Teacher told us about this brilliant scientist, Archimedes. I liked today's class taken by her.

The negative responses of students in both cohorts were about some of the classes being 'not so exciting' or even 'boring'. Of the two instances in inquiry, one student complained that the same topic continued for three consecutive days and another said, 'Today I did not enjoy as much as yesterday. We enjoyed the first session but after that I was not understanding [sic]'. Evidence of such conscious awareness of their learning was absent in the diaries of the comparison group. Although many students in the comparison group said that the teacher explained well, there were conceptual errors in their learning while in inquiry, students said it was difficult but they tried, or were "not able to understand".

### 5.3.2 Indications of engagement from students' responses in questionnaires and interviews

**Discussion at home or with friends about these classes:** As indicated in the earlier section, for many students in the inquiry group, participation in the science class predominantly entailed asking questions and discussing with friends. Further, there were more reports from students in inquiry that they began to discuss their science learning with friends as well as family. For many students in inquiry, that was a salient outcome for them as a result attending these classes.

> We (friends) interact more, talk about what we learn, what teacher taught…
>
> *… kuch sikhaya toh discuss karte hain uske baad.* (After something is taught we discuss about it).
>
> I shared puzzling facts, interesting information with friends.

In a specific question on this matter, comparatively more students in inquiry reported that they often discussed, amongst friends or family, the classes in the program (Table 5.19) and most of them assigned the reason for this to finding the classes absorbing (Table 5.20). Corroborating evidence came from parents from this group, many of whom also reported that their child discussed the classes in the program more than school. (Table 5.21)

**Table 5.19** Did you discuss with your parents or friends what happened in HBCSE science classes?

| | **Inquiry group (%)** | **Comparison group (%)** |
|---|---|---|
| Many times | 70.97 | 58.33 |
| Sometimes | 29.03 | 33.33 |
| Never | 0 | 2.78 |
| NA | 0 | 5.56 |

**Explicit mentions of enjoyment in learning science from Inquiry group:** While reporting changes students found in themselves as a result of attending the science classes in this program, students in inquiry, mainly talked about increase in interest in learning science - *"science seekhne mein mazaa aata hai"* (I enjoy learning science*), "plants ke baare mein seekhne mazaa aata hai"* (I enjoy learning about plants), *"Science easy lagta hai, mazaa aata hai, connect kar sakte hain to what we know"* (I find science easier, enjoy it and can connect it to what we know).

**Table 5.20** Students' reasons for discussing what happened in these classes

| Students' reasons for discussion at home | Inquiry group (N=31) | Comparison group (N=35) |
|---|---|---|
| Videos and slide shows | 1 | 6 |
| They were interesting | 19 | 7 |
| Learned new things/ different than school/ out of textbook | 3 | 2 |
| Gave us information | 0 | 2 |
| School classes not as good | 4 | 1 |
| Experiments | 3 | 4 |
| Attended something like this for the first time | 0 | 1 |

**Table 5.21** Parents' reports about discussion on HBCSE science classes

| | Inquiry group (N=27) | Comparison group (N=26) |
|---|---|---|
| More than discussion about school classes | 21 | 14 |
| Same as discussion about school classes | 3 | 11 |
| Less than discussion about school classes | 3 | 1 |

As discussed in an earlier section, eight out of fifteen students in inquiry explicitly mentioned that their interest in science has increased while the rest mentioned some related aspect – paying more attention in science classes (4) and answering teachers' questions (4), increased curiosity (6) and discussion with friends about science (5). In comparison, only four of the fourteen students in the comparison group reported an increase in interest as an outcome for them in the interview.

There were similar responses by students in inquiry to the question "Is there any subject that you did not like much before but *started liking* after coming to HBCSE classes? Why?" -

> I did not know that it (science) will be so much fun.
>
> I used to study science because of exams, now out of interest.
>
> I started enjoying it.
>
> It became my favourite subject.

**Responses showing sustained interest and effort:**

Instances from students in the inquiry group -

> I am getting interested in doing science, want to know more
>
> I like to search, find out more. You used to give questions to find out an answer, I continue to do so. We (friends) interact more, talk about what we learn, what teacher taught…
>
> Started to take part in activities in the science class, answer and ask more… read science related books and try out experiments.
>
> *Zyada questions aate hain dimaag mein… kuch sikhaya toh discuss karte hain uske baad… pehle questions ka answer book mein doondhta tha, ab concept samajhta hoon aur khud ke mann se answer likhta hoon…* (More questions come to my mind… when something is taught, we discuss it amongst us… earlier I used to look for answers in the textbook, now I try to understand the concept and write the answers on my own).

There were fewer such instances reported by students in the comparison group -

> *Ghar mein zyada baatein karti hoon science ke baare mein*, participation in science class at school more (I talk more about science related stuff at home).
>
> Parents ke saath discuss karti hoon, kuch samajhta nahi hai toh poochti hoon (I discuss with my parents, if I don't understand something, I ask about it).

**Indications from parents' reports -**

Students' questions reported by parents from the inquiry group included questions on the topics taught in the summer camp, which indicates that students were engaged in the discussions and thinking further on these topics at home.

> If we go on putting more pins on a thermacol [styrofoam] cube it sinks, then if we remove one pin, it will sink or float?
>
> Is there any fish that does not have gills?

Amongst students' observations reported by parents, there were instances from both groups about students observing fish bought from the market, and also ants, both topics dealt with in the classes in the program.

### 5.3.3 Reports on students' engagement from interviews with the teachers

While teachers in inquiry talked about how students participated in their class and commented on the change in students' participation over time in the camp, they gave indications of how, and how much, students were involved in their class -

> Eventually many students participated in the class discussions. But some did not speak up much, especially girls though they did come to the teachers' desk in the break or after class to tinker around with the activities and the materials kept on the desk, and to ask a question or to discuss. (Teacher IJ)

> Their engagement with the topic increased because all these shy kids going home and doing it… Madhuri[5] asked me, "Teacher, why carbon dioxide goes into transparent lime water and turns it milky? I am not able to bear it any more, just tell me the answer"… so they are worrying about problems and not giving up easily. Akshara… she is going on trying at home… she comes and tells me the observation… Harsh who was always rattling off stuff from encyclopaedias… came up with a brilliant idea – salt water is denser than 1gm/cc but ice is less than 1 gm/cc, so he thought he can make ice cubes out of salt water that would be perfect. And he tried but he was disappointed because salt-water doesn't freeze easily. Even when we gave them ants observation, they went and they did things on their own. They did more than what we had told them. (Teacher IJ)

> They were thinking about the topics… were answering, asking questions, arguing for others' answers… they agreed/ disagreed with others' answers or what the teacher said… (Teacher IK)

Teachers from the comparison group also reported that students were very engaged in their classes, but the nature of this engagement that they reported was starkly different -

> All the kids were attentive but only few there who were actively participating, *jo frequently answer karna chahte the* (who frequently wanted to answer). (Teacher TA)

> One girl in the starting she was not that much interested. But baad mein mujhe aisa laga ki she was giving answers very nicely (Teacher TN)

> They answered all revision questions well. (Teacher TA)

> *Chote chote definition bhi deti thi toh woh usse note karte the* (They would note down even brief definitions that I gave). (Teacher TA)

> *Phir baad mein bacche books bhi dhoondke laate the, ki* Ma'm here is a photograph. (Later the children would bring books/ photographs related to the content). (Teacher TN)

5 Students' names in the narrative accounts and tables in the thesis are pseudonyms

Indications for students' involvement in the comparison class were answering teacher's questions, taking down notes diligently and finding relevant content in reference books.

### 5.3.4 Difference in students' engagement: In summary

Data corroborated from across reports of students, parents, teachers and observers (Appendix M) indicates that most students in inquiry (38 out of 40) were engaged with the science learning they had experienced, in at least in one aspect (Table 5.25), while 30 out of 42 students in the comparison group reported an aspect of engagement (Table 5.26).

## 5.4 A Culture of Collective, Co-operative Learning Against Competitive, Individual Learning

As discussed earlier, many students in the inquiry group reported that they began to discuss what was learned in science with their friends and at home. Notably, for many students in inquiry, that was a major change for them as a result of undergoing teaching in these classes. Participation in class for them predominantly entailed asking questions and discussing with friends (Figure 5.1). This also points to a culture of learning collectively, of trying to solve a problem or find an explanation collaboratively instead of stress on individually answering teacher's questions or getting to know more, as reported by the students of the comparison group, which seems more attuned to performance-oriented goals of learning.

Another indication of a cohesive culture building up in inquiry classes is the data in the interviews, when students were asked if they saw any change in any of their friends or classmates who also attended these classes in the intervention, many students in inquiry (7 out of 15) had noticed and described changes in their friends which were supportive of what the students had said about themselves. The most prominent changes noted were increased interest and participation in science classes at school, discussion among friends about science and trying out experiments together. It is notable that only 2 out of 14 students in the comparison group reportedly noticed a change in their peers.

**Excerpt from the researcher's field diary noting such a difference in the classroom culture:**

> 25th December 2009
>
> Children in the comparison group throughout this camp were observed to be very eager to go through the resource books like *Campbell's Biology* that they saw with the teacher. In fact, they were not ready to leave after class and also sometimes came early just to read these books. It was difficult even during teaching, sometimes, to make them keep the books away. I found it very striking that they did not want to share these books with each other, even with their friends. If any of them would be coming early or staying a bit late to read these books, they did not want us to let their friends know about it (particularly the class toppers - Preeti, Ajitha and Ayush).
>
> On one occasion, some of the children from inquiry group came in while some of the students from morning group [comparison group] were still at these books. Students from inquiry seemed to find it very puzzling, even funny[6], to see why these students were reading so much. The books were kept on the table during their classes too and they sometimes skimmed through them in groups during the break and animatedly discussed the content.

6 This was indicated to the researcher from students' expressions – facial and verbal - "*Yeh itna kya padh rahe hain?*" (What are they reading so much?)

Though this excerpt is about the researcher's observation after the classes, it points to the competitive culture developing in the comparison classroom, during Phase I of the study, wherein individual students were engaged in pursuit of knowledge that they inferred was sourced from the reference books. This was different from the culture developing in the inquiry classes where students explored and discussed things together, in and beyond the classroom.

## 5.5 Self-efficacy and self-confidence

### 5.5.1 Indications from interviews and questionnaires at the end of the program

There were indications of increase in students' self-confidence and self-efficacy in learning science from both the groups. There were many self-reports of such changes by students in the inquiry -

> Previously I was not confident about anything like I don't used to ask any question and won't answer what teacher used to ask... but now I am much more confident.
>
> I can answer better... This thing I like about me... *aata hai toh interest bhi badhta hai subject mein. Interest badhta hai toh theek se samajhmein bhi aata hai...* (When I am able to understand, my interest increases in the subject. With increased interest, I can understand better...) I answer even if I am not sure, I will get feedback... In earlier grades it was easy but then it got very hard, but I know maths and science are important, I have to increase understanding...
>
> I have more courage to ask questions in class.
>
> I am learning science with interest, so find it easy... it is difficult but now it is becoming easy because I find it interesting.

Further, a student's elaboration on the change in his way of studying science also reflects greater ease with learning science by adopting deeper learning strategy instead of surface level learning -

> *Pehle questions ka answer book mein doondhta tha, ab concept samajhta hoon aur khud ke mann se answer likhta hoon* (Earlier I used to look for answers in the textbook, now I understand the concept and write the answer in my own words.)

There were also many reports from the comparison group, in response to interviews and questionnaires, indicating increased self-confidence and self-efficacy

> I was very weak in science, *abhi acche marks aate hain* (I get good marks in science), I answer in class, know more...
>
> I have become more faster... *faster matlab pehle answer sochna padta tha.. abhi itna sochna nahi padta* (Now I don't have to think much to give an answer).
>
> I can study science without help.
>
> Little bit of confidence increased.
>
> *Friends scholar bulate hain* (friends call me a "scholar") because I answer questions...
>
> When the topic is same, it is easier.
>
> Pehle kuch poochti nai thi, darr lagta tha teacher se (Earlier I wouldn't ask anything, I was afraid of the teacher).

Note that this increase in self-confidence and efficacy is mostly reported in terms of ease in answering questions (especially when the topic is familiar), getting more marks and rarely in terms of asking questions, again pointing to the frame of '*doing the lesson*' being more prevalent in this group.

### 5.5.2 Indications from students' diaries

There were similar reports from the inquiry group in their diary entries; while teachers in inquiry have noted that students enjoyed intellectual challenges (Kawalkar & Vijapurkar, 2013), it is interesting to find that students have themselves reported their higher cognitive engagement in problem-solving:

> It was a good and tricky sum [problem] **but we tried our best**.
>
> Today we learned how to prove that an organism is a fish. It made us very excited.
>
> Today we had to find the volume of a thermocol [Styrofoam] piece. We dipped thermocol [Styrofoam] in water but it floated … we kept putting washers on it till it completely sank, but it was difficult because the block with washers would always topple. So we stuck tape … whole day's time it took [sic] [a two-hour class period]. But it was enjoyful [sic].
>
> Teacher showed us a picture and we were guessing which animal it was … but we all felt it was difficult. First I thought it was a dolphin then I changed my mind but I was sure that it was a mammal. I again had to change my mind as its tail was moving right to left but mammals' [tails] move up and down. The most shocking thing was it was a reptile.

There were no such implicit reports in the diaries of students from the comparison group.

### 5.5.3 Increase in self-efficacy and confidence: In summary

Data from across the multiple sources, collated together (Tables 5.24 and 5.25, details in Appendix M), indicate that about 20 students from both groups reported an aspect related to increase in self-confidence and efficacy in learning science.

Analysis of students' reports indicates that for students in the comparison group, confidence in learning science stemmed from a feeling of getting things right, from seeing themselves as being able to answer correctly. On the contrary, students in the inquiry group got their confidence from trying; they reported taking the risk of being wrong and persisting even when they found a question or task or the subject itself difficult.

## 5.6 Indications of Self-reflection

### 5.6.1 Reflections from students' diaries

Instances from students' diaries in inquiry show that these students reflected on their self-understanding, reporting not only what they found difficult but also what intrigued them. Some instances from their diaries in which they were attentive to what fascinated them in class and articulated it in detail:

> I **noticed** the gills and the tail fins of the fishes. They were all different shaped and interesting.
>
> We were shown different pictures of unique and beautiful fish.
>
> We washed the gills and touched them. It was soft and had many filaments.

They wrote more and in more detail in the diaries across the categories of 'what was done' and 'what was learned', and 'what was felt'.

### 5.6.2 Explicit reports from students

A few students in inquiry reported being more reflective as an outcome of the teaching-learning in these classes -

> I became little observant, after class I recall what we did... this was more after the summer camp.
>
> Every day after a class, I think about what happened, what I learnt and if I

> could think about a question.
>
> I started to think deeply about some observations and things.

There were also indications of greater reflection in these students' responses elsewhere in questionnaires and interviews; they had verbalised a change in their approach to learning: "*Pehle questions ka answer book mein doondhta tha, ab concept samajhta hoon aur khud ke mann se answer likhta hoon" (*Earlier I used to look for answers in the textbook, now I understand the concept and write the answers on my own) and perceived self-efficacy: "I can answer better. This thing I like about me." In fact, this student who reflected on her developing self-efficacy further explained how optimum cognitive challenge led to increased interest and efforts which in turn translated to better understanding and positive efficacy beliefs -

> *Aata hai toh interest bhi badhta hai subject mein. Interest badhta hai toh theek se samajhmein bhi aata hai…* (When I am able to understand, my interest increases in the subject. With increased interest, I can understand better…) I answer even if I am not sure, I will get feedback.

We did not find such instances of reflective thinking in responses from the comparison group.

When students were asked to write what they thought had brought the change (if any) they had described, a lot of students in both groups had difficulty explaining and around half of them left this question unanswered. Articulating this kind of explicit reflection is known to be difficult for students and limited by the language they possess (Iii, Hand & Prain, 2002) especially when they are not exposed to this kind of self-reflection.

Seventeen students in inquiry and thirteen students in the comparison group assigned the reason to HBCSE classes. Seven of the thirteen students in the comparison group merely mentioned the HBCSE classes in general without explaining further; others maintained the tone in diaries that the teachers explained very nicely, were encouraging and kind. Responses from the inquiry group were a little more reflective, detailing what aspects of the classes or the teaching led to a change in their interest and participation in school science. While some students (six of them) explained that the teacher was nice, taught playfully, encouraged them to ask questions, and instilled in them an excitement about science, some (eight students) attributed the reason for their change to “the way of teaching” – “the way the topic was discussed”, “explained clearly”, more interactions, and the experiments. Only a couple of them mentioned “HBCSE classes” in a general way.

Further, students from inquiry, gave detailed differences when asked, “In what ways are the science classes at HBCSE and your school different?” (detailed in Section 4.5.2). This was  also evident from their elaborate suggestions for science teaching at school, noting what changes could be done in the pedagogy (Box 5.9).

Students in the comparison group voiced concerns over “completing the portion” and wanted teaching geared towards making science more interesting and imparting more knowledge (Box 5.10). Also, their responses were about the interactional problems in the class. – teachers paying more attention to only a few students, and punishing students.

Students from inquiry verbalised their discontent with ‘*doing the lesson*’ in their usual science classes which involved explanations exclusively from the teacher which were not based on experiments, teaching limited to what is in the textbooks, chapters not related to one another, frequent tests and the whole teaching-learning process geared towards securing marks. Also, they were more vocal and assertive in voicing these suggestions.

**Box 5.9: Suggestion from the inquiry group for school science teaching**

i) **Change:** There were a lot of changes, students wrote, they would like to see in their regular science classes at school. They disliked "Teaching from the textbook" and complained "In our science classes, teachers read the chapter and do not show us experiments"; some went on to say "Science textbook that I hate. I want no textbooks for science." They suggested "Not to teach us everything by explanation but by experiments", "Add more labs only for children", "include experiments for better understanding" and "I also want the discussions on subjects indirectly related to the chapter".

They were very vocal about their concerns; some more responses best represented in direct speech: "The classes must be interesting", "the number of students should be less", "They should reduce study burden and frequent tests", "reduce the chapters and mix related chapters", "give less notes and teach more", "In school, there is only writing and studying as if we have to win a race".

ii) **Add:** Students need more activities and experiments, and more direct participation in them "we should do experiments in the lab ourself".

iii) **Retain:** Interestingly, they did not want their teachers to be changed and seemed to like them. They seem to be able to separate the teacher's personality from the pitfalls of the teaching method.

**Box 5.10: Suggestions from the comparison group for school science teaching**

i) **Change:** Students in this group too shared very insightful suggestions for changes they would like in commonplace science teaching: "They should not only try to complete the portion but try to increase the interest & knowledge of students", "They should be more interesting, teaching pattern should change", "That teachers should pay attention to each child", "School science classes are also good but teacher pay more attention only towards the first benchers & the class toppers not on the weak students (some teachers only)"; "Teachers should have interest in teaching science but till now in my experience teachers only like punishing students. They pay no attention on teaching", "more interesting topics, less notes", less homework

ii) **Add:** They would like addition of more and fun experiments, use of more diagrams, applying more examples, more time for classes and experiments, "Teacher should have interest in science", inclusion of videos and slide shows, computers, new tools for experiments and conducting experiments by students

iii) **Retain:** Similarly, again, students liked their teachers and did want "good teachers" to be retained.

## 5.7 Students' Vocal Participation in Whole-Class Interactions

According to sociocultural perspectives on learning, participation in discourse is a primary characteristic of learning and knowing (Lave & Wenger, 1991). In this sense, enhanced participation in discursive practices is the improvement in learning itself and not just something that supports learning (Yun & Kim, 2015). In this section, we present an analysis of whole-class interactions (which formed a major part of the lessons in the study in both the groups) and how actively students participated in them.

### 5.7.1 Nature of students' participation

The classroom vignettes (Figures 4.1 & 4.2) illustrated the stark contrast in the way students in the two classrooms participate. Teachers in the comparison group often started the class with questions, solicited them during class, and appreciated students' questions (if any). Indeed, they had explicitly told students at the beginning of the intervention not to hesitate to speak or ask questions. However, as evident in the illustrated episode (Figure 4.1), rarely was a discussion developed or sustained in the class unlike in inquiry classes. When teachers mainly focus on factual information, taking on the role of the knowledge provider in discussions, students' contributions often tend to be brief, with limited instances of students providing reasoning in their responses (Lemke, 1990). In the inquiry class, there were elaborate responses from students sharing their ideas and opinions, identifying reasons for and against claims. Note how towards the end of the episode in the inquiry classroom (Figure 4.2), students responded to each other, critiquing or presenting an alternate viewpoint. More interestingly, students' participation did not remain merely as responses, they initiated a discussion with their own questions and observations. There were several instances in inquiry when students articulated their difficulties or disagreements with a concept or claim put forward by the teacher or other classmates or pointed out a seeming contradiction.

### 5.7.2 Amount, patterns and change over time

Overall, there was a high amount of student participation in the inquiry group in terms of spontaneous student contributions to class discussion. Table 5.19 indicates the higher number of student responses and questions in the inquiry classes in Phase I (in the sub-sample of classes analysed for teacher's questions, presented in Chapter 4). An extensive and detailed quantitative analysis of student talk over Phase II was done to capture the patterns - which are the students who participate and how much and what is the change in students' participation over time? In this phase too, there were more spontaneous student contributions to the class discussion in inquiry with an average 38 spontaneous student turns at talk in a class compared to the 14 in the comparison group. Also, the average number of students who individually and voluntarily contributed to discussions was greater in the inquiry classes (13 students) than the comparison classes (7 students). Notably, the participation was not only sustained over time in the inquiry classroom but it increased while there was a dip in the comparison classroom both in terms of e proportion of student talk and number of students speaking out (Figure 5.6 and 5.7).

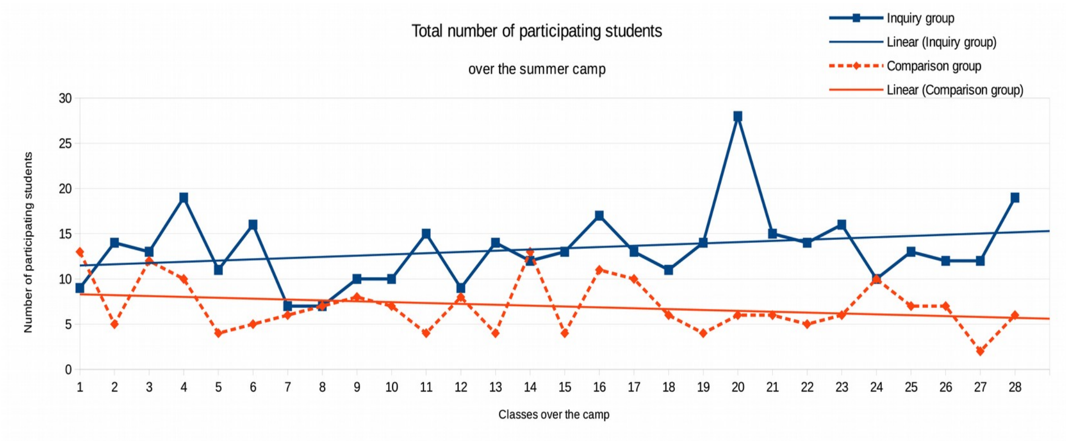



**Figure 5.6** Number of students speaking in class spontaneously over Phase II

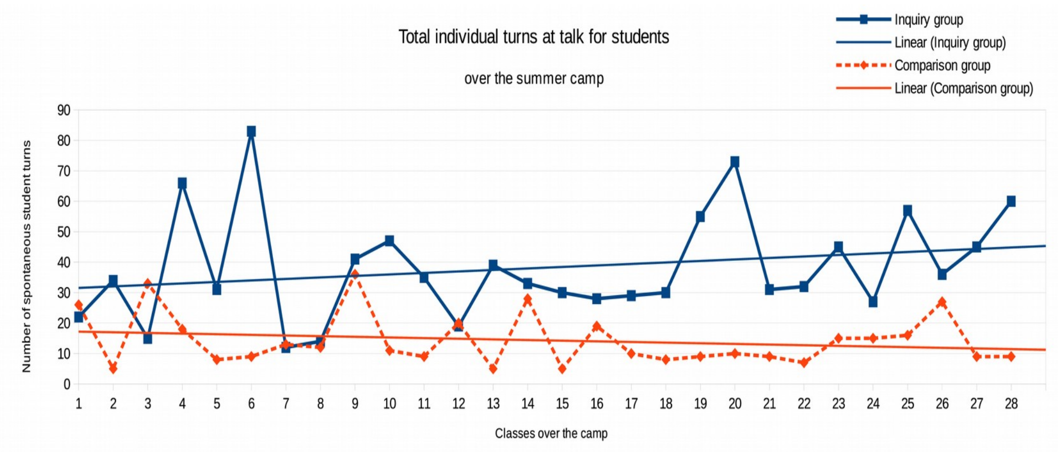



**Figure 5.7** Total spontaneous turns at talk by students in the two classes over Phase II

This was more evident in the Physical science classes conducted by Teacher IJ and Teacher TN in the respective groups (Figure 5.8 and 5.9); in the Biology classes, Teacher IK managed to foster higher participation early on and tried to maintain it through the classes (Figures 5.10 and 5.11).

Moreover, participation in the inquiry class was broad-based and most students, though not all of them, participated to some extent, over the period of the summer camp (Table 5.22). In stark contrast, the same set of a select few students eventually took the floor in the comparison group (Table 5.23).

There were noteworthy within-group differences in the two classrooms. In the comparison group, students who vocally participated more frequently in the whole class interactions were those with higher academic scores (Figure 5.12) and came from higher-income families (Figure 5.13).

Higher participation in class discussions in the inquiry group, on the other hand, came from a more diverse range of students, from across the academic and socio-economic spectrum. In the comparison group (Table 22), all the seven students whose participation was more than the class average were high achieving students with scores in science (in school exams) ranging from 81 to 93 out of 100. Only one of these seven students had family income lesser than the average of around 43,000 Rupees per month.

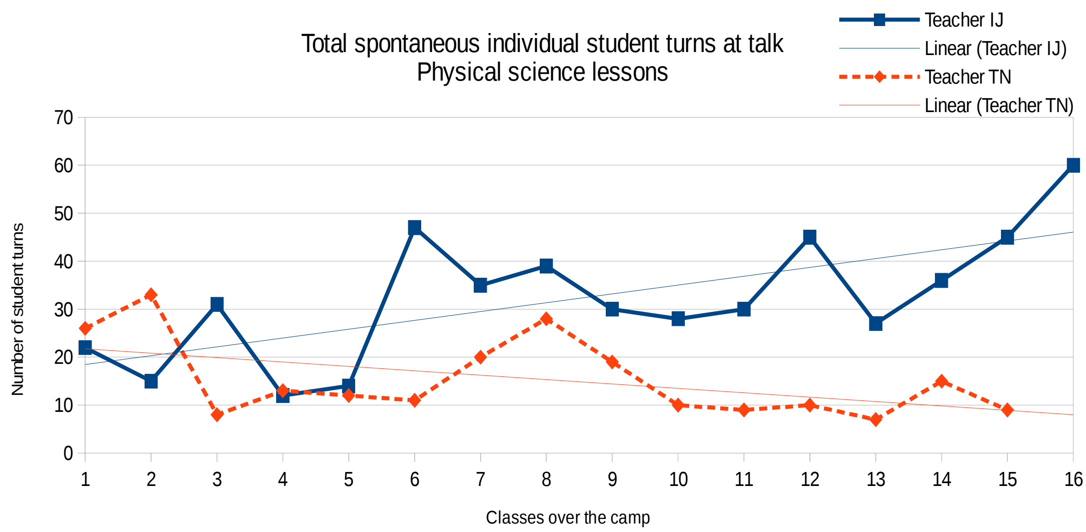



**Figure 5.8** Spontaneous turns at talk by students over Phase II in Physical science lessons

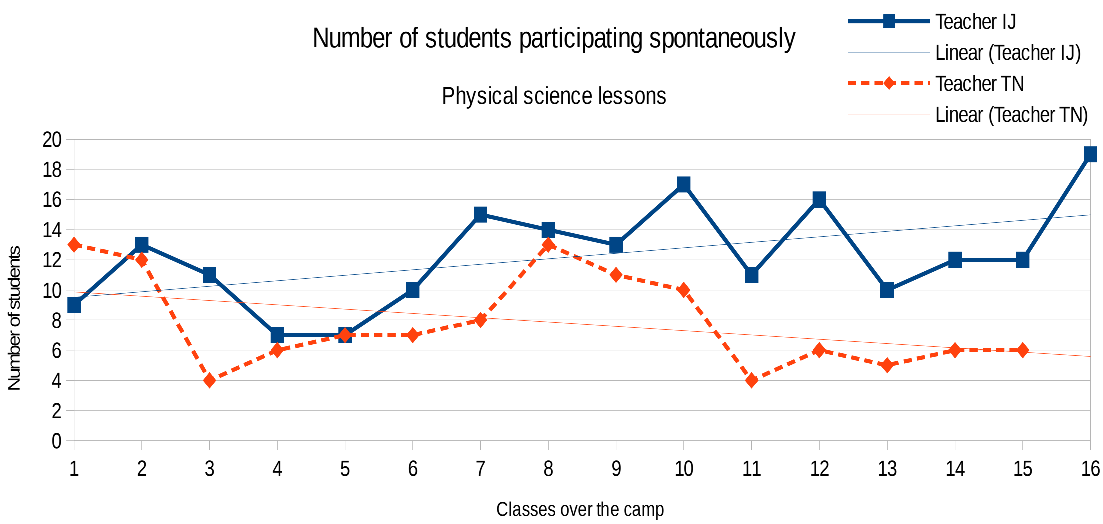



**Figure 5.9** Distribution of number of students participating spontaneously in class discussion in Physical science lessons over Phase II

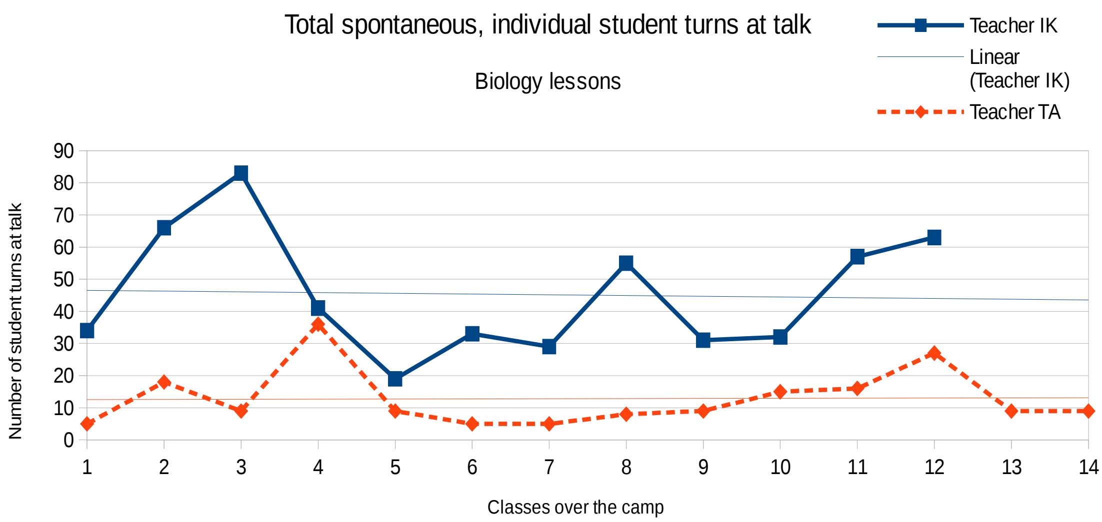



**Figure 5.10** Spontaneous turns at talk by students over Phase II in Biology lessons

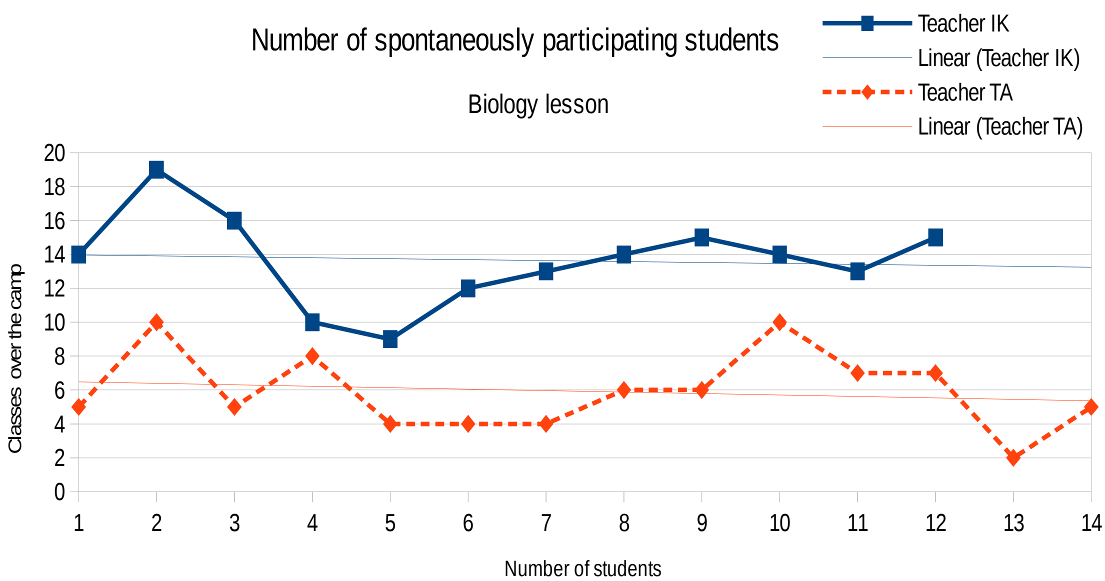
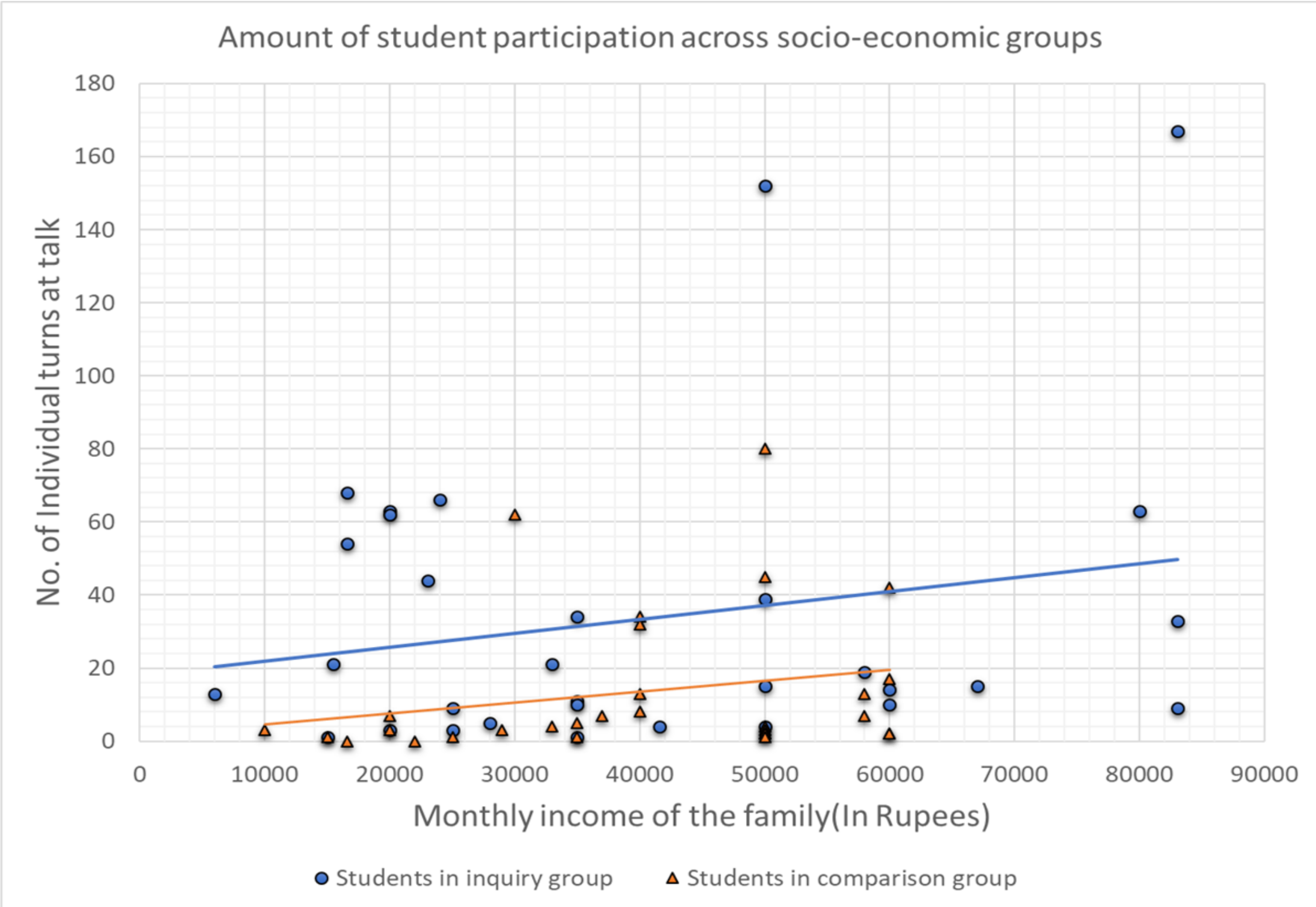



**Figure 5.11** Distribution of number of students participating spontaneously in class discussion in Biology lessons over Phase II

**Figure 5.12** Students' spontaneous vocal participation in Phase II across academic scores



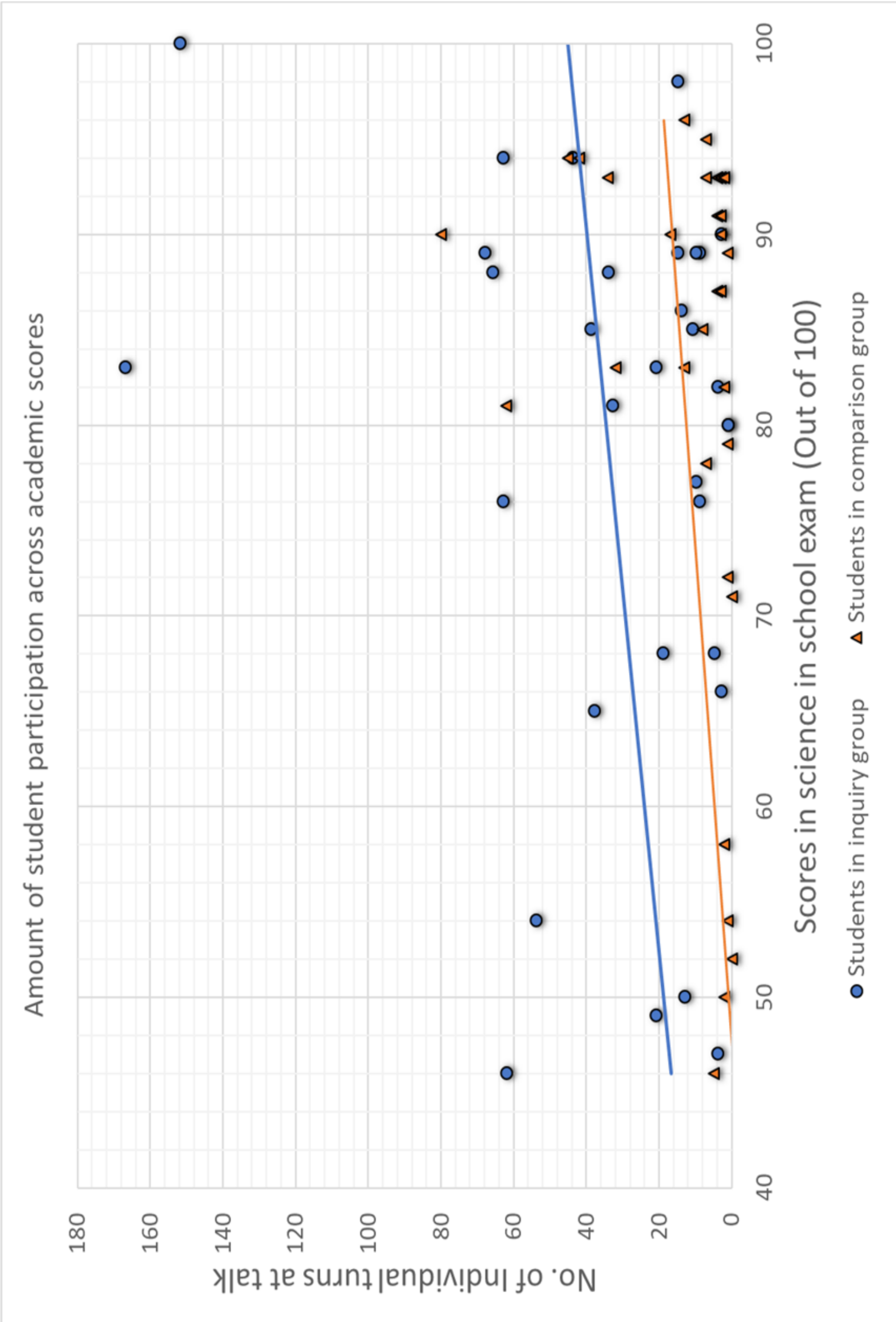



**Figure 5.13** Students' spontaneous vocal participation in Phase II across income groups

**Table 5.22** Level of students' spontaneous participation in class in Inquiry in Phase II

| No. | Batch | Gender | Marks in Science at school | Monhly income of family (Rs.) | Students | Individual total turns at atlk | Day 1 IJ | Day 1 IK | Day 2 IJ | Day 3 IJ | Day 3 IK | Day 4 IJ | Day 4 IK | Day 5 IJ | Day 6 IJ | Day 7 IK | Day 8 IJ | Day 9 IJ | Day 9 IK | Day 10IJ | Day 10 IK | Day 11 IJ | Day 12 IJ | Day 12 IK | Day 13 IJ | Day 13 IK | Day 14 IJ | Day 14 IK | Day 15 IK | Day 15 IJ | Day 16 IJ | Day 17 IK | Day 17 IJ | Day 18 IJ | Day 19 IJ | Day 19 IK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | n | b | 83 | 83000 | Erwin | **169** | 7 | 6 | 2 | 3 | 16 | 5 | 17 | 4 | 3 | | 8 | 0 | | 4 | 4 | 6 | 2 | 4 | 10 | 13 | 7 | 1 | 2 | 2 | 3 | 15 | 9 | 7 | 9 | 1 |
| 2 | n | b | 100 | 50000 | Harsh | **157** | 4 | 4 | 5 | 4 | 10 | 9 | 14 | 2 | 6 | | 7 | 1 | 4 | | 3 | 5 | 3 | 5 | 3 | 9 | 7 | 7 | 7 | 5 | 3 | 11 | 10 | 3 | 6 | |
| 3 | c | b | 89 | 16600 | Abhijeet | **68** | | | | 1 | | 5 | 8 | | | 6 | 2 | 4 | 4 | 6 | 4 | 1 | | | | 3 | 4 | 4 | 4 | 3 | 2 | | 1 | 2 | 4 | 1 |
| 4 | n | g | 94 | 80000 | Payal | **64** | 4 | 7 | 1 | 3 | 6 | 1 | 12 | | 2 | 5 | 7 | 2 | 3 | 2 | | | | 1 | | | 4 | 2 | 2 | A | A | A | A | A | A | A |
| 5 | n | b | 76 | 20000 | Imran | **66** | | 1 | 3 | | 4 | 1 | 8 | 1 | | | 2 | 1 | | 3 | 5 | 3 | 2 | 3 | 2 | 5 | 2 | 1 | 1 | 1 | 2 | 3 | 1 | 7 | 4 | 2 |
| 6 | n | b | 46 | 20000 | Harshal | **69** | | 2 | 7 | 1 | 5 | 1 | 3 | 1 | | 6 | 1 | 3 | 3 | | 1 | 2 | 3 | 3 | | | 3 | 3 | 2 | 6 | 5 | 2 | 1 | | 5 | |
| 7 | c | b | 88 | 24000 | Suhail | **66** | A | A | | A | A | A | A | | | 5 | 10 | 1 | 1 | 7 | | | | 1 | | | 4 | 2 | 5 | 6 | 5 | 4 | 2 | 9 | 4 | 1 |
| 8 | c | g | 54 | 16600 | Akshara | **54** | A | A | | A | A | A | A | | | 6 | 4 | 6 | | | | 3 | 2 | | 3 | 1 | 3 | 4 | 1 | 4 | 1 | 6 | 4 | | 6 | |
| 9 | c | b | 94 | 23000 | Kushal | **44** | | | | | 1 | | 2 | | | 4 | | 1 | | 2 | 5 | 1 | 1 | 1 | | 8 | 2 | 1 | 1 | 1 | | | 1 | 9 | 3 | |
| 10 | n | b | 85 | 50000 | Akhil | **39** | | | | 1 | 1 | 1 | | | | 2 | 2 | | | | 2 | 4 | 2 | 2 | | 4 | 4 | 1 | 1 | 4 | | | 1 | 3 | 4 | 1 |
| 11 | n | b | x | 125000 | Kevin | **40** | 1 | 3 | 2 | 1 | 4 | 3 | 2 | | | | | | | 1 | | | 1 | | | 4 | 3 | 1 | | 1 | 4 | 5 | 2 | | 2 | |
| 12 | n | b | 88 | 35000 | Ronit | **34** | | | | | 2 | | 2 | | 2 | 4 | 1 | | 1 | 4 | | 1 | 2 | 2 | 2 | 1 | 3 | 1 | 2 | | 1 | 1 | | | 2 | 1 |
| 13 | n | b | 81 | 83000 | Arun | **35** | 2 | 2 | 2 | | 1 | | 3 | 1 | | 2 | 1 | 2 | | 1 | 3 | | 2 | 2 | 3 | 2 | 3 | | 1 | | | | | 2 | | |
| 14 | n | b | 83 | 33000 | Nitesh | **21** | | 1 | | | 1 | | | | | | | 4 | | 4 | 2 | | 1 | | 1 | 1 | 4 | 1 | 1 | | | | | | | |
| 15 | c | b | 49 | 15500 | Gyan | **21** | | | | | | 1 | | | | | | | | 3 | | | 1 | 1 | 2 | 1 | 2 | | | 1 | | 5 | | 1 | 3 | |
| 16 | n | b | 68 | 58000 | Shaan | **20** | | 1 | 1 | | 2 | | 6 | | | | 1 | 3 | | | | | 2 | | | 2 | 1 | | | | | | | | 1 | 2 |
| 17 | n | g | 86 | 60000 | Kulpreet | **14** | 1 | | | | 3 | | 1 | 2 | 1 | 1 | 1 | 1 | | 1 | 1 | 1 | | | | | | | | | | | | | | |
| 18 | c | b | 50 | 6000 | Himanshu | **14** | | | 1 | 1 | | | | | | | | 4 | 1 | 1 | | 1 | | | | 1 | 2 | | | 1 | | 1 | | | | |
| 19 | n | g | 98 | 67000 | Asha | **15** | | | | | 1 | | 2 | | | | | | | | | | 1 | 1 | | | 1 | 1 | 1 | | | 4 | 1 | 1 | 1 | 1 |
| 20 | n | g | 85 | 35000 | Sarah | **11** | 1 | 1 | | | 2 | | | | | | | | | | 1 | | | | | | 2 | | | | 1 | | | | 3 | |
| 21 | n | g | 89 | 50000 | Madhuri | **15** | 1 | 2 | | | | | | | | | | 1 | 1 | | | | 1 | | 3 | | 2 | | | 1 | | | 1 | 1 | 1 | |
| 22 | n | g | 76 | 83000 | Arti | **9** | | | | | | 2 | | | | | | | | | 2 | | | | | | 1 | | | 3 | | | 1 | | | |
| 23 | n | b | 77 | 60000 | Ambrish | **10** | | | | | 4 | | 2 | | | | | | 1 | | | | | 2 | 1 | | | | | | | | | | | |
| 24 | n | b | 89 | 25000 | Pranav | **10** | | 2 | 1 | | 1 | | 1 | | | | | 1 | | | | | | | | | 1 | 1 | 1 | | | | | | 1 | |
| 25 | n | g | 89 | 35000 | Deeksha | **10** | | 1 | | | 1 | | | | | | | | | | | | 1 | 1 | | | 2 | | | 2 | | | 1 | | 1 | |
| 26 | c | b | 68 | 28000 | Mayur | **5** | A | A | | A | A | A | A | | | | | | | | | 1 | | | | | 1 | | | 3 | | | | | | |
| 27 | n | g | 82 | 50000 | Veena | **4** | | | | | 1 | 2 | | 1 | | | | | | | | | | | | | | | | | | | | | | |
| 28 | n | g | 90 | 20000 | Bhavna | **3** | 1 | 1 | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| 29 | c | g | 47 | 41600 | Srishti | **4** | | | | | | | | | | | | | | | | | 1 | | | | 2 | | | 1 | | | | | | |
| 30 | c | g | 66 | 25000 | Jaya | **3** | | | | | | | | | | | | | | | | 1 | | | | | 2 | | | | | | | | | |
| 31 | c | b | 80 | 15000 | Nitin | **1** | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| 32 | n | g | 80 | 35000 | Swara | **1** | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| | | | | | **Chorus responses** | **9 (Avg.)** | 2 | 5 | 9 | 6 | | 10 | 21 | 5 | 5 | 0 | 17 | 17 | 3 | 18 | 5 | 19 | 5 | 7 | | 11 | 4 | 7 | 7 | 18 | 7 | 6 | 12 | 4 | 11 | |
| | | | | | **Total individual student turns** | **38 (Avg.)** | 22 | 34 | 25 | 15 | 66 | 31 | 83 | 12 | 14 | 41 | 47 | 35 | 19 | 39 | 33 | 30 | 28 | 29 | 30 | 55 | 73 | 31 | 32 | 45 | 27 | 57 | 36 | 45 | 60 | 10 |
| | | | | | **Total student turns including chorus** | **43 (Avg.)** | 24 | 39 | 34 | 21 | 66 | 41 | 12 | 17 | 19 | 41 | 64 | 52 | 19 | 57 | 38 | 49 | 33 | 36 | 30 | 66 | 79 | 38 | 39 | 63 | 34 | 63 | 48 | 49 | 71 | 10 |
| | | | | | **No. of participating students** | **13 (Avg.)** | **9** | **14** | **10** | **13** | **19** | **11** | **16** | **7** | **7** | **10** | **10** | **15** | **9** | **14** | **12** | **13** | **17** | **13** | **11** | **14** | **28** | **15** | **14** | **16** | **10** | **13** | **12** | **12** | **19** | **10** |
| | | | | | **No. of student questions** | **6 (Avg.)** | 0 | 0 | 1 | 2 | 0 | 0 | 12 | 0 | 0 | 21 | 1 | 6 | 15 | 0 | 2 | 6 | 3 | 12 | 11 | 9 | 39 | 5 | 12 | 1 | 0 | 11 | 3 | 3 | 1 | 3 |

**Table 5.23** Level of students' spontaneous participation in whole class disussion of Comparison group in Phase II

| No. | Batch | Gender | Marks in Science | Monthly income of the family | Students | Total responses in the camp | Day 1 TS | Day 1 TA | Day 2 TS | Day 2 TA | Day 3 TS | Day 3 TA | Day 4 TS | Day 5 TS | Day 5 TA | Day 6 TS | Day 6 TA | Day 7 TS | Day 7 TA | Day 8 TS | Day 8 TA | Day 9 TS | Day 10 TS | Day 10 TA | Day 11 TS | Day 12 TS | Day 12 TA | Day 13 TS | Day 14 TS | Day 15 TA | Day 16 TA | Day17 TA | Day 18 TA | Day 19 TS | Day 20 TA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | c | g | 90 | 50000 | Ajitha | **80** | 5 | 1 | 7 | 3 | 4 | 3 | 2 | 3 | 11 | 6 | 3 | 4 | 1 | 5 | 2 | 2 | 2 | 1 | | 1 | 2 | 1 | | 3 | 6 | 1 | | 1 | |
| 2 | n | b | 81 | 30000 | Ansh | **62** | 4 | | 3 | 1 | 3 | 3 | 3 | 5 | 14 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 3 | 2 | 4 | 2 | A | A | A | A | A | A | 2 | |
| 3 | n | g | 94 | 60000 | Anuja | **42** | 2 | 1 | 3 | 2 | 1 | 1 | 3 | | | | | 1 | 1 | 5 | | 1 | 1 | | 1 | | 1 | | 3 | 3 | 4 | 2 | | 4 | 2 |
| 4 | n | b | 94 | 50000 | Ajinkya | **45** | | | 3 | 1 | | | 2 | | | 1 | | 2 | | | | 3 | 1 | 1 | 5 | 2 | | 2 | 5 | 2 | 1 | 10 | 2 | | 2 |
| 5 | n | g | 93 | 40000 | Indira | **34** | | | | 4 | | 1 | 1 | 1 | 3 | 1 | 3 | 7 | 2 | | 1 | 2 | | 1 | | | 1 | 1 | 2 | | 2 | | | 1 | |
| 6 | n | b | 83 | 40000 | Nitin | **32** | 3 | 1 | 1 | | | | 2 | | 2 | | | | | 1 | | 1 | | | | 1 | 1 | | | | | 10 | 7 | | 2 |
| 7 | n | b | 90 | 60000 | Kinjal | **17** | | | 2 | 1 | | | | | 1 | | | | | 2 | | 2 | | 1 | | | | | | 3 | | 1 | | 1 | 3 |
| 8 | n | b | 83 | 40000 | Tathagata | **13** | 2 | | 1 | 1 | | 1 | | | 1 | | | | | 2 | | 2 | | | | 1 | | | 1 | 1 | | | | | |
| 9 | n | b | 96 | 58000 | Ashutosh | **13** | 2 | | | 2 | | | | | | | | 1 | | 1 | 1 | 1 | 1 | | | | 2 | | | 1 | 1 | | | | |
| 10 | n | b | 85 | 40000 | Arpit | **8** | 2 | | 1 | 1 | | | | 1 | | | | | | 2 | | 1 | | | | | | | | | | | | | |
| 11 | n | b | 93 | 37000 | Anup | **7** | 1 | 1 | 1 | | | | | | | | | | | 1 | | | 1 | | 1 | | | | | 1 | | | | | |
| 12 | c | b | 95 | 20000 | Pravin | **7** | | | | 2 | | | | | 3 | | 2 | | | | | | | | | | | | | | | | | | |
| 13 | n | b | 78 | 58000 | Kartik | **7** | | | 1 | | | | | | | 1 | | 1 | | 1 | | 1 | 1 | 1 | | | | | | | | | | | |
| 14 | n | g | 46 | 35000 | Archana | **5** | 2 | | 2 | | | | | | | | | | | | | 1 | | | | | | | | | | | | | |
| 15 | n | b | 93 | 33000 | Abhay | **4** | | | 1 | | | | | | | | | | | 2 | | | 1 | | | | | | | | | | | | |
| 16 | n | b | 91 | 50000 | Prabhat | **4** | 1 | 1 | | | | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | |
| 17 | n | g | 87 | 150000 | Radha | **4** | 1 | | 1 | | | | | | | | | | | | | | | | | | | 1 | | 1 | | | | | |
| 18 | c | b | 93 | 50000 | Ayush | **3** | | | | | | | | | | | | | | | | | | | | | | | 2 | | 1 | | | | |
| 19 | n | g | 90 | 29000 | Pragya | **3** | 1 | | 1 | | | | | | | | | | | 1 | | | | | | | | | | | | | | | |
| 20 | c | g | 87 | 10000 | Poorna | **3** | | | 1 | | | | | | | | | | | | | | | | | | | 2 | | | | | | | |
| 21 | n | b | 82 | 60000 | Vinay | **2** | | | | | | | | | | | | | | 2 | | | | | | | | | | | | 2 | | | |
| 22 | n | b | 93 | 50000 | Ethan | **2** | | | | | | | | 1 | | | | | | 1 | | | | | | | | | | | | | | | |
| 23 | n | b | 58 | 50000 | Prashant | **2** | | | | | | | | | | | | 2 | | | | | | | | | | | | | | | | | |
| 24 | n | g | 50 | 60000 | Rohini | **2** | | | 1 | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| 25 | c | g | 91 | 20000 | Komal | **3** | A | A | A | A | A | A | A | | | | | | | | | | | | | | | | 2 | | | 1 | | | |
| 26 | n | b | 79 | 25000 | Samar | **1** | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| 27 | n | g | 89 | 50000 | Mugdha | **1** | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | n | g | 54 | 35000 | Sejal | **1** | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29 | c | g | 72 | 15000 | Arpita | **1** | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | c | g | 52 | 16600 | Vaishali | **0** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | c | g | 71 | 22000 | Ashwini | **0** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | **Chorus responses** | **9 (Avg.)** | 12 | 21 | 9 | 21 | 4 | 7 | 11 | 7 | 24 | 11 | 4 | 21 | 11 | 13 | 6 | 12 | 7 | 8 | 4 | 3 | 4 | 1 | 7 | 8 | 6 | 8 | 2 | 6 | 2 |
| | | | | | **Total Individual student turns** | **14 (Avg.)** | 26 | 5 | 33 | 18 | 8 | 9 | 13 | 12 | 36 | 11 | 9 | 20 | 5 | 28 | 5 | 19 | 10 | 8 | 9 | 10 | 9 | 7 | 15 | 15 | 16 | 27 | 9 | 9 | 9 |
| | | | | | **Total student turns including chorus** | **23 (Avg.)** | 38 | 26 | 42 | 39 | 12 | 16 | 24 | 19 | 60 | 22 | 13 | 41 | 16 | 41 | 11 | 31 | 17 | 16 | 13 | 13 | 13 | 8 | 22 | 23 | 22 | 35 | 11 | 15 | 11 |
| | | | | | **No. of participating students** | **7 (Avg.)** | **13** | **5** | **12** | **10** | **4** | **5** | **6** | **7** | **8** | **7** | **4** | **8** | **4** | **13** | **4** | **11** | **10** | **6** | **4** | **6** | **6** | **5** | **6** | **10** | **7** | **7** | **2** | **6** | **5** |
| | | | | | **No. of student questions** | **1 (Avg.)** | 0 | 0 | 3 | 1 | 1 | | 2 | 0 | | 0 | | 2 | | 0 | 3 | 2 | 3 | 4 | 2 | 2 | 1 | 1 | 0 | 0 | 4 | 1 | 2 | 1 | 0 |

On the other hand, among the 11 students who were most vocal in the inquiry class (Table 22) were those who scored as less as 46 and 54 out of 100. Also, six of these 11 students had family incomes about half the average of around 42,000 Rs per month. Figures 5.12 and 5.13 show that low achieving students (scoring less than 60 marks out of 100) and those from lower-income families (less than 30,000 Rs per month) hardly ever spoke in the comparison class.

However, participation was skewed based on gender in the inquiry classroom, with boys taking much more of the discussion space than girls (Table 5.24). Only two of the fifteen students who were most vocal in the class were girls, in the inquiry group, while in the comparison group there was not much difference in the participation of girls and boys, where three out of the five most vocal students were girls. To put it differently, out of 11 students in the inquiry class who had an average number of spontaneous talk turns more than the class average of 38, only two were  girls. In the comparison group, three out seven such vocal students (with an average more than 14 spontaneous talk turns) were girls. Towards the end of the program there was a slight increase in the number of girls speaking up in class in the inquiry group (Table 5.23). There was a similar pattern of participation over time noted during classroom observations in the two groups in Phase I which noted in classroom vignettes, field notes and lesson summaries by teachers.

**Table 5.24** Student participation across gender: Difference in the average number of spontaneous turns at talk for boys and girls

| | **Group average** | **Average for girls** | **Average for boys** |
|---|---|---|---|
| Inquiry group | 33 | 16 | 46 |
| Comparison group | 13 | 13 | 12 |

There was no gender bias noted in the pedagogic interactions in the inquiry classes, in the sense that there was no indication of teachers' nominating boys more to answer or addressed certain questions to only boys. In fact, girls were praised for the questions they asked in the after-class interactions and were encouraged to speak up during class discussions. But even when everyone was required to speak out, for example, in reading out the poems they had written, girls were hesitant to speak in class and wanted the teacher to read out the poem for them.

### 5.7.3 Students' self-reports on their vocal participation

When students were asked: "If you don't answer or ask questions often (many a time) in HBCSE science classes, give reasons.", a greater proportion[7] of students in inquiry (11 out of 30, out of which 8 were girls) informed that the reason was fear that 'others may laugh at them' and/ or 'think that their question or answer was stupid/ silly/ wrong'. Lesser number of students from the comparison group (5 out of 32, only one of them was a girl) reported this as the reason for lower levels of asking or answering in class; for many of them (11 out of 32 as compared to 3 students in inquiry) the reason for not participating often in class was that 'others always answered or asked questions before them'. This points to a difficulty some students have in speaking out in a class discussion in the inquiry mode, pronouncedly for certain groups of students. Therefore, learning how to provide affective scaffolding to bring about a supportive learning environment becomes very important for inquiry teaching to be effective for all students.

We again note that this particular group of students seemed comparatively more shy to participate in class discussions; this was not the case in earlier classes conducted as part of the curriculum development project. Perhaps, students' adolescent age, their specific context and the relatively shorter duration of contact could be the possible reasons.

7 Z-score=1.89, p=0.05

## 5.8 Summary of Findings in this Chapter

This study brought out a variety of differences in the learning outcomes in the two sets of classrooms. Our analysis of students' diaries proved to be a useful tool for the comparison of the teaching-learning between the two groups. A large number of instances of 'what was learned' written by the comparison group indicated a lack of conceptual clarity and several instances of a misunderstanding of the concepts. There were errors of observation and argument made in the diary entries of students in inquiry too but they were fewer and were noted in the initial stages of a sub-topic, as opposed to the errors by students in the comparison group that were made even after instruction. As the unit progressed, building on concepts tackled through earlier activities and discussion, there were opportunities for such errors to surface in the inquiry class and were directly addressed by the teacher which might account for the fewer number of content errors in the diary entries.

Further, students in inquiry demonstrated a frame of *doing science* (Jimenez-Aleixandre et al., 2000) - they expressed what they had learnt in their own, personalised manner and based it on evidence and discussions, many of them described science as processes, participated in the science classes by asking questions and discussing with friends instead of only to answering, significant outcomes for them out of this program was 'increase in interest and asking questions' rather than 'answering more and getting to know more', they asked more wonderment questions based on their based on observations and experiences.

In stark contrast was the frame of '*doing the lesson*' adopted by students in the comparison group wherein, more often than not, they described the learning in their diary entries through formal, conventional statements and involved a recall of facts, definitions and laws explained by the teacher. Such a conception of learning as acquisition and reproduction of facts also points to a conception of science as self-evident and objective truth and students' acceptance that the teacher has social and epistemic authority in what is 'correct'. There was evidence, on the other hand, that students in inquiry internalised that they shared epistemic authority with the teacher to construct and articulate explanations, often in collaboration with each other and the teacher. This is evident in the higher number of instances of students' own reasoning to answer a teacher's question, explain an observation, infer from an experiment or as resolution of a class discussion. This also indicated that students in this group internalised, implicitly, the inquiry approach to learning science. Notably, these aspects were not explicitly verbalised to students but were picked up by them from the way the classes were taught: classroom discussion and argument were used as an integral part of the teaching strategy, initiated through questions; activities and experiments were designed to be investigative, with further lessons being built on students' conclusion drawn from the activity. There was also evidence of increased student engagement, self-efficacy and self-reflection in the inquiry classroom and also a developing classroom culture of co-operation with more equitable participation from students. As many students in the comparison group as in inquiry, came out feeling that their engagement and confidence in learning science had increased, although as discussed earlier, more instances of genuine engagement and improved learning were observed in the inquiry group.

Thus, we explored learning outcomes across the conceptual, epistemic, affective domains, and also looked at how teaching in both the modes affected students individually and at the collective level. Except for content learning (which was studied only through students' diary writing), rest of the outcomes were corroborated through various sources (Tables 5.25 and 5.26, Box 5.11). Analysing the data in these two tables depicted further interesting patterns (detailed in Appendix L) which are consistent with our other findings.

**Table 5.25** Collated data on student outcomes for the Inquiry group[8]

| No. | N/C | M/F | Student | Reports indicating engagement in learning science | | | | | | | | | Reports indicating confidence in learning science | | | | | | Reports indicating conceptions of science as processes | | | | | | Reports indicating a classroom culture of collaboration | | | | | | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | B1 | B2 | B3 | B4 | B5 | B6 | C1 | C2 | C3 | C4 | C5 | C6 | D1 | D2 | D3 | D4 | D5 | D6 | |
| 1 | C | M | Suhail | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | | | | 17 |
| 2 | C | M | Kushal | | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | | ■ | | | | | ■ | ■ | ■ | | ■ | ■ | | ■ | | | ■ | | 15 |
| 3 | N | F | Asha | ■ | | | ■ | | | ■ | ■ | | ■ | | | | | ■ | | ■ | | ■ | ■ | | ■ | | ■ | | | | 11 |
| 4 | C | M | Gyan | ■ | ■ | | ■ | | | ■ | ■ | | ■ | | | | | | ■ | ■ | | ■ | ■ | | | | | | ■ | | 11 |
| 5 | C | F | Jaya | | ■ | ■ | ■ | | | | ■ | | | | | | | | ■ | ■ | | | ■ | | | ■ | ■ | ■ | ■ | | 11 |
| 6 | C | M | Mayur | ■ | ■ | ■ | | ■ | ■ | ■ | | | | ■ | | | | | ■ | | | | | | | | | ■ | ■ | ■ | 11 |
| 7 | C | M | Nandan | ■ | ■ | | | | | ■ | ■ | | ■ | ■ | ■ | | ■ | | | ■ | | ■ | ■ | | | | | | | | 11 |
| 8 | N | F | Sherley | | | | | | ■ | ■ | ■ | | | ■ | | | | | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ | | | | 11 |
| 9 | N | M | Harshal | ■ | ■ | ■ | ■ | | ■ | | ■ | | | | | | | | ■ | ■ | | | ■ | | | | | | | | 9 |
| 10 | C | M | Shubh | ■ | ■ | | ■ | | | ■ | | | | ■ | | ■ | | | ■ | ■ | | ■ | | | | | | | | | 9 |
| 11 | C | F | Srishti | ■ | ■ | ■ | ■ | | | | ■ | | | ■ | | | | | ■ | | | | ■ | | | | | ■ | | | 9 |
| 12 | C | F | Akshara | ■ | ■ | | | ■ | ■ | | ■ | | | ■ | | | | | | | | | ■ | | | | ■ | | | | 8 |
| 13 | N | M | Nitesh | | | ■ | | ■ | ■ | | ■ | | ■ | | | | | | | | | ■ | ■ | ■ | | | | | | | 8 |
| 14 | C | M | Abhijeet | ■ | ■ | | ■ | | | | | ■ | | | | | | | ■ | | | | | ■ | | ■ | | | | | 7 |
| 15 | N | M | Akhil | ■ | ■ | ■ | | ■ | ■ | | | | | | | | | | | | | | | | | | ■ | | | ■ | 7 |
| 16 | N | M | Anil | ■ | | ■ | | | ■ | | ■ | | | | | | | | ■ | | | | ■ | | | | ■ | | | | 7 |
| 17 | N | F | Kulpreet | ■ | ■ | | | | ■ | ■ | | | | | | | | | ■ | | | ■ | | | | | ■ | | | | 7 |
| 18 | N | F | Sarah | | | ■ | | ■ | | ■ | ■ | | | | | | | | | | ■ | ■ | ■ | | | | | | | | 7 |
| 19 | N | M | Saurav | ■ | | | | | ■ | | ■ | | ■ | | | | | | ■ | ■ | | | ■ | | | | | | | | 7 |
| 20 | N | M | Harsh | | ■ | | | | | ■ | ■ | | | | | | | | | | | ■ | ■ | | | | ■ | | | | 6 |
| 21 | C | M | Nitin | ■ | | | | | | ■ | | ■ | | | | | | | ■ | ■ | | ■ | | | | | | | | | 6 |
| 22 | N | F | Arti | ■ | ■ | ■ | | | | | | | | | ■ | | | | | | | | | | | | ■ | | | | 5 |
| 23 | N | M | Deeksha | | | | | | ■ | | ■ | | | | | | | | ■ | | | ■ | ■ | | | | | | | | 5 |
| 24 | N | M | Erwin | ■ | | | | | ■ | | | | | | | | | ■ | | ■ | | | | | | | ■ | | | | 5 |
| 25 | C | M | Himanshu | | ■ | | | | | | ■ | | | ■ | | | ■ | | | | | | ■ | | | | | | | | 5 |
| 26 | N | M | Imran | ■ | | | | | | | ■ | | ■ | | | | | | | ■ | | | ■ | | | | | | | | 5 |
| 27 | N | F | Swara | ■ | ■ | ■ | | | | | ■ | | | | | | | | | | | | ■ | | | | | | | | 5 |
| 28 | N | M | Umesh | | | ■ | | | | | ■ | | | | | | | ■ | | | ■ | | ■ | | | | | | | | 5 |
| 29 | N | F | Bhavna | ■ | | ■ | | | ■ | | | | ■ | | | | | | | | | | | | | | | | | | 4 |
| 30 | N | F | Jojo | | | | | ■ | ■ | | | | | | | | | | ■ | | | | | | | | ■ | | | | 4 |
| 31 | N | F | Pranav | ■ | ■ | ■ | | | | ■ | | | | | | | | | | | | | | | | | | | | | 4 |
| 32 | C | M | Ronit | | | | | | | ■ | | | | | | | | | ■ | ■ | | ■ | | | | | | | | | 4 |
| 33 | N | M | Aman | | | | | ■ | | | | | | | | | | | | | | ■ | | | ■ | | | | | | 3 |
| 34 | N | M | Shaan | ■ | | | | ■ | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 35 | N | M | Ambrish | | | | | | | ■ | | | | | | | | | | | | | | | | | | | | | 1 |
| 36 | N | M | Gaurang | ■ | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 37 | N | M | Sanket | | | | | ■ | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 38 | C | F | Vedika | | | | | | | | | | | | | | ■ | | | | | | | | | | | | | | 1 |
| 39 | N | F | Veena | ■ | | | | | | | | | | | | | | | ■ | | | | | | | | | | | | 1 |
| 40 | C | F | Tarika | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| | | | Total 40 | 38 | | | | | | | | | 19 | | | | | | 30 | | | | | | 18 | | | | | | **6.4** |

8 Note: N/C in the second column of Tables 5.25 and 5.26 stand for New/ Continuing student while third column indicates the gender.

**Table 5.26** Collated data on student outcomes for the Comparison group

| No. | N/C | M/F | Student | Reports indicating engagement in learning science | | | | | | | | | Reports indicating confidence in learning science | | | | | | Reports indicating conceptions of science as processes | | | | | | Reports indicating a classroom culture of collaboration | | | | | | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | B1 | B2 | B3 | B4 | B5 | B6 | C1 | C2 | C3 | C4 | C5 | C6 | D1 | D2 | D3 | D4 | D5 | D6 | |
| 1 | N | F | Mugdha | | | | | | | | | | | | | | | | | | | | | | | | | | | | 9 |
| 2 | C | F | Amrita | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 3 | N | M | Hardik | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 4 | N | F | Indira | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 5 | C | F | Komal | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 6 | N | M | Tathagata | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 7 | N | M | Arpit | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 8 | C | F | Arpita | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 9 | C | F | Preeti | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 10 | N | F | Sejal | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 11 | N | M | Ansh | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| 12 | N | F | Anuja | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| 13 | N | M | Nitin | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| 14 | N | M | Ajinkya | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 15 | C | F | Ajitha | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 16 | C | F | Anu | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 17 | C | F | Ashwini | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 18 | C | M | Ayush | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 19 | N | M | Kinjal | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 20 | C | M | Pralhad | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 21 | N | M | Pravin | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 22 | C | F | Vaishali | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 23 | N | M | Archit | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 24 | C | M | Arsh | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 25 | C | F | Poorna | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 26 | N | M | Prashant | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 27 | C | M | Vardhaman | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 28 | N | M | Vinay | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 29 | N | M | Abhay | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 30 | C | F | Antara | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 31 | N | M | Anup | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 32 | N | F | Archana | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 33 | N | M | Ashutosh | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 34 | C | M | Devesh | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 35 | C | M | Dhamma | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 36 | N | F | Naina | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 37 | N | F | Pragya | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 38 | N | F | Radha | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 39 | N | M | Ethan | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 40 | N | M | Prabhat | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 41 | N | M | Ravi | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 42 | N | M | Samar | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| | | | Total 41 | 30 | | | | | | | | | 14 | | | | | | 18 | | | | | | 3 | | | | | | **2.71** |

**Box 5.11: Data from the following sources were collated in Tables 25 and 26; A1, A2... stand for the column headings. Specific details for each of instance are given in Appendix M.**

**Instances showing students' engagement with science learning**

A1. Reports of engagement in response to post-instruction questionnaire
A2. An aspect of engagement reported during Interview
A3. An aspect of engagement reported by parents
A4. Reports from friends
A5. Reports from teachers
A6. Reports from observers
A7. Wonderment question/ observation by student
A8. Student's wonderment question or observation reported by parent
A9. Students' reports from winter camp (mid-way interviews)

**Indications of confidence in learning science**

B1. An aspect reported in response to questionnaire
B2. An aspect reported in interviews
B3. Reports from parents
B4. Reports from friends
B5. Instances from students' diaries
B6. Students' Reports from winter camp

**Indications of a conception of science as processes**

C1. Response to the question "What is Science?" in the post-instruction questionnaire: Whether science is described as processes
C2. An aspect reported elsewhere in the questionnaire/ interview
C3. A change reported by parents
C4. A wonderment question or making an observation reported by students
C5. Student's wonderment question or observation reported by parent
C6. Aspect reported in winter camp

**Indications of a developing classroom culture of collaboration**

D1. An aspect reported in response to questionnaire
D2. An aspect reported in interviews
D3. Instances from diaries
D4. Reports from parents
D5. Reports from friends
D6. Reports from observers

# 6

# Discussion and Conclusions

This chapter reviews and discusses the findings, highlights the significance and relevance of the results presented in previous chapters, drawing empirical and theoretical connections to the relevant, extant research and addresses the issues raised in the literature section. A brief summary of results is provided at the end of the two chapters on results (Chapter 4 and 5). Here, further discussion on the results is organized according to the research aims proposed in Chapter 1, focusing first on characterising teaching science as inquiry by zooming in on teacher's discursive moves and then connecting it to the various outcomes explored. Finally, the implications of the findings for science teaching, teacher preparation and professional development and further research are discussed.

## 6.1 Role of Teachers' Questions in Co-ordinating Classroom Discourse

Teachers' scaffolding of students' thinking in the various ways described in this study brought the quality of exploratory talk (Mercer & Wegerif, 1999) to the inquiry classrooms. The teachers' questions aided in stimulating students' thinking and guided it through successively higher cognitive levels (Figure 6.1). The essence of scientific inquiry in the classroom, as Marshall et al. (2009) and NRC (1996) point out, is that students critically engage in investigating questions regarding the world around them, come up with explanations and evidences, then communicate conclusions with convincing arguments. This study portrays how teachers can facilitate such an inquiry through the categories of questions we have detailed.

We wish to emphasize that the inquiry lessons themselves necessarily had a progression - from the initial ideas, observations and questions students have, to the forming of a coherent picture or concept. The progression of questions the teacher asks, whether embedded in an activity or building upon students' responses in a discussion, reflects this aspect of inquiry teaching and enables students to arrive at a conclusion without the teacher going into the explanation mode. This is a significant difference between inquiry and traditional modes of teaching.

Note that the sub-categories of questions show the progressively higher level of cognitive demands on students. This is particularly noticeable in the question types that can appear in more than one category; for instance, sub-category 'Encouraging wider response' occurs in three categories in Table 4.1. In the initial phases (Category 1: Exploring prerequisites), these questions probe the entire gamut of preconceptions, get all students involved, and explore and arouse their interest. In the second category their role is to generate a wide variety of ideas on the topic and finally (Category 5: Guiding the entire class towards the scientific conception) they play a prominent role in guiding the entire class towards scientific conceptions). These various roles of this sub-category are illustrated in Table 4.1. Another example is that of the sub-category 'Taking stock' which can serve as a diagnostic for the teacher through exploration of initial ideas or gauging the effect of the intervention towards the end. Yet another example is 'Asking for justification' which can ask for evidences for initial conjectures like 'raindrops may be of different sizes' or ask for complex reasoning while summing up the topic.

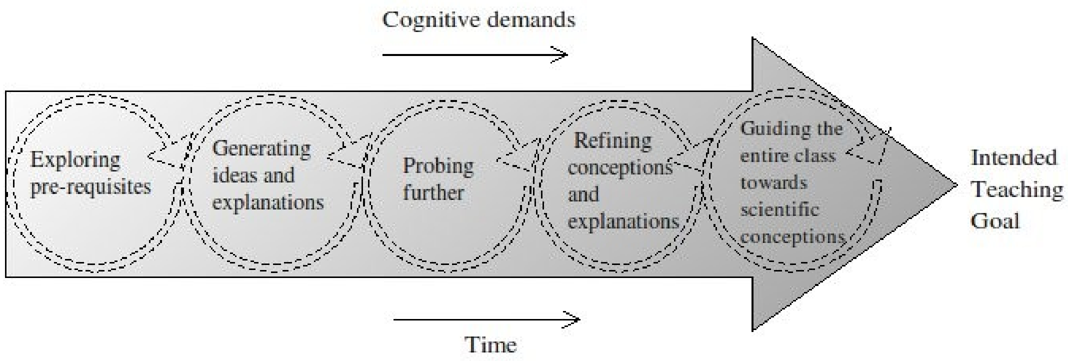



**Figure 6.1** Progression of questioning in inquiry teaching

In order to bring about such a progression, teachers' questions in the inquiry classes were necessarily contingent on students' responses, as is reflected in the high proportion of teachers' questions asked as a direct follow-up of students responses. Their lesson plans were tentative and changed even within the duration of a single class, in response to what the students' ideas were. Also, the inquiry teachers made active attempts to engage all the students in the discussions and move them towards conceptual understanding.

This high level of teacher's engagement with students' ideas and their responsiveness helped the teacher bring out and deal with students' existing conceptions and their concerns. For example, while discussing rain measurement in the unit on 'Immediate environment', Teacher IJ found that students had no idea why rain is measured in millimetres; in fact on probing it was found that some students thought that a certain number of millimetres of rain meant that raindrops during that time were of that size. On further probing, the teacher found that students' grasp of concepts of volume and area was poor and needed to be strengthened before leading them to the concept of rain measurements. Also she built on a student's observation/ speculation that rain drops are not all of the same size for the activity (as described in Episode 4.2 in Chapter 4). In comparison, in the traditional science classes on the same topic, there was a similar starting point when the teacher was discussing heavy rainfall leading to floods but there was no probing and refining of students' understanding of the kind seen in the inquiry class.

In addressing students' responses with questions, the teachers provided scaffolding as they guided students through successively higher levels of cognitive demand. At times, when students were struggling to come up with an explanation, the teachers asked nested questions giving a hint or directing them to the prerequisites and then repeated the question. This cycle continued till the explanation was constructed wholly (as seen in the episode). Sometimes the questions also branched off to delightful and necessary digressions taking students' interests into consideration or pursuing an odd alternative conception. In fact, many activities in the inquiry classes, including the one on 'time-averaging' described in the episode, were sparked off by students' responses (questions, conjectures and suggestions).

In the traditional science classes, there was not much difference in the questions asked or their sequence in the class from what had been planned prior to class. Though there were questions that explored students' prerequisites - ones that elicited students' experiences and observations - and occasionally questions that encouraged students to give explanations, there were hardly any questions to probe and refine students' thinking. Also, though many a times the teacher asked "Clear? Understood?" students were given little or no time to respond before the teacher moved on, nor were any other cues taken into account (like whether students looked interested, attentive or frustrated).

Through the IRE sequences in these classes, the teacher seemed to be playing the 'guess the answer in my head game' (Amos, 2002) by simply aiming to get students to give the answer that the teacher expected. Students' responses were rarely followed up with further probes to explore and extend the responses. Thus, the sequence in the teaching here was of a different kind (Figure 6.2) from the one seen in the inquiry classes; note that here there was no progression in the level of cognitive demands with time. Invariably, in the inquiry classes the teachers repeated or rephrased students' responses and questions. This 'revoicing' (O'Connor & Michaels, 1996) served not only to affirm students' contribution and make it available to the whole class but also acknowledged students' ideas as important topics to be pursued further. As students' responses were treated in a respectful manner and actively solicited, they formed a substantial part of the classroom talk in inquiry.

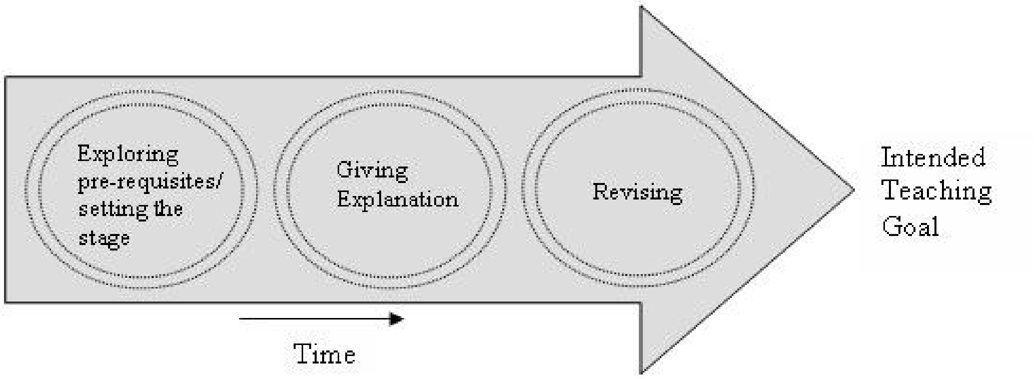



**Figure 6.2** Progression of questioning in traditional teaching

Out of the ways of speaking during science instruction described by van Zee et al. (2001), we found in this study that there were more of lectures and recitations in the traditional classes while guided discussions as well as student-generated discussions were characteristic of inquiry classes. Revision questions, asking for mere recall, formed a major fraction of questions in the traditional classes. They were asked at the end of the class or throughout the class period to revise every sub-topic. Closed-ended and factual questions were an integral part of the inquiry teaching too but they were less frequent than in traditional classes. Revising was also less common in inquiry classes. Whenever questions were asked for this purpose, it was often in later classes and served to summarise and connect ideas across topics to help build coherent explanations. There was, thus, sustained inquiry through several classes. Indeed, Episode 4.2 presented in Chapter 4 gives a glimpse of several interconnected branches of inquiry as they evolved (Does raindrop size vary in time and over a surface? Is there a randomness in their distribution? When averaged over time, will it give the same measure of rain in two closely placed gauges?). These were later consolidated by the teacher as she guided the class to the intended pedagogic goal, in addressing the overarching question. The teaching sequence in the unit 'What makes a fish a fish?' (illustrated in Figure 4.2) is another example of such a sustained, in-depth inquiry into the content being studied.

Thus, teachers' questions along with those for classroom management, their response moves and directives aided in creating a supportive environment in the inquiry classrooms. For instance, if a student did not know an answer or felt unsure or shy to talk, (s)he was asked if (s)he needed more time to think and to let the teacher know when (s)he was ready to speak; the teacher made it a point to come back to the student to ask if (s)he was ready.

In contrast, in the traditional classes, there was no such follow-up with individual students when they were not able to answer and at times they were left standing as if to be punished for not being able to answer, with the sole assumption that they were not paying attention in class and therefore could not answer. While it is a possibility that students were distracted in those particular instances, the teachers rarely probed for other possible reasons; this is consistent with their view of teaching as transmission in which case the major responsibility on part of the learners is to simply pay attention.

In inquiry, students' perceptions of their ability to do science were nurtured by the teachers through their discursive moves. Yung & Tao (2004) argue that when capability is not attributed to natural ability or academic ranking, rather it is construed as students' experiences and understandings, all students, even the academically low achieving ones can be shown to be capable of doing science, and even more importantly, of beginning to value their science learning.

Furthermore, teachers' questions in inquiry possessed peculiar linguistic features (Oliviera, 2008) such as modal verbs (would, could, etc.), hedges (might, possibly), question form instead of imperatives ("can you...?"), inclusive pronoun 'we' (e.g., "How can we find out?", "Why did we do this experiment?") and 'you' prefaces (e.g., "Which, do you think, are the youngest larvae?" rather than "Which are the younger larvae?"). These devices, Oliviera points out, foster students' interactional involvement, build an atmosphere of solidarity and co-operation, and encourage students to focus on expressing their own tentative thoughts rather than on trying to give the 'correct' answer.

Also, the inquiry teachers continually assessed and adjusted the elements of the task at hand, taking into account students' abilities and interest, and to promote continued student interest and efforts which is necessary in carrying the inquiry ahead. Thus, in addition to cognitive scaffolding, questions also provided affective scaffolding - motivating, engendering confidence, giving respect.

The questions also played crucial pragmatic and epistemic roles - aiding the teacher to relinquish, at least partially, her expert interactional rights such as providing the right answers, imperatively telling students what to do, and evaluating their ideas during the discussions. At the same time, they enabled students to partially relinquish their novice roles and take on expert interactional rights (such as asking their own questions, responding to each others' answers, refining, extending and revising their own answers) thus contributing to form a more symmetric interactional structure.

This did not lead however to a complete loss of control for the teachers, as is often feared; the teachers while encouraging and responding to students' ideas, could exercise subtle control in deciding which lines of thought need to be pursued and how elaborately so that the discussion/ lesson remained on track in spite of digressions.

The traditional teachers, despite markedly greater efforts than their regular classes, led an authoritative, transmissive discourse, arguably because they paid less attention to the multi-functional role that teacher talk serves, mediated by questions.

The practice of questioning in the inquiry classroom also brought an added advantage - as reported by the teachers, it made teaching interesting for the teachers themselves and engaged them in an inquiry into what goes on in children's minds - something they enjoyed thoroughly. The inquiry teachers affirmed that the high level of interest that questions bring about in them, the level of engagement they demand, the challenge of thinking on their feet (a class where questions are asked has the potential to develop in any direction, and often unexpected issues come up)[1] and the sheer fun of figuring out what is going on in children's minds, made inquiry worthwhile for them and they believed that this attitude transfers to the children.

Indeed, the novice teacher in this program (Teacher IK) who adopted teaching science as an inquiry reported that she enjoyed teaching this way a lot, internalised it quickly and was enthused so much about it that she conceded she cannot teach in any way other than inquiry now.

1 It is pertinent to note here that enjoying this kind of pedagogical challenge necessitates, and indicates, a high level of preparedness and comfort with the content areas involved in teaching, which the teachers in the inquiry mode in this study certainly had. Both teachers not only had robust subject expertise in the areas they taught, they also researched the specific topics well before and during the teaching. As Gess-Newsome (1999) asserts, teachers need to have deep and highly structured content knowledge (which is not fragmented or compartmentalized) in order to craft instruction that represents science as an inquiry. However, they maintain that content knowledge alone does not guarantee it. This was evident in the case of teachers in the comparison group in this study who had expertise in the subject area they taught and yet resorted to didactic teaching.

## 6.2 Outcomes of Teaching-Learning through the Two Modes

Through the repertoire of questioning practices reported here, the teachers in these inquiry classes tried to give children a flavour of what inquiry is. In Teacher IJ's words -

> One of the best outcomes of [this practice] is that children develop this habit of engaging in the exercise for sheer intellectual satisfaction - an aspect that is often overlooked in science teaching. That experience - of arriving at an answer through thought and through experiments one can design and conduct - is an empowering one and develops confidence in oneself.

Note that at the end of Episode 4.2, presented in Chapter 4, the student concluded that the experiment was done "to check if..." and not "to show that..." (a phrase appearing commonly in the comparison classes). There were a lot of questions from the students in inquiry classes. Students explicitly pointed out when they did not understand a question or a statement and persistently reminded the teacher when their question was not answered.

Further, at times they even questioned the teacher ("How can that happen?") or went on to point a mistake ("How can the anther fall?") when the teacher mistakenly said "anther" instead of "pollen". There was an interesting discussion in a class when a student questioned the teacher who, while talking about living cells described cancer as uncontrolled cell division, "So what if cells keep on dividing? Wouldn't it be good for the body?".

Another wonderful question came from a student when the teacher was asking them if the heart too needs a separate oxygen supply and how would that be possible. The student asked "How do veins get oxygen?" (they knew due to an earlier discussion that veins have multicellular wall) and this provided the class with clues to the solution. These instances show not only that students got into the spirit of inquiry as modelled by the teachers but are indicative of students' progression in thinking.

Students' in-class engagement with the topic was higher in inquiry which is evident from the nature of their participation in class as described in context of the vignettes discussed in Chapter 4. Students' spontaneously got re-engaged in a topic, and stayed engaged for a longer period. Also, the number of students who individually and substantively contributed to whole-class discussions were more in inquiry than in the comparison group. These parameters are described by Engle & Conant (2002) as indicators of students' 'productive, disciplinary engagement' with their science learning.

Students' conceptual understanding and the classroom events that led to it became evident from diary entries, as did the nature of their difficulties with a particular concept. While most assessments test a concept after the teaching, that is, the final stage the student arrives at, regular diary entries of what students are learning provided information about students' emerging conceptions. Open-ended, reflective diary entries, being spontaneous and generative (unlike responses in tests), showed the potential to truly assess learning, and thus be useful for formative assessment (although in our study they were not used for that purpose). Note that the diary entries brought out significant differences in the conceptual understanding of the two groups of students in our study though there was no difference in their academic performance in school exams. As Hestenes, Wells & Swackhamer (1992) point out, even in more widely administered standardised tests performance can be good if students are taught to the test.

As discussed in the Introduction chapter, the goal of teaching science is not merely to help learners acquire conceptual clarity, but also to develop favourable attitudes towards science and to inculcate a way of thinking - to develop scientific habits of mind (Alberts, 2008). The diaries, serving equally well as evidences of such concurrent affective outcomes, indicated that inclusion of activities and demonstrations in class led to a high degree of self-reported enjoyment by students of both cohorts. However, genuine emotional and cognitive engagement with the content taught was observed to a markedly greater extent in students taught through inquiry. Our analysis also brought to light other important outcomes of inquiry: the development of a conscious awareness of learning, a questioning attitude (students asked several questions probing and building on the content taught) and a learning approach in which they based their explanations on evidence and argument rather than on authority. However, this study can still be relevant even in contexts where acquisition of conceptual clarity is the goal of teaching science.

Beyond conceptual clarity and affective outcomes discussed above, researchers have pointed out that “the inquiry vs. direct teaching debate is also about a ‘feel’ for science and hence some appreciation of the nature of scientific inquiry” (Cobern et al., 2010, p. 92). This study provides support to their proposition that though traditional, direct instruction might require less time for some topics, it does risk sending the message that science is simply a body of knowledge to be learned, which is encyclopaedic, impersonal and non-negotiable. Such conceptions have implications for public attitudes towards science since experiences of science at the school level are likely to shape the conceptions of science held as adults (Stein & McRobbie, 1997). Teaching through inquiry models scientific inquiry and the diaries of students taught through inquiry reflected this aspect. Thus, a salient feature of students’ learning through inquiry emerged, apart from the differences in conceptual and affective aspects, that they have internalised, implicitly, the inquiry approach to learning science. Students’ diaries of the two groups reflected this epistemic difference in their conceptions of learning science - whether it is “explained nicely” or it is “thinking how” and “to figure out [something]”.

Through the questionnaires and interviews, we set out to further explore whether students moved away from viewing science as merely a body of knowledge or as a school subject with little connection to the real world to a broader view as a result of learning through the two modes of teaching in our intervention. As many researchers like Clough (2006), Lederman et al. (2014), Khishfe & Abd-El-Khalick (2002) insist, students should not be assumed to develop informed views about nature of science or about processes of scientific inquiry implicitly, merely by engaging in investigations in the classroom. However, we feel that what is learned is most certainly impacted by how it is learned, and the role and impact of implicit learning cannot be dismissed. We need to understand how learners' participation in the different forms of classroom discursive practices (such as in traditional and inquiry science instruction) change their personal epistemologies (Sandoval, 2005), that is their ideas not about formal science that is distant to students but their own experience of school science.

Our analyses of students' class participation and students' self-reports additionally complemented this array of outcomes reported by students and further helped elucidate the dynamics of teaching-learning in the two sets of classrooms. For instance, the trends in students' spontaneous participation in whole class interactions indicated how the discourse in the two classrooms was inclusive to certain social groups while excluding some others, despite the teachers' best efforts, thereby drawing our attention to the wider social values and conflicts in which teacher and student talk is embedded.

Tracking patterns of teachers' and students' interactions allowed us to study how the teachers' use of scaffolding and the students' participation in whole class discussions developed over time. In our study, starting with similar available resources, teachers were free to organize the instructional activities in their classrooms as they wanted. The different approaches teacher adopted were associated with different patterns of learning and engagement by the students. The educational rationales underlying the explicit instruction in the comparison group and inquiry-based instruction were fundamentally different; the former emphasized the transmissive function of teacher talk while the dialogic function of teacher talk was evident in inquiry as the teachers encouraged students to put forward their ideas, to explore and to debate points of view. This difference led to the divergent patterns of classroom discourse. In the later classes of both phases in the study, more students presented their own ideas and showed active participation in group argumentation. The results indicate that differences in the level of students' participation diminished, and the status of the students in the group became more equal, as the previously dominant, academically high-achieving student began to share more opportunities with their peers to present their opinions. Some factors seemed to help improve students' participation and build social and argumentation norms in this group. Teachers' questions were clearly one of the key factors of classroom discourse affecting students' participation. In the inquiry classroom, the teachers asked more open-ended questions with no definite answers, requesting for what the students thought (e.g. "What features *do you see* in an animal to call it a fish?"). So, the students did not have to worry if their answers were correct; they just had to share their personal, tentative views or observations. Such open-ended questions help build an inviting and safe environment for students to contribute to class discussions.

The supportive environment was further fostered by the kind of feedback moves the teachers used. Even when students' responses were incorrect (for example, giving whale as an example of a fish or saying that prawns don't have gills), the teacher did not provide an immediate evaluation but either tossed the response back to the students or to the class to think about it or countered it with evidence. Often there was a neutral feedback from the teacher or a positive one acknowledging what the students said. Thus, students' ideas were treated as leverageable intellectual resources. One class of resources that were mostly drawn on, in the inquiry teaching in this study was concrete, phenomenon-specific intuitions and experiences. The uptake of students' ideas, and also questions, into the discussions, resonating with responsive and equitable teaching, demonstrated respect and value for students' contribution and acknowledged them as more equal conversational partners. Also, the teachers actively elicited students' contributions and provided scaffolding to help students to build their thinking and make it explicit on the public plane of the classroom in ways discussed in Chapter 4. Consequently, nature of the classroom talk changed; 'true dialogue' (Lemke, 1990) developed not just between the teacher and students but also amongst students. Thus, in inquiry, the classroom transformed into a community of learners where there was a shared authority between the teachers and students over the learning process.

We note that there were more affordances in the inquiry classroom for a diverse range of students to participate reducing the gap between high-achieving and low-achieving students and between students of various socio-economic strata (based on their family incomes). This could be explained based on the negotiation of 'what counted' as science ideas between the teacher and their students in the two classrooms and the framing of science learning as a 'public' or 'private' activity. In the inquiry classroom, students' responses could be tentative guesses (eg. responses for what criteria make a fish a fish), students' own experiences and observations ("prawn… is covered by thick, nail like shell on top"), personal reasons for their conjectures ("I am saying it is not a fish because…"), a refinement of an earlier response ("There is no opening for gills like in fish…" as against previous "There are no gills"), wonderment ("A tadpole has many of these features, can we call it a fish?") and reasoning ("Shark also gives birth to young ones though it's a fish") in addition to learned responses (like "Dolphin is warm-blooded").

Students tended to respond in terms of personal experiences, stories and anecdotes which became the context of the class discussions. Even reports of experiments hinged on personal narratives of what students did and saw during their experiments. They tried to reason about and account for the phenomena by grounding it in what they knew from their everyday lives. Thus, the ideas that were discussed in the inquiry class seemed to be perceived by students as tentative and malleable, which could be worked on over time by anyone in the classroom. Contrast this with the kind of responses elicited in the traditional science teaching in the comparison group ("*Paired* fins", "*Streamlined* body"); they involve low-level recall but with emphasis on specific terms/ nominalisation. Though teachers in both groups assured students saying that, “It’s okay to be wrong”, the nature of questions asked in the comparison group (a majority of them being factual) emphasize correctness of answers whereas incorrect answers were promptly reprimanded and corrected (“How can you say it is a fish? It is not a fish…”). Also, the explanations from the teachers were high in lexical density. We argue that all of this implicitly conveyed to the students that science learning was meant to be abstract, impersonal, and non-negotiable.

Engle and Conant (2002) make the case that a pedagogical shift allowing student voice to affect the direction of instruction, creates a classroom environment that enhances ownership for learning and thereby fosters active participation from students. However, this sharing of ideas on the public plane of the classroom is inherently risky for the students, unless the teacher helped everyone in the classroom develop the habits of listening to and critiquing the partial understandings of others rather than the individuals themselves (Oliviera, 2008). Many students in the inquiry class, especially girls and low academic achievers (as reported in midway interviews and post-instruction questionnaires), avoided participating in class discussions initially. More students in the inquiry group reported that they did not speak out in class because they feared that others would laugh at them; for students in the comparison group the most prominent reason for not participating vocally was that others would answer before them. These reports from the students can also be interpreted in light of the negotiation of what counted as science ideas in the two classrooms, reflected in the kinds of questions asked, the level of cognitive demands placed and the kind of participation expected from students in the two teaching modes.

The high proportion of low-cognitive demand questions asked by the teachers in the comparison group was perhaps less threatening compared to open-ended responses that involved individual guesses, justifications, opinions or premature ideas as required in an inquiry class. Perhaps, this explains the difficulty some students, in the initial classes, had in speaking out in discussions in the inquiry group, pronouncedly so for the adolescent girls[2]. Kumar (2010) notes that,

> as a philosophy, child-centred education has not been easy to implement in the case of boys too... the challenge of noticing and enhancing the child's individual interests and capacities is applicable to boys as well as girls. The crucial difference is that in the case of boys, the success of child-centred pedagogy depends largely on the teacher; in the case of girls, the teacher's attempt, if it were to be made, is pitted against the full force of culture (p. 81).

Morever, when the class floor is opened up for discussion, compared to girls, boys are generally more likely to initiate teacher interactions, to volunteer to answer questions, and to call out answers (Jones & Wheatly, 1990; Kahle & Meece, 1994). They are also more likely to interrupt peers or teachers in order to make room for their own talk (Eliasson, Karlsson, & Sørensen, 2016), however when teachers consistently ask open-ended, higher-order questions, for which students cannot shout out answers, all students might get an opportunity to speak (Eliasson, Karlsson, & Sørensen, 2017).

On the other hand, as Lemke (1990) observes, the level of participation in authoritative, traditional discourse practices achieve is illusory: high on quantity, low on quality and over time most students get alienated and demotivated from the class interactions. Our findings with the comparison group, empirically support this view. As the classes progressed, only a few privileged students were provided with 'the wind beneath their wings' (Hanrahan, 2006), who then monopolised the class

2 We note that this marked gender difference in students' vocal partication inclass discussions in the inquiry classes was peculiar to this particular group of students. Most girls in the previous classes (conducted over the years, as part of the curriculum project, with several cohorts of students) either did not show such diffidence or grew out of it quickly. One of the possible reasons may perhaps be that they were younger when they joined these classes (Grade 5 or 6) and had less inhibitions than adolescent girls.

interactions in the comparison group. In inquiry, as a variety of knowledge bases and resources (thinking processes, ideas, experiences) that students bring to the class were valued, science learning seemed more accessible eventually to a wider range of students who began to vocally participate in a self-initiated manner towards the later classes.

The changes reported by the students are supportive of theories of intrinsic motivation which propose that students are inherently driven to develop themselves as a result of the pleasure they derive from achieving higher levels of understanding but need supportive conditions to maintain and enhance this motivation (Ryan & Deci, 2000). We believe that the intellectual engagement during learning through inquiry, fun but disciplined and structured, is of intrinsic value to the learners. It caters to students' curiosities and supports them in resolving conceptual conflicts in the inquiry classroom. This kind of intense engagement requires persistent effort and attention from the student along with cognitive as well as affective support from the inquiry teacher. Therefore, we argue that cognitive engagement and affective changes of the kind reported in this study go hand in hand in the process of learning science through inquiry.

The teaching was not designed for specifically bringing about these affective changes; they were among the significant outcomes of a project that concentrated on conceptual learning. This finding should help garner additional support for teaching science through inquiry since it suggests that the teacher need not put in extra effort for all these outcomes, spanning various domains, apart from teaching concepts through inquiry. Since inquiry teaching does require more effort on part of the teacher, highlighting the array of outcomes possible through inquiry teaching will lead to a wider acceptance of this teaching method both by teachers and policy makers.

No debate on the comparison between inquiry and traditional science teaching is complete without talking about the issue of time involved. In this study, the difference in the time needed to transact the units in the two modes of teaching was much larger for some of the units, as in the case of the units on 'Immediate Environment' and 'Density'. So there is some merit to the argument, often used against adoption of teaching through inquiry, that it can be more time-consuming for some challenging concepts. However, our findings also suggest that not all units necessarily take more time in inquiry – some units (like 'Internal transport in Plants' and 'Biogeochemical cycles') took almost the same time to be covered in both teaching modes (Table 4.2 & 4.3).

Notably, how the teachers in the two modes spent that time varied, as depicted in the progression of teaching in the two modes (Figures 6.1 and 6.2). Teachers in traditional science classes in the study as well as at school often spent a lot of time in revision and recall of what was already taught in a shorter duration. Even when they had the freedom to take adequate time for their teaching, as much as they wanted, teachers in the comparison group, in Phase II, could not use the available time (and took extra units on concepts of 'Biological cell' and 'Magnetism'). Hence, though it is true that a lot of content is crammed in traditional curricula (which also needs to change to bring in depth rather than breadth in content learning), the seemingly hurried way of traditional science teaching is arguably due to the nature of this teaching mode which does not necessitate deeper, sustained interactions between the teacher, student and the content, and not merely due to shortage of teaching time.

Evidence from the diaries further shows that the time and attention in inquiry was well spent especially for complex concepts such as density that are known to be difficult for school students. The advantage of time saved by teaching the traditional way was far outweighed by the lack of conceptual clarity among the students. Furthermore, a lot of time was spent in inquiry building prerequisites for concepts to be taught. This was an imperative in inquiry while perhaps not necessary for expository teaching. If students already had the foundational concepts in place, the time difference in teaching through inquiry would be lesser than was taken in this study. Also, the context of curriculum development, where the purpose was not just teaching but development of lessons, required cycles of trials, probing of students' conceptions, and allowed branching and subsequent development of sub-topics. Teaching of already developed and trialled units may perhaps take less time as the teacher would be able to more effectively traverse the well charted territory of students' conceptual frameworks and documented difficulties when informed by curricular and teacher support material developed for such purpose. It is likely that the inquiry teacher may still encounter newer and unexpected ideas from students and will have to find ways to explore and address them. This may ease out with experience; Yackel and Cobb (1996) point out that as the teacher continues to guide whole-class discussions and listen to students' ideas, the teacher's knowledge and practice too becomes more sophisticated in terms of understanding students' conceptual development and responding to it. To sum it up - inquiry teaching may involve more time than the traditional chalk and talk, for some topics more than others but support from curricular material, professional development and teachers' continued engagement with inquiry (individually and as a community) may be helpful in reducing the gap.

## 6.3 Significance and Limitations of the Study

This study analyzed some of the crucial aspects of inquiry-based science teaching and learning, from multiple sources of data representing perspectives of the various stakeholders involved (researchers, teachers, students, parents). One of the strengths and distinctive features of the study is the range of both qualitative and quantitative methods used for collecting and interpreting data. Different methods and elements of the study combined to provide a composite picture of various aspects of teaching and learning in the science classrooms studied (Figure 6.3).

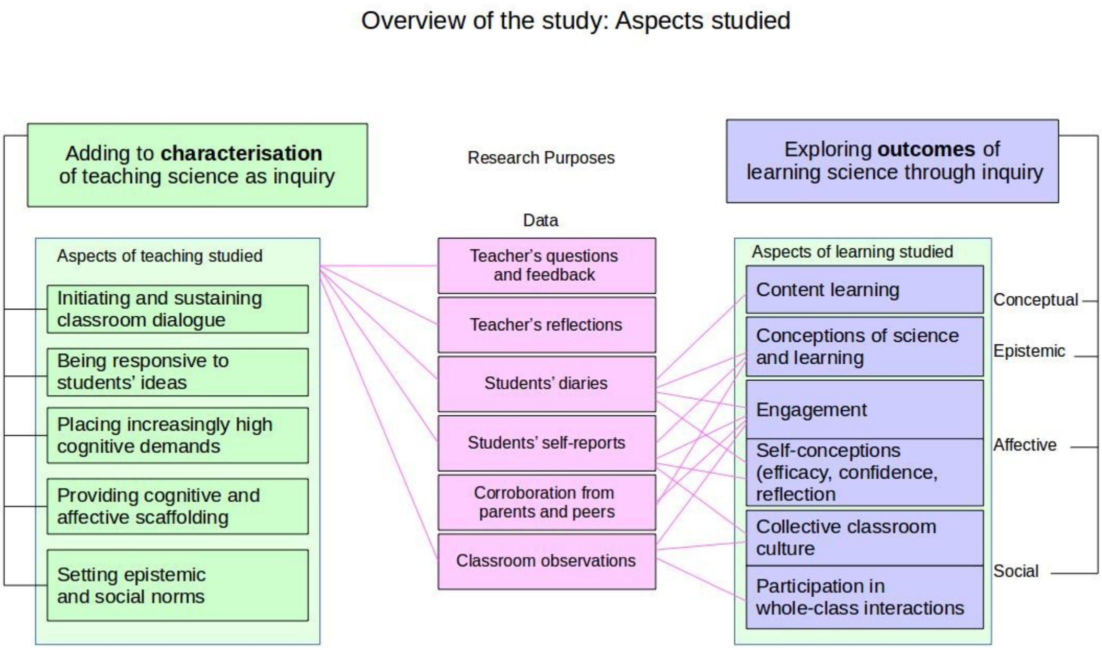



**Figure 6.3** Overview of the aspects studied

Our analysis of students' diaries underscored several advantages of using this classroom artefact (Martinez et al., 2012) to study science teaching and learning. It could capture important components of the teaching–learning process that classroom observations and tests could not. It brought out several aspects of teaching as well as learning in these settings, many more than we had anticipated. The open-ended and reflective nature of the entries enabled a more nuanced look at the meaning and outcomes of the classroom experience for students in these groups. A spectrum of outcomes, and clear differences in those outcomes between the two modes of teaching, emerged through this analysis - conceptual, affective and epistemic. Although diary writing is not a common practice at all in India, this artefact was easy to introduce and yielded rich results on several aspects of teaching and learning science.

There are several limitations of this study stemming from its exploratory nature, settings and the methods employed.

a) The specific situational context of voluntary, out-of-school classes conducted in an urban setting by the researchers is an important limitation of the study, possibly reducing generalisability or transferability of the findings. There are many constraints in the traditional classroom setting that teachers experience on a daily basis. For instance, they many have limited freedom and time to deviate from the lesson plans or the textbook lessons, and the class durations are usually much shorter than the classes in this study. Furthermore, in this program, the students were voluntarily attending and most students were excited about learning the content.

b) There were several logistical difficulties due to the quasi-longitudinal nature and out-of-school context of the study. For example, (1) we intended to conduct a longitudinal study across a year with the same set of students. However, due to logistical constraints, the duration of the study was much shorter than intended and split in two phases, making the contact period with the cohorts of students shorter. (2) There was a drop in the number of students attending classes in both groups, over Phase I, due to various reasons like students opting out for attending National Cadet Corps (NCC) sessions after school. We, therefore, had to take in more students from other schools in Phase II. As described in the Methods (Chapter 3), though these students were from the same school system, they were from higher socio-economic class than the students who continued from Phase I. This affected the class dynamics in the initial classes of Phase II during which many of the continuing students felt intimidated to talk in class and the teachers had to again work towards establishing the classroom norms. (3) There were constraints of working along the schedule of the schools. For instance, duration of Phase II was cut shorter than was planned due to unexpected change in the vacation schedule of schools. Consequently, just when the classroom environment, especially in the inquiry group was getting established, it was time for the classes to end. Also, classroom observations in the school were fewer than we had planned due to several logistical difficulties like the changing time-table/ schedule of the schools (4) Due to sudden unavailability of Teacher RT, some of the classes for the comparison group had to be cancelled in Phase II.

In section 3.7 in the Methods chapter, we have discussed some methodological choices we made and their strengths and limitations.

c) We acknowledge the limitation of small sample sizes in our study especially for the quantitative part of the study.

d) Students' conceptual understanding was not independently assessed using pre- and post-intervention tests. This could have corroborated our findings and helped in establishing diaries as an effective stand-alone tool for assessing concept acquisition.

## 6.4 Implications and Way Forward

Science involves talking about, seeing, valuing and reasoning about the world in particular ways that are shared by a scientific community (Lemke, 1990). In the science classroom, students learn to participate in the language and practices of science through classroom discourse. The teacher who is the foremost model in the classroom of how to think and act, plays a significant role in guiding students into an emergent science community. This study illustrated how the level and complexity of teacher's questions, the classroom environment that is created by the teachers' talk moves, and the patterns of teacher-student interactions are some of the key factors affecting not only students' learning but also their attitudes towards science and their conceptions of science and of what learning involves.

The analyses of classroom episodes presented in Chapter 4 are illustrative of how teaching of a science concept could either be transmissive or inquiry-oriented. The enhanced awareness resulting from such analyses open up possibilities for making discursive choices that could enable inquiry in the science classroom and foster ways of relating to science that are inviting to a wide range of students.

We summarise here the specific steps taken by teachers of the inquiry classes in creating a classroom atmosphere that encouraged students to get engaged in the process of inquiry; these steps could help guide teachers in adopting inquiry-based science teaching:

(1) While each lesson was planned in meticulous detail, the lesson plans were open, tentative and flexible to take into consideration students' ideas, questions, interests and difficulties.

(2) Not only were a large number of open-ended questions asked, but there was a clear progression in the questions as detailed earlier; this helped move the lesson forward.

(3) We have illustrated, especially in categories 'Probing further' and 'Refining conceptions and explanations' how teachers can respond in various ways to incorrect, incomplete or tentative answers; each interaction served as a launching pad for further queries and clarifications, without the teacher directly giving the answer or going into explanation mode. Note that even a correct answer by just one or two students was not immediately acknowledged as such, but other students' responses were actively sought, encouraging the entire class to engage with the question at hand.

(4) A variety of hands-on activities were woven into the lessons through questions and served as anchor points for discussion. The questions types in our category 'Generating ideas and explanations' illustrate how activites can be used in inquiry classes and how the topic can be taken further through activities.

(5) Questions were used to develop the topics by not only generating discussion but to guide the discussions. The teacher, while encouraging and responding to students' ideas, exercised subtle control in deciding which lines of thought need to be pursued and how elaborately so that the discussion/lesson remained on track in spite of digressions. The rain-drop experiment for instance, described in the Episode 4.2, developed from a student's observation and evolved further to tackle students' difficulties with concepts needed to understand rain measurement.

## 6.5 Concluding Remarks

One of the hurdles teachers face in adopting inquiry-oriented teaching practices has been that they have few operational models of teaching science as inquiry, and of what their own roles might be in helping students develop scientific understanding through inquiry (Asay & Orgill, 2010). As noted by Erdogan and Campbell (2008) it is important to identify mechanisms employed by teachers as they strive to implement effective teaching strategies in their classrooms. This study is just such an attempt to make explicit teachers' tacit strategies employed in inquiry teaching. It contributes to building a clearer, nuanced picture of the complex processes, possibilities and difficulties involved in inquiry teaching and learning developed from multiple sources of data incorporating perspectives of the researchers, teachers, students and parents. Studies of this kind can help science education researchers, teacher educators and practicing teachers to understand both how environments conducive to inquiry are created and the central role teachers' questions and interactions play in establishing these environments.

We believe that the teachers' self-reports, along with our analysis of questions and their progression would be useful to teachers who want to frame questions that aid in making a science lesson into an inquiry one. This study also contributes to the research on how teachers' discursive practices affect the kinds of learning, epistemologies, affective responses and self-concepts that enhance or limit students' participation in science. It also brings out some of the difficulties of enacting true inquiry within the complex power dynamics of the classroom. With an understanding and appreciation of classroom power relationships and how they can work towards more equitable classroom relationships, teachers can begin to support more authentic inquiry in science classrooms (Donnelly, McGarr & O'Reilly, 2014). Careful analysis of what went well or did not, and why, in a particular instance may help others think about what to look for in engaging their students in inquiry. Also, learning how to recognise positive aspects of student inquiry can help instructors to support it. We hope that the varied outcomes reported in this study contribute to garnering support for teaching science as inquiry.

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# Appendices

# A

## Format of the Classroom Observation Protocol Developed and Used in Our Classrooms (Part A)

Class: .................. Date: ..................... Name of the Teacher:........................ Name of the Observer: .....................
Topic: ................................................................................................................ Number of students in class : ...........
Plan for the class: ......................................................................................................................................................................
..................................................................................................................................................................................

| **Teacher's initiation** Questions/ statements/ explanations | **No. of hands raised** (many/ a few/ count) | **Who answered?** (Student's name/ Chorus) Volunteered (V)/ called upon (CU) | **Students' response** | **How did the teacher respond?** (Accepted/ appreciated/ further questions) | **Observer's notes** |
|---|---|---|---|---|---|
| ............................................ | ......... | .................... | ........................................ | ............................................ | ............................ |
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# B

# Part of the class observation sheet (Part B) developed but not analysed for this study

**I. Overall impressions**

1. Enthusiasm/ excitement level of the teacher - Very high ☐ High ☐ Average ☐ low ☐ very low ☐

2. Number of students contributing to class (discussion) - Most of the class ☐ many ☐ some ☐ a few ☐

3. Students' overall attention level during the class (Use options from (a), (b) and (c) to describe the class) -

a) Most of the class ☐/ many ☐/ some ☐/ a few ☐

b) Excited ☐/ very interested ☐/attentive ☐/ disinterested ☐/ distracted ☐/ bored ☐/ frustrated ☐/ tired ☐ ..................................

c) Most of the time ☐/ For some time ☐/ Initially ☐/ during ..........................................................................................................

4. Did the teacher give enough time for kids to try to come up with an answer? (Yes/ No/ mark in the earlier notes if any striking example)

5. Were students called upon even when they didn't raise their hands? (Yes/ No/ mark in the earlier notes if there is any striking example)

6. Did the teacher attempt to involve all students – shy/ quiet students too? (Yes/ No/ mark in the earlier notes if there is any striking example)

7. How did the teacher encourage participation?

Invites opinions or alternative answers ☐/ called for examples ☐/ rephrased questions in different ways ☐/ tried to draw on experiences ☐

Any other - ..........................................................................................................................................

8. Were the teacher's questions directed to the entire class or to some particular students only? ..................................................

9. How did the teacher respond to students' answers (during discussion)?

Listened attentively/ sought clarification/ encouraged contribution or appreciated/ repeated or rephrased for the entire class

Any other - ..........................................................................................................................................

10. a) Teacher's response to surprise (unexpected) answers (if any) - ..................................................

b) Teacher's response when (s)he did not know the answer to a child's question - ..................................................

11. If the correct answer is given by one student, what about others – were they asked too or did the teacher move on? ..................................

12. a) How many times were answers given in chorus? Most of the time/ often/ sometimes/ rarely b) Teacher accepted/ discouraged chorus response

13. Did the teacher appreciate/ acknowledge students' answers/ questions/ comments? ..................................................

(Some instances) (May be marked where in earlier notes) ..................................................

**II. Student involvement (especially case study students)**

1. Number of times class was addressed (number of teacher's questions) - ...............

2. Number of hands raised in response to teacher's questions (on an average) - Most of the class □ many □ some □ a few □

3. Kind of responses – Questions ☐ Answers ☐ Clarifications ☐ Comments ☐

4. Number of student questions - ...............

5. a) Did students say they have a problem (did not understand something/ need clarification or explanation)? ..................................................

b) Are students easily convinced? Accept any answer? ..................................................

c) Did they comment/ add/ relate to what is said in the class? ..................................................

d) Particularly, did any of the student show their disagreement with teacher's/ other students' statements? ..................................................

**III. Reflections by the observer**

(Overall mood of the class, discipline in the class, noise level (most of the time), teacher's control over the class (academic), amount of flexibility - is occasional straying away from topic allowed? How much of do's and don'ts of teaching followed or were there lapses? Highlights of the class...)

..................................................

..................................................

..................................................

..................................................

..................................................

**VI. Observation for case studies**

1. Students' attention levels – excited/ very interested/attentive / disinterested/ distracted/ bored/ tired/ frustrated…

[Noted at regular intervals (every 10 min)]

| Time Interval* | CS1 | CS2 | CS3 | CS4 | CS5 | CS6 |
|---|---|---|---|---|---|---|
| 2.45 | | | | | | |
| 2.55 | | | | | | |
| 3.05 | | | | | | |
| 3.15 | | | | | | |
| 3.25 | | | | | | |

(*Exemplified for classes held between 2.30 pm to 3.30 pm)

2. Overall Involvement in class:

| | CS1 | CS2 | CS3 | CS4 | CS5 | CS6 |
|---|---|---|---|---|---|---|
| a) Answers when called on by teacher or volunteers? | | | | | | |
| b) Raises hands for answering/ waits to be asked or shouts out answer/ vies for attention? | | | | | | |
| c) What does the student do when called on by the teacher? (shies away/ attempts an answer or guess/ is confident/ says not sure/ hesitates/ becomes conscious or nervous/ giggles…) | | | | | | |

**IV. Observations during Activities**

Description of the Activity - ..........................................................................................................................................

1. a) Activity done by individual students or in groups? Individually □ / In groups □ b) (If in group) number of students per a group - ...............
2. Did students talk to each other about the task at hand or off the topic (most of the times during hands-on activity)? On task □ / Off task □
3. Students' overall attention level – Excited/ totally involved/ uninvolved/ disinterested/ bored/ involved in 'off task' activities/ frustrated/ ..................

Individual students (case studies) during activity : (Were involved or not? Participation - actively engaged or passive? gave ideas/ listened to others' views/ followed others/ dominated/ co-operated/ shared resources/ shared responsibilities) (CS1, CS2 ... refers to students selected for case studies)

CS1

CS2

CS3

CS4

CS5

CS6

**V. Demonstration of an activity/ experiment by the teacher -**

Aim was to demonstrate what is already known or to find out something?

(How does the teacher present it? Teacher clarifies aim before the demo? Does the teacher point out what to observe? / gives some questions to which this demo will provide answers?)

..........................................................................................................................................

..........................................................................................................................................

# C

## Excerpts from researcher's field diary

**17th June 2009:** Planned meeting with Teacher TN

Planned to tell her - We are looking at students' behaviour in the classroom and whether it changes over the academic year. We are interested in questions asked in the class and how students respond to them. We have two groups of students attending these classes. Similar content will be taught in both the classes but teaching styles may be different. We would help her with the content, sharing all the resources we had but she had to make the lesson plan - how she would teach the content would be left to her.

**3rd July 2009:** Met Teacher TN

She has about 1 year of experience in teaching (maths and science) in primary school and has a Bachelors in Zoology and a B.Ed. Recommended by the Principal of the school in which our study is being conducted as a "good teacher", in fact, one of the best, he said. (TN realises that the Principal appreciates her teaching, however she said that he has never observed any of her class though. We think we should ask the Principal for a characterization of a "good teacher".)

**8th July 2009**

In the first class, TN tells the students these classes are going to be different - more interactive, unlike their classes in school - no note-taking, everyone is expected to participate/ answer. Some students and the teacher know each other already. She seems to be one of their favourite teachers. There is a lot of interaction in the class in the form of revision questions and answers; after every 10-15 min, TN asks questions based on what she has just explained, repeating the points. Students are very enthusiastic to answer. She also encourages those who do not volunteer to speak - specifically asks girls and “last benchers”. If a student does not answer though, she keeps them standing; later instructing them to pay more attention next time.

**3rd August 2009:**

TN plans to come to the Centre a lot of the time but does not come. Time and again, we keep telling her that we need to interact more if we are to share our resources.

When asked if she wanted the video we had on mosquitoes, TN said she had no problem with showing it but was not particular, remarking that there is so much to show if there is this facility. She did not include it in her lesson plan for the next class. She was, however, happy that she could use the laptop in the class (with or without overhead projector/OHP) so that she could use presentation slides for the lessons (that did not happen though due to problems with OHP in school). Then students in her group heard from the other group that they had seen a video and asked her for it, and so she requested that we show this video in her class as well.

**20th August 2009:** Difficulties in class observations at school

Even after about two months into the academic year, the timetable is not fixed. Classes were rescheduled at the last moment, and they could often not tell us which period would be allocated for science the next day. Sometimes the teacher would be absent or involved in some other work. For about two weeks, the school was closed due to swine flu, then there were ‘Unit tests’ for a week. Further, there were several such reasons, for example -

On 2 Sept - one class observed but the teacher only gave notes

On 4 Sept - one class observed, but teacher did not allow observation for rest of the two classes because she again wanted to give notes

On 10 Sept - Teachers did not come to the class (were involved in *Hindi divas* program)

On 15 Sept - Unexpected school holiday for some training of teachers

**7th September 2009:** Teacher TN cancels a lot of classes due to some or the other problems. Children from TN's class ask for classes during our visit to their school, they are feeling sad that their classes are not taking place. We have been looking for another teacher for the comparison group - we intensify the search - ask Teacher TN/ Principal/ some other teachers/ colleagues to help us find a teacher for this purpose.

**14th September 2009:** Teacher TN continues cancelling class due to personal problems. We ask SM (who had newly joined the team) to teach as substitution for a couple of classes.

**17th September 2009:** An Ad-hoc teacher, TP who hears from a colleague that we need a teacher comes to meet us. She teaches grade 5 Maths and EVS in a central school nearby and has earlier taught in the same school as our sample. She has a Bachelors in Chemistry and in Education. Seems interested in the project but cannot commit right away as she is already teaching in a school but assures that she will be available when TN is not able to take class.

**22nd September 2009:** TN cannot be contacted so we call TP for taking the class on a chapter from class 7 textbook - Transportation in Animals and plants. We had decided earlier that we will teach one chapter from the textbook in both the groups in the different methodologies. After discussing with Teacher TN, this chapter was chosen. There is a unit on circulatory system that has already been developed for class 5, *Small Science*; insights from that unit would help teach this chapter in the inquiry mode.

**12th October 2009:** We arranged to help TP with the activities she wanted to do in class (like making stethoscope). These were given in the textbook chapter. We also showed her a plaster model of the heart available in the centre which she could use if she wanted and told her that the centre would pay if she wanted to buy a goat heart. She was not comfortable with handling a real organ; she studied the heart model and decided to use it. We also thought we would share the heart model developed by IJ for class 5.

**13th October 2009:** Camp started yesterday but the turnout was very poor. So we called the students and reminded them. Today in Group C the attendance was good (25), it was a little less in Group I – 18 (some students have gone out of town ) and some have tuitions.

I am working with both IK and TP helping them with their lesson plans and with four hours of observation each day it is difficult to write up the impressions on the same day.

**20th October 2009:** Only 10 kids from Group C and 7 kids (all boys) from Group I came for classes today and so we decided to discontinue the camp. I sat in for the latter half of TP's class. Only three kids in the front row were engaged while the others looked bored/ distracted. This was very different from IK's class - students started to ask questions today too and she also encouraged them, asking each one to ask a question and steered the discussion, throwing back students' questions and prompts to make them think (sometimes I pitched in too), relating to their experiences.

All students were very involved in the discussion and all of the two hours, in fact almost two and a half hours, went in discussing their questions. Even Umesh who used to be distracted most of the time was not only attentive all the time but also participated; not only Suhail and Abhijeet (as ever) but also Mayur (who was very shy initially), Nitin and Nandan (who were quieter and sometimes distracted) were involved very actively. Sanket was still a bit quiet but asked good questions at times. Gyan asked a lot of questions and gave fantastic guesses and amazed us at times. Himanshu though seemed to keep a lower profile than in IJ's classes, answering very few times in class but sometimes coming in the break to talk. Tarika and Harshali were quiet most of the time but were very attentive all through, answering whenever IJ prodded them to. Overall children seemed to thoroughly enjoy the intellectual engagement. Children from both the groups, especially Gyan pleaded repeatedly to continue the camp however the numbers seemed too low as many students had gone out of station.

**29th October 2009:** Though the attendance was a bit less, the one week camp turned out to be a very fruitful one. Children from both groups seemed to enjoy the camp. However, in group C the same pattern continued - a few (literally, the first benchers) were active while others seemed less engaged and hardly participated in the class discussions while the whole of group I was engaged in the class. They have begun to ask good questions, tried to come up explanations for their own as well as others' questions, exploring possible explanations and IK too handled it very well. I feel like congratulating her for carrying out such fine inquiry classes having just started teaching recently. In the previous two-three classes there has hardly been an activity as such (or even much "teaching" in terms of exposition) but still the interest and engagement level of children has been high and there has been a lot of exploration in terms of thinking. But perhaps I should tell her later, after these classes?

I did give her feedback on the content a little bit and class management - like pointing out that sometimes children laughed at each others' responses. At times, I have told her the class went well specially when she was not very confident but it has been a restrained feedback. I also could not resist participating in the discussions at times and suggested questions to make children think about their own questions/ guide them. I think it is ok because it was a discussion and I did not interfere in her teaching. IJ pointed out that this is also a training period for IK and I have also supported TP with the content and teaching as well.

**4th November 2009:** TP came to HBCSE after the class. IJ asked her how the class went. She said these students are very interested and so it is very easy to teach them, in fact they are the type of students that every teacher wishes to have. They are very attentive and most of them listen to you, though every class has a few students who do their own thing. IJ pointed out that this has been a general observation in all her classes and helped her to think how today's class was different and offered to write the summary together but we could not discuss it today since TP had to leave. IJ again stressed that summaries should be written on the same day or at most next day when the observations/ impression are fresh.

**6th November 2009:** We have repeatedly insisted that TP write her impressions of her classes and also explained and given examples of what she can write. However each time she has the same thing to say in her summaries that the class went well and children are attentive even though they were some glitches in the class and again today she send a similar summary - there seems to be a lack of introspection on her part in spite of encouragement and demand from us. Or is it that she does not want to show others that were any problems in her class? In school it is not a common practice due to fear of the authorities. But here we had assured her all through that this is not an evaluation of her teaching and it will not have any consequences for her. Or is it a lack of acceptance or even understanding that there are problems because again it is not a common practice for teachers to think about each of their classes given the large amount of classes they have to teach and also it is not a must for the traditional way of teaching unlike for inquiry. Also, she does not yet know or even attempt to know the names of students in her group. She does not talk much about how the class went at the end of the class, however now she does ask immediately after class if anything was missed or if there was any “problem” (content error).

IJ today again explained and gave examples of the kind of thinking that she does after each class, for example: Did the children understand? Or were there any problems with understanding something? Were the children bored at some juncture? Did some teaching strategy work very well or did not work? How she had to change some strategy of teaching or tweak the lesson plan according to children's response? Were there any shortcomings in the content/ mistakes in teaching? We assured TP that there were no consequences of admitting mistakes and that at times mistakes do happen with everyone. She also showed TP a few summaries she had written for earlier classes and also examples where some errors were made by the teacher and the children had corrected her. This session lasted almost 40-45 min.

**6th April 2010:** Classes resumed today after a gap of three months. We thought we should hold classes in this month lest there be a big gap before summer camp and selected the density unit which had activities for students to start working in groups, so far that has not happened much.

In teacher’s IK’s class today, the attendance was low but the teacher decided to do the activity of comparing of volumes with two pairs of containers so that those who came would not be disappointed and it would perhaps tempt others to come too. It went pretty well, children were completely engaged and made good attempts at giving explanations for their guess of which container would hold more water. They were very curious to do and see which could hold more water and also for the reason why. We asked them to think about it and gave it as homework. Another nice thing that happened was that they wanted to compare one of the containers brought for the activity with a water bottle that I had taken - it was also a good pair for the guessing game. They were eager to do the activity and see.

However, the most positive highlight of the class for me was that Soham was engaged for the most part and also gave good explanation for his guess. He also took part in the discussion on Akshara's question of fertilizers and made a very good point - I think this happened for the first time. Also, both of us observers noted that Himanshu who many a times gives vague responses earlier just to keep answering (and perhaps gain attention), and was of late quieter especially during productive discussions, today made some well articulated arguments.

On a different note, there were a few significant statements made by students which were missed by the teacher initially and the observer pointed out to pursue, like when Gyan said earthworms will not come in humus in this season, they only come in rainy season. Another one was Himanshu wanting to measure the capacity of the bottle using a scale. During the chaos of classroom transactions it is likely that some student responses go unheard and perhaps it needs more experience not to miss those that show significant student difficulties.

**12$^{th}$ April 2010:** It was TA's first class on the 8th, not only with us but for her teaching in an actual classroom. She has done B.Ed and is pursuing a Ph.D on Oyster mushrooms. She was pretty confident in the class and tried to connect the idea of volume well with daily experiences. But it was quite a traditional science class in that the teacher gave the most explanations, children were given definitions to copy down and mostly it was just Ayush or sometimes Ajitha and Preeti who spoke in class while others remained passive. Also there was no eagerness/ excitement for the activity of finding out which container holds more water or to know why it happened that way for which the kids in Inquiry group (class on 6$^{th}$ April) were very curious and on prompting, gave very good explanations. Here the teacher asked for guess, one or two replied, the teacher did the activity and explained it.

TA did a good job of writing down the lesson plan and summary in detail - something that was very difficult to get out of the earlier teachers of this group. She also comes to the centre for preparation and discussing the lesson plans.

**March 2010:** For the comparison group, we now have Teacher TS with us, in addition to TA, for the summer camp. TS has a B.Ed and M.Sc (Chemistry) degree and teaches science as an ad-hoc teacher in the school from where our earlier sample was. She has previously taught at school to the same division and grade to which students from our inquiry group belong but not to the other two divisions to which students of comparison group belong.

We have almost a month and a half for preparation for the summer camp. All the material - information gathered, resources (books, videos and pictures) and details of experiments planned and the material needed for them have been shared with the teachers of the comparison group and they are encouraged to modify/ add to the teaching plan. We also discussed with them the difficulties/ misconceptions students have in these topics, for example, that children think that anything that has air in it floats (not thinking about the average density).

# D

## A Summary of the Components of Questionnaires and Interviews in the Study

- **Pre-instruction questionnaire for students**

I. Interest in school science:

  i. Favourite subjects and least favourite subject

  ii. Topics in science that they liked and did not like

II. Motivation for joining this program

- **Mid-way questionnaire and interviews**
  **(**administered during winter camp)

I. Any changes students noticed in themselves in the time they attended the intervention

II. Self-reports of participation level in science classes at school and in the intervention

III. Students' out of classs questions and observations

IV. Disposition towards learning science (What do students like/ not like about learning science?)

V. Views of science

VI. Future career choice

- **Post-instruction questionnaire (**administered at the end of summer )

I. Participation in the science classes in the intervention

II. Comparison of science classes at school and those in the intervention

III. Dispositions towards learning science

- **Delayed post-instruction questionnaire and interviews**

Students' self-reports one month after the program attempted to explore differences, if any, between the two groups in terms of -

i. Interest in science outside of the program -
    i. Did they ponder about any questions
    ii. Did they make any puzzling/ interesting observation?

I. How was their participation in school science classes this year?

II. Any change they had felt about themselves in how they learned/ talked/ behaved? (Was this noticed by significant others?)

III. Disposition towards learning science - did they start liking/ disliking any particular school subject?

IV. Views of science – 'What is science?'

V. Career choice

- **Individual semi-structured interviews**

They were used to obtain a personal, subjective, experience of the participants - with all students after mid-way questionnaires and with a subset of students while following up the delayed post-intervention questionnaires.

- **Questionnaires administered to parents**

At the beginning of the program, they helped us get data on students' socio-economic status, academic achievement and activities related to interest in science while the those administered after the program explored changes in students, if any, that parents had noticed.

# E

## Comparison of the two incoming groups of students: Data from questionnaires to parents at the start of the program

Parents of students in both groups were administered written questionnaires before and after the program (Table E1).

**Table E1.** Details of questionnaires given to parents (see in conjunction with Figure 3.1 on study design)

| | | Number of respondents in Inquiry group | Number of respondents in Comparison group | Date administered |
|---|---|---|---|---|
| 1. | **Pre-instruction** (at the start of school year/ Phase I) | 27 | 33 | July 03, 2009 |
| 2. | **Pre-instruction** (at the start of Summer camp/ Phase II, only for new students) | 27 | 25 | May 17, 2010 |
| 3. | **Post-instruction** | 27<br>(16 new + 11 continuing students) | 26<br>(20 new + 6 continuing students) | July 10, 2010 |

The pre-intervention questionnaire, (appended at the end of this document), helped us understand the characteristics of the two groups as they entered the program and also served as a baseline for changes, if any, reported by parents in the post-intervention questionnaire (Appendix G). Questionnaires were made available in both Hindi and English; parents could choose to answer in either of the languages. In Phase I, nine parents from Group 1 filled the forms in Hindi while everyone from the comparison group answered in English. In Phase II, three parents in the inquiry group answered in Hindi the post-intervention questionnaire while one in the comparison group answered bilingually in Hindi and English.

**Table E2.** Components of the pre-intervention questionnaire given to parents

| Factors | Question number |
|---|---|
| I. Interest in science | |
| (a) Discussion with parents about school and school science | 1-3 |
| (b) Watching popular science related programs on TV | 7 (b) |
| (c) Participating in science related co-curricular activities | 8 |
| (like projects for science exhibition, quizzes) | |
| (d) Reading science related books/ magazines | 9 |
| II. Level of curiosity - Asking questions about events in daily life | 10 |
| III. Perceived level of self-confidence of the child | 11 |
| IV. Academic achievement | 12 |
| V. socioeconomic status | 13 |
| VI. Routine outside school hours | |
| (a) Academic support outside of school (Tuitions) | 4-6 |
| (b) Activities engaged in out-of-school hours | 5 |
| (c) Number of hours of watching TV | 7 (a) |

## I. Characteristics of the inquiry and comparison groups in Phase I

With respect to gender, age, socioeconomic status (Table E3 and Figure E1) and academic achievement (Table 4), the two groups in the study were found to have similar compositions.

**Table E3.** Summary of demographic data of students in Phase I

| | **Inquiry group** | **Comparison group** |
|---|---|---|
| Gender | 60% male, 40% female | 56% male, 44% female |
| Age (mean) | 11.80 | 11.82 |
| Average monthly family income (in Rs.) | 21,429 | **22,227** |
| Parents' education | | |
| (Number of years) | | |
| Father's education | 13.50 | 13.20 |
| Mother's education | 12.10 | 13.05 |

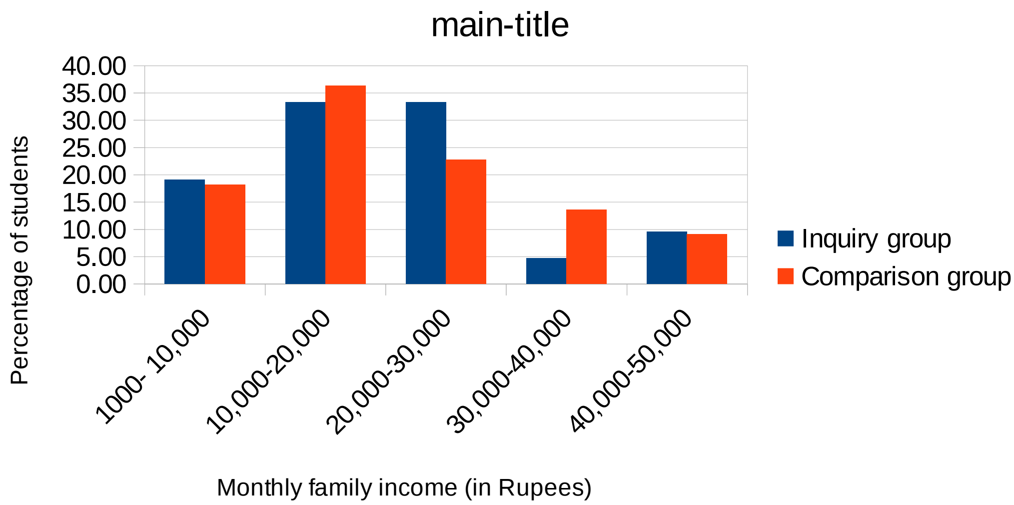


**Figure E1.** Distribution of students across income levels in Phase I

**Table E4.** Comparison of the academic performance of the two groups in Phase I based on their annual examinations at school at the end of Grade 6

| | **Overall scores (Out of 750)** | | **Scores for Science (Out of 100)** | |
|---|---|---|---|---|
| | **Inquiry group** | **Comparison group** | **Inquiry group** | **Comparison group** |
| Mean | 511.78 | 510.54 | 69.22 | 67.54 |
| Standard deviation | 118.39 | 85.68 | 19.31 | 15.82 |

The proportion of students going to tuitions or coaching classes for academic support was similar in the two groups – 62 % of student in Inquiry group and 55% from comparison groups went for tuitions.

**Factors related to interest in science:** There was some difference between the two groups, in parents' reports related to students' level of interest in academics and particularly science. Parents were asked if and how much their children discussed at home about what happened at school and what they learned in school. Responses in the category 'Always' and 'Very often' clubbed together (Figure E2), were found to be more from the comparison group than those reported by the inquiry group. Students in the comparison group also seemed to talk more about science compared to other subjects taught at school (Figure E3).

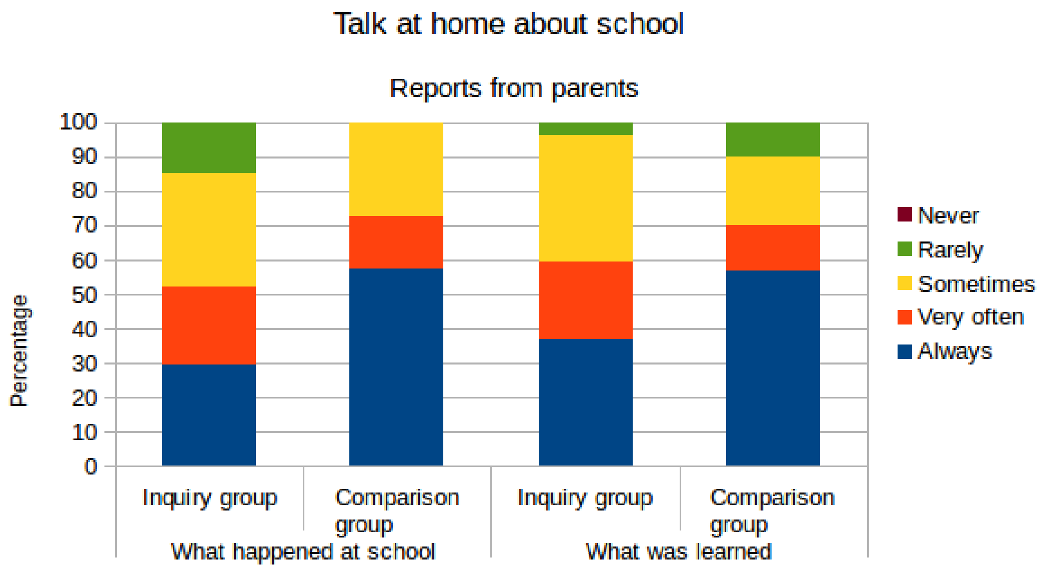


**Figure E2.** Parents' reports on level of discussion at home with their child about what happended at school (Phase I)

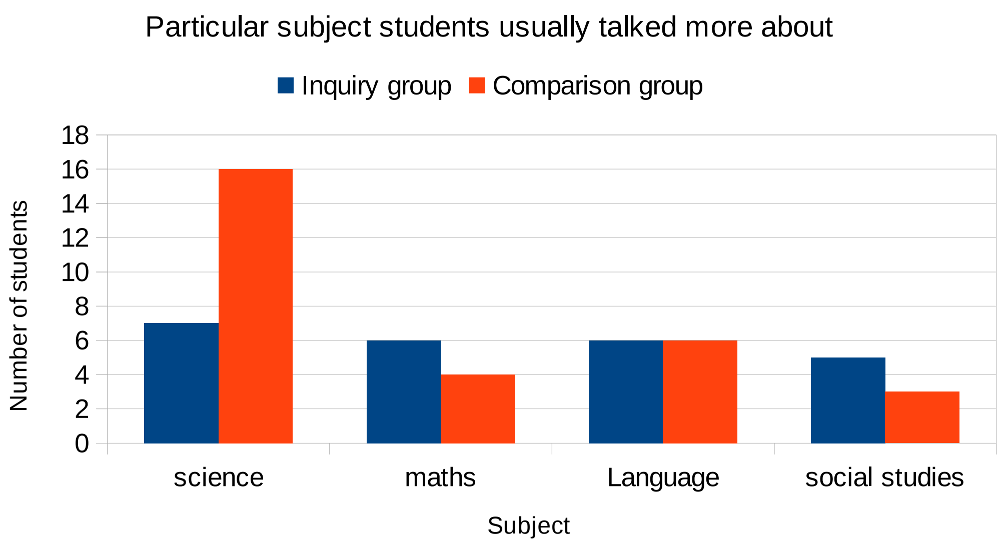


**Figure E3.** Parents' reports on the academic subjects that students talked more about at home (Phase I)

### II. Characteristics of the inquiry and comparison groups in Phase II

Data collected from parents, when the students joined the classes, indicated that the two groups of students were similar in terms of demographic composition and socioeconomic status (Table E5 and Figure E4), academic achievement (Table E6) and factors related to students' interest in science.

**Table E5.** Summary of demographic data of students in Phase II

| | **Inquiry group** | **Comparison group** |
|---|---|---|
| Gender | 60% male, 40% female | 55% male, 45% female |
| **Age (mean)** | 12.46 years | 12.67 years |
| Monthly family income (Rs.) | 46,016 Rs | **43,350 Rs.** |
| **Parents' education** | | |
| **(Number of years)** | | |
| **Father's education** | **15.00** | **15.74** |
| Mother's education | 14.94 | **15.10** |

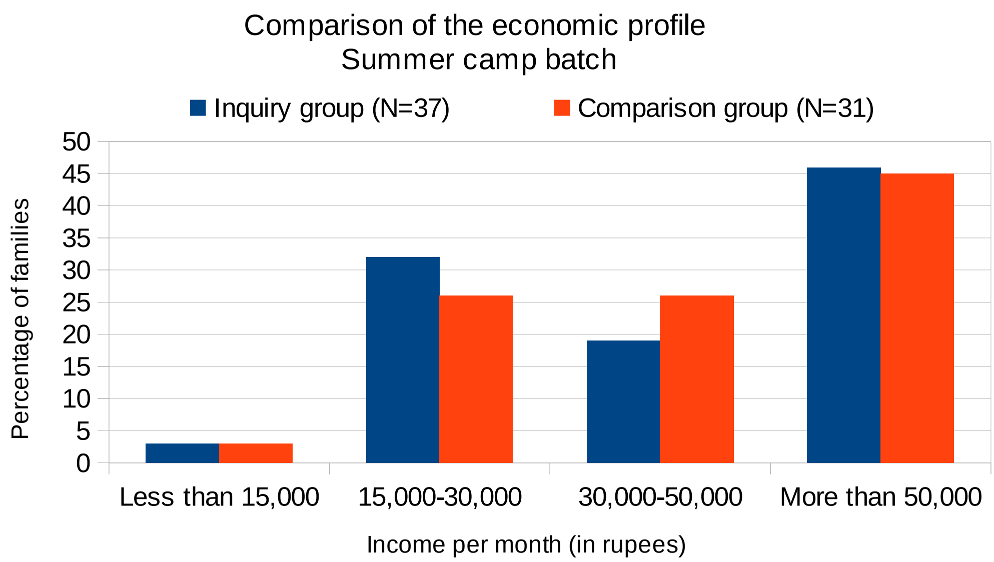


**Figure E4.** Comparison of economic profile of the two groups in Phase II

**Table E6.** Academic performance of the two groups (Phase II) in their annual examinations at school at the end of Grade 7

| | Overall scores | | Scores for Science | |
|---|---|---|---|---|
| | **Inquiry group** | **Comparison group** | **Inquiry group** | **Comparison group** |
| Mean | 563.50 | 568.77 | 79.24 | 80.34 |
| Standard deviation | 84.60 | 89.13 | 13.80 | 15.1 |

**Factors related to interest in science:** Parents were asked about their child's interest in academics in general (Table E7, E8 and E9) as well as in co-curricular and extra-curricular activities related to science and their level of curiosity about events in daily life/ what the child sees around him or her.

### (a) Talking about school and school science with parents

**Table E7.** Discussion with parents about what happened in school

| Response | Inquiry group | Comparison group |
|---|---|---|
| Always | 10 | 12 |
| Very often | 13 | 11 |
| Sometimes | 12 | 10 |
| Rarely | 2 | 0 |
| Never | 0 | 0 |
| Total | 37 | 33 |

**Table E8.** Discussion at home about what the child learned at school

| Response | Inquiry group | Comparison group |
|---|---|---|
| How often? | | |
| Always | 8 | 16* |
| Very often | 10 | 10 |
| Sometimes | 7 | 7 |
| Rarely | 2 | 0 |
| Never | 0 | 0 |
| How much? | | |
| A lot | 9 | 9 |
| Quite a bit | 18 | 18 |
| A little | 5 | 6 |
| Not answered | 1 | 4 |
| Total | 37 | 33 |

**Table E9.** Subject preference: Particular subject the child talks more about

| School subject | Inquiry group | Comparison group |
|---|---|---|
| Science | 17 | 15 |
| Maths | 11 | 8 |
| Computer Sc | 2 | 0 |
| English | 4 | 1 |
| Marathi | 2 | 4 |

**(b) Involvement in science-related activities**

**Table E10.** Comparison of students' interest in science related activities

| Factors related to interest in science outside of school | Inquiry group | Comparison group |
|---|---|---|
| Watching science related programs on channels like Discovery, National Geographic, Animal Planet | 17 | 14 |
| Participating in science related co-curricular activities | | |
| Projects | 27 | 25 |
| Quizzes | 8 | 13* |
| Reading science related books/ magazines | 10 | 14 |

II. **Level of curiosity:** There was not much difference between the two groups in the reported levels of student questioning at home.

**Table E11.** Response to the question, "Does your child ask questions about events in daily life or what she/he sees around?"

| | Inquiry group | Comparison group |
|---|---|---|
| Often | 19 | 15 |
| Sometimes | 12 | 9 |
| Rarely | 1 | 0 |
| Never | 0 | 0 |
| Questions given as example and categories* | 12 questions (6 seeking factual and 6 seeking explanatory information) | 11 questions (2 seeking factual and 9 seeking explanatory information, mostly mechanism) |

* Using question categories from Cakmakci et. al (2012) for questions asked in informal settings

**Box E1: Examples of questions given by parents from the Inquiry group**

*Questions seeking explanatory information -*

From where does salt mix in sea water?

Why does the sun appear different in the evening?

How are rates of things regulated?

*Questions seeking factual information -*

How does monorail differ from other trains?

How to differentiate between male and female dogs?

**Box E2: Examples of questions given by parents from the comparison group**

*Questions seeking explanatory information -*

How electric poles are placed in sea water?

About conjunctivitis, how does it transfer from one person to another?

Why insects or moths stick to the (lighted) bulb?

How does a motor run?

*Questions seeking factual information -*

What is the current temperature?

How far can we travel in space?

### III. Self-confidence level of the child as perceived by parents:

No significant difference at the 5 % level, in average score of the groups was found using independent sample t-test), t(67)=1.96, p=0.02, but there is a difference in frequency distribution as can be seen in Figure D5.

**Table E12.** Self-confidence level of the child as perceived by parents (Phase II)

| | Inquiry group | Comparison group |
|---|---|---|
| Mean | 7.19 | 7.9 |
| Std. Deviation | 1.73 | 1.28 |

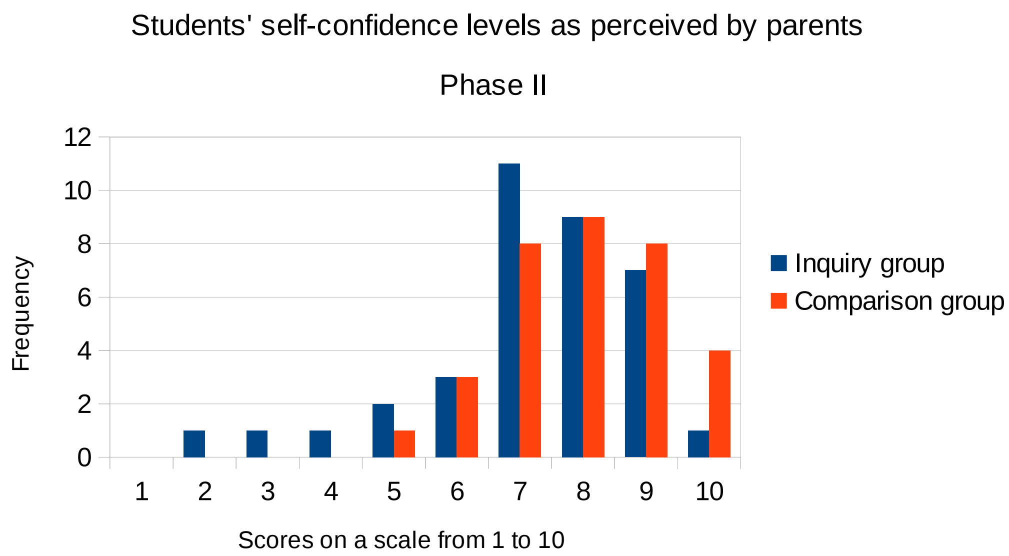


**Figure E5.** Frequency distribution of students' self-confidence levels as reported by parents

**VI. Academic support**

**Table E13.** Percentage of students going for coaching classes in each group

| | Inquiry group (N=33) | Comparison group (N=37) |
|---|---|---|
| Percentage of students going for tuitions | 63.63%* | 43.24% |
| Average number of hours per week | 8 | 8 |

**Table E14:** According to the parent, whether the child studies on her/ his own or does she/ he need encouragement?

| | Inquiry group | Comparison group |
|---|---|---|
| Needs encouragement | 15 | 14 |
| Studies on his own | 16 | 12 |
| Both | 6 | 6 |
| Total | 37 | 33 |

### III. Difference in the socioeconomic status of the continuing and new students in Phase II

We noted a stark difference in the socioeconomic status of the new students in Phase II and the previous students of both groups in Phase I (Table E15). The newer students came from higher income families and had parents who had more number of years of education. Nine of the new students in inquiry group and seven in the comparison group had atleast one parent with a career in science while none of the previous students did.

**Summary:** No systematic differences were found between the two groups prior to the instruction. The groups had similar demographic characteristics (age, sex ratio, socioeconomic status) and academic achievement levels. They were also similar in factors related to interest in science, asking questions, self-confidence levels (as reported by parents) and their routines after school hours. However, there was a difference in the socioeconomic status of the students in Phase II and those continuing from phase I, although this was the case for both inquiry and comparison group.

**Table E15.** A comparison of the socioeconomic status of continuing and new students in Phase II

| | **Mother's education (Number of years)** | | **Father's education (Number of years)** | | **Family income per month (Rs.)** | |
|---|---|---|---|---|---|---|
| | **Inquiry group** | **Comparison group** | **Inquiry group** | **Comparison group** | **Inquiry group** | **Comparison group** |
| Average for the group | 14.94 | 15.1 | 15.00 | 15.74 | 46,016 | 43,350 |
| Average for continuing students | 13.25 | 13.86 | 13.56 | 14.43 | 22,158 | 20,786 |
| Average for new students | 15.44 | 15.48 | 15.52 | 16.13 | 54,852 | 50,217 |
| SD for the group | 2.65 | 2.84 | 2.64 | 2.99 | 26,984 | 26,320 |
| SD for continuing students | 2.76 | 2.12 | 2.60 | 2.3 | 9,413 | 13,362 |
| SD for new students | 2.44 | 2.97 | 2.50 | 3.1 | 26,029 | 25,557 |

**Questionnaire administered to parents at the start of the program**

HOMI BHABHA CENTRE FOR SCIENCE EDUCATION

TATA INSTITUTE OF FUNDAMENTAL RESEARCH

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Dr. Jyotsna Vijapurkar Tel: 022-2558 0036

Email: jyotsna@hbcse.tifr.res.in Fax: 091-22-25 566 803

URL: http://www.hbcse.tifr.res.in

Dear Parents/Guardians,

It is a great pleasure to have your child in our HBCSE science classes. This program is part of a research project and it is important that your child be with us for the entire study. It is also important for us to get to know more about your child - this will help us in our program. We request you to take a few minutes to answer the questions given below and send this form back in a week's time. We assure you that your response will not affect, in any way, your child's selection/ participation in our classes and it will be kept strictly confidential – it will not even be shared with your child's school. The information you provide here will useful to us for our research purposes. So please feel free to be very frank and accurate in your responses to these questions.

Questions in both Hindi and English are attached; please choose one for your responses.

Your name - ……………………………………………………

Your child's name - ……………………………………………

1. Does your child talk about what he/she has learned in school?

How often? Always ☐ Very often ☐ Sometimes ☐ Rarely ☐ Never ☐

How much? A lot ☐ Quite a bit ☐ A little ☐ Very little ☐

2. Does your child study on her/ his own or does she/ he need encouragement?

……………………………………………………………………………………………………………

……………………………………………………………………………………………………………

3. List the activities your child is engaged in outside school hours - such as tuition, team sports, sports training, informal play, swimming, music lessons, others (please specify).

……………………………………………………………………………………………………………

……………………………………………………………………………………………………………

4. If your child goes for tuition, how many hours a week?

……………………………………………………………………………………………………………

……………………………………………………………………………………………………………

5. Does your child participate in activities (other than regular classes) organized by the school, such as projects, quizzes, cultural events etc? Which ones?

……………………………………………………………………………………………………………

……………………………………………………………………………………………………………

6. Which TV channels (or which kind of programs?) does the child see mostly?

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7. Which (kind of) books/ other reading material does your child read other than school books?

..........................................................................................................................

..........................................................................................................................

8. Does your child ask questions about events in daily life or what she/ he sees around?

Often ☐ Sometimes ☐ Rarely ☐

Please give at least one recent example.

..........................................................................................................................

..........................................................................................................................

9. Tell us about your child's academic performance in last year's annual exam :

Overall Marks ................. out of .................

Marks in Science ................. out of .................

10. Details about the child's guardians:

(Please note that personal information regarding individual students requested here will not be considered individually – this data will help us characterize the group of students coming to us and thus help in our research.)

(a). Relationship to child (mother/aunt/grandmother...) .................................

Education: .................................

Profession: .................................

(b). Relationship to child (father/uncle/grandfather...) .................................

Education: ..................................

Profession: ..................................

(c). Number of members in the family: ............................

(d). Annual income of the family: .................................. Rupees per annum

If you do not wish to give exact figures, you may tick one of the categories below -

Below 15,000 Rs per month ☐

15,000 to 30,000 Rs per month ☐

30,000 to 50,000 Rs. per month ☐

More than 50,000 Rs. per month ☐

Thank you very much! We are grateful for your time and support.

# F

## Comparison of the two incoming groups of students: Data from students' self-reports

### A. Data from Phase I (21 July 2009)

Following factors were the components of the questionnaire administered to students in the intial period of Phase I:

I. Interest in school science:

a) Favourite subjects and least favourite subject

b) Topics in science that they liked and did not like

II. Motivation for joining this program

**I. Interest in school science:**

**a) Subject preference:** Students were asked to specify three of their favourite subjects in school in order of preference and also the subject that was their least favourite. Since this program involved voluntary, post-school engagement, a high amount of interest in school science was expected. Responses to this question were elicited to check if both groups were similar in this aspect. Indeed, a large proportion of students in both groups reported science as their favourite subject: 12 out of 22 (54%) in inquiry and 19 out of 27 (70%) in comparison group. This is congruent to the findings by a recent study (van Griethuijsen et al., 2015) which reported that students (aged 10-14 years) from India were the most likely to have written down the name of a science or mathematics course as a favourite class, compared to five other Europian and Asian countries.

The main reasons students cited for liking science were also similar across the groups – it being interesting, useful in daily life, getting to know new things and because they liked experiments. Mathematics was the second most favourite subject, with 36% students in inquiry and 37% students in comparison group mentioning it in the two most liked subjects. However, it was also the subject some students reported as their least favourite (40% in inquiry and 18% in comparison group). For three students in both groups, science did not figure in their three most liked subject; a girl student in inquiry (Srishti) mentioned science as her most disliked subject. These students were interesting cases to be followed through the study. The pre-instruction questionnaire was administered after a few classes so that students feel comfortable to give honest answers. It was heartening that students seemed to respond honestly - not all students mentioned science as their most favourite subject considering that they were responding to this question in the context of the science classes conducted in the program. The teacher in inquiry, during the ensuing discussion after the lesson, was happy that students were beginning to get comfortable in expressing their thoughts.

**b) Topics in science that they liked and did not like**

There were no large differences again between the two groups in terms of the topics liked and disliked (Table F1). Oftentimes in such out-of-school classes, students come with an expectation to learn something distant from their syllabus, usually topics like astronomy. This group did not seem no have joined the classes with such expectations which was good for the intervention as it was a quasi-longitudinal one and included a lot of topics across their syllabus though not necessarily limited to it.

**Table F1.** Students reports on their affinity towards particular topics in science (Phase I)

| Content areas | Liked | | Disliked | |
|---|---|---|---|---|
| | Inquiry | Comparison | Inquiry | Comparison |
| Biology or related topics | 4 | 7 | 2 | 2 |
| Physics or related topics | 6 | 5 | 1 | 2 |
| Chemistry or related topics | 4 | 4 | 0 | 2 |
| Astronomy | 1 | 2 | 0 | 0 |
| Applied science topics like Food, Fibre to Fabrics and environment related topics | 0 | 1 | 2 | 3 |

(N=22 for Inquiry, N=27 for comparison group)

## II. Motivation for joining this program

Except for few students in each group who stated that they joined the program because they were asked to join by others, most students said they had volunteered for the program because they themselves wanted to.

**Table F2.** Students' reasons for attending the classes in this program (Phase I)

| Group | Your friends asked you to join | Your parents/ teachers/ principal asked you to join | You were interested to join |
|---|---|---|---|
| Inquiry group (N=18) | 2 | 3 | 17 |
| Comparison group (N=23) | 0 | 6 | 22 |

## B. Data from Phase II (Summer camp) (17 May 2010)

In addition to the components of the questionnaire administered to students in Phase I, we asked for students' career aspirations in the pre-instruction questionnaire in Phase II.

**I. Interest in school science:**

**a) Subject preference:** Students were asked to specify three of their favourite subjects in school in order of preference and the subject that was their least favourite. The two groups were similar in terms of their preference for science and mathematics which were ranked much higher than other subjects (Table F3). 81% students in Inquiry and 86 % of students in the comparison mentioned science as their first or second most favourite subject. After science, mathematics was liked by many students; 51% in inquiry and 55 % students in comparison reported mathematics to be their first or second favourite subject. None in both groups reported science to be their least favourite subject. Three students in comparison batch though said that Mathematics was their least favourite subject.

**b) Topics in science that they liked and did not like**

There were no large differences again between the two groups in terms of the topics liked, except that many more students from the inquiry group reporting dislike towards Biology.

**Table F3.** Students' reports on their affinity towards certain topics in science (Phase II)

| | **Liked** | | **Disliked** | |
|---|---|---|---|---|
| | **Inquiry** | **Comparison** | **Inquiry** | **Comparison** |
| Biology or related topics | 5 | 8 | 9* | 2 |
| Physics or related topics | 8 | 8 | 3 | 2 |
| Chemistry or related topics | 6 | 4 | 4 | 2 |
| Astronomy | 2 | 2 | 0 | 0 |
| Applied science topics like Food, Fibre to Fabrics and environment related topics | 0 | 1 | 1 | 4 |

(N=27 for both groups)

### III. Future career choice

**Table F4:** Students' career aspirations (Phase II)

| | **Inquiry group** | **Comparison group** |
|---|---|---|
| Scientist | 8 | 11 |
| Science related (Doctor/ Engineer/ Astronaut) | 14 | 13 |
| Others | 4 | 7 |

(N=27 for both groups)

### IV. Motivation for joining this program

Most students in both groups report that they joined the program because they were interested in science rather than extraneous reasons which were also not completely ruled out indicating students felt comfortable giving honest responses.

**Table F5:** Students' reports on why they attended the classes in the program (Phase II)

| | Your friends had join/your friends ask you to join | Your parents/ teachers/ principal asked you to join | You are interested in science | You are weak in science & wanted to get better | You had heard about HBCSC classes & were curious | You have holidays & wanted to keep busy | Any other reason |
|---|---|---|---|---|---|---|---|
| Inquiry group | 0 | 0 | 26 | 2 | 1 | 4 | a |
| Comparison group | 1 | 2 | 21 | 2 | 4 | 3 | b |

(N=27; Students could choose more than one reason)

a. I am already there in the library. b. I once wanted to see HBCSE

**Summary:** The inquiry and comparison groups in both phases of the study were similar in terms of aspects related to interest in school science, to start with (based on students' reports). Reported levels of participation in school classes from the inquiry group in Phase II was however higher than the comparison group. This could not be triangulated with classroom observations since no observations were conducted in the schools of these new students since they came from three different schools and different divisions within these schools therefore observations were not feasible.

# G

## Questionnaire administered to parents after the program

Dear Parents/Guardians

It was a great pleasure having your child in HBCSE science classes. We request you to take a few minutes to answer the questions given below and send this form back in a week's time. *Your feedback is invaluable and important for our project*. We assure you that your response regarding your child will not affect, in any way, his/her selection/ participation in future classes, if and when they are held; and *it will be kept confidential*. Please feel free to be frank and critical in your response to these questions.

Your Name: ..................................................................................

Your child's name: ......................................................................

1. Did your child share/ discuss with you what happened in HBCSE classes?

How often? Always ☐ Very often ☐ Sometimes ☐ Rarely ☐ Never ☐
How much? A lot ☐ Quite a bit ☐ A little ☐ Very little ☐

Was this less/ more/ same as compared to discussion about regular school classes?

..........................................................................................................................
..........................................................................................................................

2. From what you have heard from your child, what do you think happens in HBCSE science classes?

……………………………………………………………………………………………………
……………………………………………………………………………………………………

3. Did you find any change in your child after he/she attended HBCSE classses?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

4. During this time, how did your child's interest level in science change - please indicate with a tick mark: Increased □ Decreased □ Remained the same □

How do you know? (Please justify your answer).

……………………………………………………………………………………………………
……………………………………………………………………………………………………

5. Did you notice any change in your child's confidence levels, during this time -

Please indicate with a tick mark if it - Increased □ Decreased □ or Remained the same □

If there was a change, by how much? Slight □ Moderate □ Considerable □ A lot □

6. After attending HBCSE classes, does your child -

Observe less or take less interest in the surroundings □

Observe more or take more interest in the surroundings □

Observe or take interest in the surroundings in the same way □

Please give an example of a recent observation by your child, if any.

……………………………………………………………………………………………………
……………………………………………………………………………………………………

7. Does your child ask more questions now about events in daily life or what they see around or is it less or the same as before?

..........................................................................................................................

Please give an example of a question your child asked recently, if any.

..........................................................................................................................

..........................................................................................................................

8. Were any of the changes negative or undesirable?

..........................................................................................................................

..........................................................................................................................

9. Do you believe HBCSE classes are responsible for the changes you observed in your child?

Yes □ No □

If so, how much do you think these classes contributed to bring about this change?

Slight □ Moderate □ Considerable □ A lot □

Anything else that you would like to add/ comment/ suggest -

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

Thank you very much! We are grateful for your feedback.

# H

## Questionnaire administered to students in a staggered way towards end of Phase II

1. How do you find science as a subject?

(Put a tick mark on the dash ( _ ) closest to your answer)

| | | | | | | |
|---|---|---|---|---|---|---|
| • Easy | ___ | ___ | ____ | ____ | ____ | Difficult |
| • Interesting | ___ | ___ | ____ | ____ | ____ | Dull |
| • Useful | ___ | ___ | ____ | ____ | ____ | Not useful |
| • Important | ___ | ___ | ____ | ____ | ____ | Unimportant |
| • Related to everyday life | ___ | ___ | ____ | ____ | ____ | Unrelated to everyday life |
| • Exciting | ___ | ___ | ____ | ____ | ____ | Boring |
| • Challenging | ___ | ___ | ____ | ____ | ____ | Not challenging at all |

2. I want to learn science because -

3. What do you like about learning science?

4. What do you **not** like about learning science?

**1. The following questions are about your regular science classes in your <u>SCHOOL</u>:**

| | |
|---|---|
| Do you answer teacher's questions? | Many times ☐ Sometimes ☐ Rarely ☐ Never ☐ |
| Do you ask questions? | Many times ☐ Sometimes ☐ Rarely ☐ Never ☐ |
| Comment on what the teacher/ other student says? | Many times ☐ Sometimes ☐ Rarely ☐ Never ☐ |
| Discuss the topic with friends | Many times ☐ Sometimes ☐ Rarely ☐ Never ☐ |

**If you don't answer or ask question many a times, give reasons for your answers:**

I don't always answer or ask questions because…

I am shy ☐ I don't get a chance to ask ☐ Teacher doesn't ask me ☐

Teacher doesn't answer me ☐ I may get scolded ☐ I do not get time to ask ☐

I may get punished ☐ Others may laugh at me ☐

Others may think my question or answer is stupid or silly or wrong ☐

I have never asked and am afraid to start, I do not have questions ☐

I find it hard to pay attention all the time, the class is not interesting ☐

Others always answer/ask question before me ☐

I do not get praised for asking or answering ☐

Any other reason ………………………………………………………………………………

………………………………………………………………………………………………

**2.The following questions are about THE HBCSE science classes:**

| | |
|---|---|
| Do you answer teacher's questions? | Many times ☐ Sometimes ☐ Rarely ☐ Never ☐ |
| Do you ask questions? | Many times ☐ Sometimes ☐ Rarely ☐ Never ☐ |
| Comment on what the teacher/ other student says? | Many times ☐ Sometimes ☐ Rarely ☐ Never ☐ |
| Discuss the topic with friends | Many times ☐ Sometimes ☐ Rarely ☐ Never ☐ |

**If you don't answer or ask question many a times, give reasons for your answers:**

I don't always answer or ask questions because...

I am shy ☐ I don't get a chance to ask ☐ Teacher doesn't ask me ☐

Teacher doesn't answer me ☐ I may get scolded ☐ I do not get time to ask ☐

I may get punished ☐ Others may laugh at me ☐

Others may think my question or answer is stupid or silly or wrong ☐

I have never asked and am afraid to start, I do not have questions ☐

I find it hard to pay attention all the time, the class is not interesting ☐

Others always answer/ask question before me ☐

I do not get praised for asking or answering ☐

Any other reason ..............................................................................................................................

..............................................................................................................................................

7. In which of the classes do you take part more?
School science classes☐ or HBCSE science classes ☐ Why?

..............................................................................................................................................

..............................................................................................................................................

1. Compare your regular science classes with HBCSE science classes.
In what ways are they the same? In what ways are they different?

2. Suppose we invite you for another set of HBCSE classes.

a) What things would you like us to change?

.....................................................................................................................

..................................................................

b) What things would you like us to add?

.....................................................................................................................

..................................................................

c) What would you like us to do in the way we have been doing so far (not change)?

............................................................................................

..........................................................................................

d) We know you enjoyed the activities and experiments in our classes. What else did you like? (Think about how the teachers taught, activities, working in groups, rules of the class etc.)

.....................................................................................................................

..................................................................

e) What did you not like? (Think about how the teachers taught, about group activities, rules of the class etc.)

.....................................................................................................................

..................................................................

f) After you started attending our classes, did you find any change in yourself? (For example, did you start liking studies more in your school? Did you start liking any subject more? Any other?)

……………………………………………………………………………………………………………

……………………………………………………………………………………………………………

……………………………………………………………………………………………………………

…………………

g) After attending HBCSE classes, was there a change in how you behaved in the science classes in your school? In other classes? Outside the class, such as home, in tuitions, with friends...? If yes, try to recall when you started to notice these changes.

……………………………………………………………………………………………………………

…………………………………………………………………

…………………………………………………………………………………………

3. a) What changes would you like to happen in your **school** science classes ?

……………………………………………………………………………………………

…………………………………………………………………………………………

b) What things would you like to be added to your school science classes?

……………………………………………………………………………………………

…………………………………………………………………………………………

c) What would you like be same in your school science classes (not change)?

……………………………………………………………………………………………

…………………………………………………………………………………………

4. Did you discuss with your parents or friends what happened in HBCSE science classes?

Many times ☐ Sometimes ☐ Rarely ☐ Never ☐

5. a) Is this less/ more/ same compared to your regular science classes at school?
b) If it more/ less - **Why?**

.......................................................................................................................................

.......................................................................................................................................

6. a) In **school** science classes if there is something you don't understand, what do you do?

.......................................................................................................................................

.......................................................................................................................................

b) In **HBCSE** science classes if there is something you don't understand, what do you do?

.......................................................................................................................................

.....................................................................................................................................

6. What do you tell about the **HBCSE** science classes to your friends/ parents?

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.......................................................................................................................................

7. What do you tell about/ talk about your **school** science classes to your friends/ parents?

.......................................................................................................................................

.......................................................................................................................................

8. What do you like about **HBCSE** science classes?

.......................................................................................................................................

.......................................................................................................................................

9. I want to learn science because - (Put a tick mark before your choice of answer)

- I want to score good marks in science ☐
- My parents want me to do well in science ☐
- I want a career in science (I want to become scientist/ engineer/ doctor) ☐
- My teachers and others tell me science is an important subject ☐
- Science is interesting ☐
- It helps me understand many things in daily life ☐
- It makes me think about many things in daily life ☐

# I

## Questionnaire administered to students one month after the summer camp (Phase II)

Name of the Student: ........................................................................... Date: ....................

1. Did any question(s) come to your mind since the time we last met/ after the camp? Write them here.

2. Please share if you have made any interesting/ puzzling observation recently.

3. Tell us about your participation in school science classes this year -

   a) Do you answer teacher's questions? Many times ☐ Sometimes ☐ Rarely ☐ Never ☐

   b) Do you ask questions? Many times ☐ Sometimes ☐ Rarely ☐ Never ☐

   c) Do you discuss about the topic being taught with your friends (during class/ out of class) Many times ☐ Sometimes ☐ Rarely ☐ Never ☐

   d) Do you add to what the teacher/ other students say (I agree, I don't think so...) Many times ☐ Sometimes ☐ Rarely ☐ Never ☐

4. a) Have there been any changes recently in how you learned/ talked /behaved/ felt about yourself etc.? Yes ☐ No ☐

   b) If yes, where did you notice this change? (Put a tick mark against all the places you noticed the change) :

5. In the science classes in your school □ In other classes □ Outside the class - such as at home □ in tuition classes □ with friends □

   Any other? ..................................................

   c) What was the change? Explain.

   ..........................................................................................................................

   ..........................................................................................................................

   ..........................................................................................................................

   d) When did this change come about?

   ..........................................................................................................................

   ..........................................................................................................................

   What, do you think, brought about this change? Please explain your answer

   ..........................................................................................................................

   ..........................................................................................................................

6. Did others around you (your parents, other family members, your teachers, friends...) notice anything different about the way you learned/ talked/ behaved? What?

   ..........................................................................................................................

   ..........................................................................................................................

7. Is there any subject that you did not like much before but *started liking* after coming to HBCSE classes? Why? You can choose from these subjects - Maths, all of science, chemistry, biology, physics, language, history or any other (specify which)

   ..........................................................................................................................

   ..........................................................................................................................

8. Is there any subject you liked before but *started to dislike* after coming to HBCSE classes? Why? You can choose from these subjects - Maths, all of science, chemistry, biology, physics, language, history or any other (specify which)

..................................................................................................................................

..................................................................................................................................

9. Suppose someone who has never got a chance to go to school asks you - What is science? What would you tell them?

   ..................................................................................................................................

   ..................................................................................................................................

   ..................................................................................................................................

   ..................................................................................................................................

   Before attending HBCSE classes, would your answer have been different? Write that answer.

   ..................................................................................................................................

   ..................................................................................................................................

   ..................................................................................................................................

   ..................................................................................................................................

10. If there is no pressure what so ever on you – you have complete freedom to decide, what would you like to become when you grow up? Why?

    ..................................................................................................................................

    ..................................................................................................................................

# J

## Interviews with students conducted one month after the summer camp

Semi-structured interviews, on similar lines as the written questionnaire, were conducted with students to probe the changes they had reported in the questionnaires. The duration of an interview ranged from 12-23 minutes.

**Sampling:** 15 students from inquiry and 14 from comparison group were interviewed (details in Table 1 and 2). These students were selected from among those who came regularly in either or both phases of the study. Random stratified sampling was used considering academic achievement scores at school for the academic year 2009-10 so that we could talk to students from across academic grades about their experience with the teaching in the intervention.

**Table 1.** Details of students interviewed from Inquiry group

| No. | Students' name | Gender | Overall total scores | Interval | Science scores | Phase attended | Number of hours of program attended | Category/ Code for change reported during interviews |
|---|---|---|---|---|---|---|---|---|
| 1 | Umesh | M | 324 | 300-350 | 33 | I | 34 | Attention |
| 2 | Soham* | M | 342 | 300-350 | 36 | I | 45 | Attention, Answering, Questioning |
| 3 | Harshal | M | 330 | 350-400 | 46 | II | 30 | Interest, Questioning |
| 4 | Gyan | M | 401 | 401-450 | 49 | Both | 84 | Questioning, Answering, Self regulation |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5 | Akshara | F | 461 | 450-500 | 61 | Both | 57 | Answering, Self concept |
| 6 | Srishti | F | 476 | 451-500 | 47 | Both | 60 | Interest, Finding science easier |
| 7 | Himanshu | M | 478 | 450-500 | 69 | Both | 64 | Interest, Finding science easier |
| 8 | Arti | F | 517 | 501-550 | 76 | II | | Interest |
| 9 | Jaya | F | 530 | 501-550 | 73 | Both | 53 | Curiosity, Discussion |
| 10 | Mayur | M | 542 | 501-550 | 68 | Both | 73 | Interest, Trying experiments at home, Answering, Questioning |
| 11 | Akhil | M | 560 | 551-600 | 85 | II | ** | Interest, Answering |
| 12 | Erwin | M | 552 | 551-600 | 83 | II | | Questioning, Know more |
| 13 | Nandan | M | 620 | 601-650 | 85 | I | 40 | Confidence, Attention |
| 14 | Suhail | M | 662 | 651-700 | 88 | Both | 71 | Self-reflection, Questioning, Discussion |
| 15 | Kushal | M | 671 | 651-700 | 94 | Both | 88 | Discussion, Questioning, answering, Way of learning, Interest |
| 16 | Abhijeet | M | 673 | 651-700 | 91 | Both | 80 | Interest, Discussion |

Pseudonyms have been used instead of students’ names.

*Soham was purposively selected for interviewing, as a special case, seeing significant changes in him during classroom observations in school after the intervention (in June-July 2010)

**Table 2.** Details of students interviewed from Comparison group

| No. | Students' name | Gender | Overall total scores | Interval | Science scores | Phase attended | Number of hours of intervention attended | Category of outcome reported |
|---|---|---|---|---|---|---|---|---|
| 1 | Samar | M | 371 | 351-400 | 50 | II | 36 | Answering, Learning science easier |
| 2 | Poorna | F | 431 | 401-450 | 46 | Both | 76 | No change due to the intervention |
| 3 | Anu | F | 433 | 401-450 | 56 | I | 42 | Knowledge, Discussion, Questioning |
| 4 | Ashwini | F | 447 | 401-450 | 52 | Both | 67 | Learning science easier |
| 5 | Arpita | F | 486 | 451-500 | 54 | Both | 49 | Interest, Questioning, Discussion |
| 6 | Antara | F | 509 | 501-550 | 73 | I | 24 | Knowledge, Marks |
| 7 | Mugdha | F | 509 | 501-550 | 79 | II | 36 | Tries experiments at home (Interest), Answering |
| 8 | Ayush | M | 572 | 550-600 | 87 | Both | 60 | Knowledge |
| 9 | Tathagata | M | 581 | 551-600 | 83 | II | 38 | Knowledge, Answering |
| 10 | Preeti | F | 585 | 550-600 | 78 | Both | 65 | Questioning, Confidence |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 11 | Indira | F | 595 | 551-600 | 93 | II | 42 | Find science easier, Confident, Discussion, Interest |
| 12 | Vaishali | F | 602 | 601-650 | 72 | Both | 44 | Interest, Answering |
| 13 | Ajitha | F | 654 | 651-700 | 90 | Both | 76 | Knowledge, answering |
| 14 | Komal | F | 670 | 651-700 | 90 | Both | 59 | Interest, Answering, Questioning |

Pseudonyms have been used instead of students' names

**Set of questions to guide the interview**

1. After the camp did you continue thinking about any topic taught in class, recalled what happened in class...?
2. Did you find any change in yourself recently (in the last one year/ in the last 1-2 months) (at home, in studies, in science classes at school, other classes, tuitions, with friends etc.)?

   (We mention HBCSE after the student does. If the student does not then we can probe -) After you started attending HBCSE science classes did you find any change in yourself?
3. Did attending HBCSE classes affect your participation in the classes in your school (science classes, other classes)? How? (Has it increased or decreased or remained the same? Do you answer more? Do you ask questions more than before?)
4. Did others around you (your parents, other family members, your teachers, friends...) also notice anything different about the way you learned/ talked/

behaved? What?

5. After attending HBCSE classes, is there any difference in how you learn science now?
6. Is there any subject that you did not like much before but **started liking** after coming to HBCSE classes? Why? You can choose from these subjects - Maths, all of science, biology, physics, chemistry, language or any other (specify which)
7. Is there a subject you liked before but **started to dislike** after coming here? Why? You can choose from these subjects - Maths, all of science, biology, physics, chemistry, language, history or any other (specify which)
8. (For students of earlier group only) Did your performance in school tests change after attending HBCSE classes? How much did you get recently? How much was it before?
9. Did you see any change in any of your friends/ classmates after he/ she attended HBCSE science classes - in the way they studied/ talked/ behaved...? since when?
10. Suppose someone who has never got a chance to go to school asks you - what is science? What would you tell them? What would your answer be before attending HBCSE classes?
11. If there is no pressure whatsoever on you, what would you like to become when you grow up? (If they say they want a career in science - What do you see yourself doing as a scientist?) (If they have chosen a career other than science and if they said they like science then - Why are you not interested in pursuing a career in science?

# K

## Questions for interviews with teachers (at the end of the program)

1. Usually, how many students actively participate in your HBCSE class discussions? A few/ some/ many/ most/ all

2. In what ways do students vocally participate in your classroom?

answer - individually/ in chorus
ask questions
say they agree/ disgree with teacher/ other students
ask for clarification/ say they did not understand something
have a say in what happens in the class (topic/ activities...)

3. Do you try to encourage student participation/ make students speak out? How? What strategies do you use? Why, do you think, students should speak out during the class/ why is it necessary for students to talk in class discussions?

5. Why do you ask questions in class? What purpose do your questions serve in class?

6. Do students generally answer individually or in chorus in your classes? Which students do you call on for answering? What decides whom you call on to answer?

7. What purposes do activities/ experiments serve in your teaching?/ What is the

rationale when you include activities in your lesson plan?

8. If somebody who has never got a chance to go to school asks you what is science, what would you tell them? (You can think about it and write it down if you want to.)

9. Why, do you think, it is required for students to learn science? Why should all students learn science  at least till the school level? (You can think about it and write it down if you want to.)

What should students be able **to do** after learning science throughout the school years?)

10. Do you think, teaching science is different from teaching other subjects? If yes, then in what ways?

11. In what ways do you think science is best taught?

12. Tell us about your experience of teaching in these HBCSE classes.

For teachers of comparison batch: Was it any different from the other classes you taught at school? In what ways?

What did you like about these classes? What did you not like?

What were the things that you found easier than in formal settings? What were the difficulties? (In that case) how did you deal with them?

What do you think were your strengths/ weaknesses in teaching in these classes? What was the most interesting part for you? The most satisfying part?

13. What would you say about your batch of students?

14. Did you notice any changes in the class as a whole and/ or in particular students as the classes/ teaching progressed? Please give you impressions of individual students on their self-confidence levels, participation levels (in writing).

15. When you think of students, which analogies do you think of? For example, some people think that “young students are like empty slates”.

16. I came across these analogies for young students - empty slates, empty bottles (to be filled), clay (can be moulded/ easily gets an impression), sponge (absorbs everything easily), a seed or a sapling (has the potential to grow, needs the right conditions; could grow on its own just needs nurturing when young), like a whale (in a sea of knowledge, filtering and digesting bits of information of use to them, at incredible rates)

Which of these analogies do you think are most appropriate?

# L

## Patterns in the collated data from Tables 5.25 and 5.26

Data on student outcomes collated from multiple sources are presented in Tables 5.25 and 5.26. Analysing the data in these tables according to different factors could show interesting patterns within and across the two groups. The data is amenable to sorting according to many parameters like students' socio-economic backgrounds or academic profiles. However, for the purpose of limiting the scope of the dissertation work, we restricted this analysis here to two student parameters, namely, the duration of attending the program and gender.

The analysis indicated that students who attended the inquiry classes in both phases (that is, for a longer duration) indicated more outcomes than those who attended only one phase (Table L1). There is only one empty row in the table for the inquiry group (Table L1); this student had attended a few classes, only in Phase I (26 out of 96 hours of interaction). This correlation was not seen in the comparison group where students mostly reported surface-level engagement and confidence, irrespective of how long they attended the program (Table L2). Comparison of the outcomes for continuing students across the groups makes the difference between the two groups even starker, especially in terms of conceptions of science as a process and collaborative classroom culture, instances of which were markedly inconspicuous in the comparison group. This indicates that the more the students are exposed to traditional, expository teaching, the likelier it is that their idea of science will become rigid as merely a subject to be learned individually.

Further, when the data was grouped according to gender, we found that there were no overall differences within the inquiry group. However, girls in the comparison group seemed to do slightly better than the boys. Across group comparison shows that outcomes for boys in the inquiry group were stronger in all aspects than boys in the comparison group. Girls in the inquiry group also indicated more changes in all aspects except those reflecting confidence in learning science. This finding is similar to the results on vocal participation as discussed in section 5.7.2.

**Table L1:** Difference in outcomes for continuing (C) and new (N) students: Inquiry group

| No. | N/C | Gender | Student | Reports indicating engagement in learning science | | | | | | | | | Reports indicating confidence in learning science | | | | | | Reports indicating conceptions of science as processes | | | | | | Reports indicating a classroom culture of collaboration | | | | | | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | B1 | B2 | B3 | B4 | B5 | B6 | C1 | C2 | C3 | C4 | C5 | C6 | D1 | D2 | D3 | D4 | D5 | D6 | |
| 1 | C | M | Suhail | | | | | | | | | | | | | | | | | | | | | | | | | | | | 17 |
| 2 | C | M | Kushal | | | | | | | | | | | | | | | | | | | | | | | | | | | | 15 |
| 3 | C | M | Gyan | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 |
| 4 | C | F | Jaya | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 |
| 5 | C | M | Mayur | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 |
| 6 | C | M | Nandan | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 |
| 7 | C | M | Shubh | | | | | | | | | | | | | | | | | | | | | | | | | | | | 9 |
| 8 | C | F | Srishti | | | | | | | | | | | | | | | | | | | | | | | | | | | | 9 |
| 9 | C | F | Akshara | | | | | | | | | | | | | | | | | | | | | | | | | | | | 8 |
| 10 | C | M | Abhijeet | | | | | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| 11 | C | M | Nitin | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 12 | C | M | Himanshu | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 13 | C | M | Ronit | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| 14 | C | F | Vedika | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 15 | C | F | Tarika | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Average for continuing students | 8.333 |
| 16 | N | F | Asha | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 |
| 17 | N | F | Sherley | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 |
| 18 | N | M | Harshal | | | | | | | | | | | | | | | | | | | | | | | | | | | | 9 |
| 19 | N | M | Nitesh | | | | | | | | | | | | | | | | | | | | | | | | | | | | 8 |
| 20 | N | M | Akhil | | | | | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| 21 | N | M | Anil | | | | | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| 22 | N | F | Kulpreet | | | | | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| 23 | N | F | Sarah | | | | | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| 24 | N | M | Saurav | | | | | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| 25 | N | M | Harsh | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 26 | N | F | Arti | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 27 | N | M | Deeksha | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 28 | N | M | Erwin | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 29 | N | M | Imran | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 30 | N | F | Swara | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 31 | N | M | Umesh | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 32 | N | F | Bhavna | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| 33 | N | F | Jojo | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| 34 | N | F | Pranav | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| 35 | N | M | Aman | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 36 | N | M | Shaan | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 37 | N | M | Ambrish | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 38 | N | M | Gaurang | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 39 | N | M | Sanket | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 40 | N | F | Veena | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Average for new students | 5.24 |
| | | | Total 40 | | | | | 38 | | | | | | | 19 | | | | | | 30 | | | | | | 18 | | | | 6.4 |

Students from the inquiry group who attended both phases of the study reported significantly higher instances of changes across the measures, t(38)=2.59, p=.01.

**Table L2:** Difference in outcomes for continuing (C) and new (N) students: Comparison group

| No. | N/C | Gender | Student | Reports indicating engagement in learning science | | | | | | | | | Reports indicating confidence in learning science | | | | | | Reports indicating conceptions of science as processes | | | | | | Reports indicating a classroom culture of collaboration | | | | | | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | B1 | B2 | B3 | B4 | B5 | B6 | C1 | C2 | C3 | C4 | C5 | C6 | D1 | D2 | D3 | D4 | D5 | D6 | |
| 1 | C | F | **Amrita** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 2 | C | F | **Komal** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 3 | C | F | **Arpita** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 4 | C | F | **Preeti** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 5 | C | F | **Ajitha** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 6 | C | F | **Anu** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 7 | C | F | **Ashwini** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 8 | C | F | **Vaishali** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 9 | C | F | **Poorna** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 10 | C | F | **Antara** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 11 | C | M | **Ayush** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 12 | C | M | **Pralhad** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 13 | C | M | **Arsh** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 14 | C | M | **Vardhaman** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 15 | C | M | **Dhamma** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 16 | C | M | **Devesh** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Average for continuing students | 3.06 |
| 17 | N | F | Mugdha | | | | | | | | | | | | | | | | | | | | | | | | | | | | 9 |
| 18 | N | F | Indira | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 19 | N | F | Sejal | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 20 | N | F | Anuja | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| 21 | N | F | Archana | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 22 | N | F | Naina | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 23 | N | F | Pragya | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 24 | N | F | Radha | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 25 | N | M | Hardik | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 26 | N | M | Tathagata | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 27 | N | M | Arpit | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 28 | N | M | Ansh | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| 29 | N | M | Nitin | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| 30 | N | M | Ajinkya | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 31 | N | M | Kinjal | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 32 | N | M | Pravin | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 33 | N | M | Archit | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 34 | N | M | Prashant | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 35 | N | M | Vinay | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 36 | N | M | Abhay | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 37 | N | M | Anup | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 38 | N | M | Ashutosh | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 39 | N | M | Ethan | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 40 | N | M | Prabhat | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 41 | N | M | Ravi | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 42 | N | M | Samar | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Average for continuing students | 2.73 |
| | | | Total 41 | 30 | | | | | | | | | 14 | | | | | | 18 | | | | | | 3 | | | | | | 2.90 |

The difference in the average number of aspects reported by continuing and new students of the comparison group is not significant at p<.05

**Table L3:** Difference in outcomes for girls and boys: Inquiry group

| No. | N/C | Gender | Student | Reports indicating engagement in learning science | | | | | | | | | Reports indicating confidence in learning science | | | | | | Reports indicating conceptions of science as processes | | | | | | Reports indicating a classroom culture of collaboration | | | | | | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | B1 | B2 | B3 | B4 | B5 | B6 | C1 | C2 | C3 | C4 | C5 | C6 | D1 | D2 | D3 | D4 | D5 | D6 | |
| **1** | **N** | **F** | **Asha** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 |
| **2** | **C** | **F** | **Jaya** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 |
| **3** | **N** | **F** | **Sherley** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 |
| **4** | **C** | **F** | **Srishti** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 9 |
| **5** | **C** | **F** | **Akshara** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 8 |
| **6** | **N** | **F** | **Kulpreet** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| **7** | **N** | **F** | **Sarah** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| **8** | **N** | **F** | **Arti** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| **9** | **N** | **F** | **Swara** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| **10** | **N** | **F** | **Bhavna** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| **11** | **N** | **F** | **Jojo** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| **12** | **N** | **F** | **Pranav** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| **13** | **C** | **F** | **Vedika** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| **14** | **N** | **F** | **Veena** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| **15** | **C** | **F** | **Tarika** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Average for girls** | **5.867** |
| 16 | C | M | Suhail | | | | | | | | | | | | | | | | | | | | | | | | | | | | **17** |
| 17 | C | M | Kushal | | | | | | | | | | | | | | | | | | | | | | | | | | | | 15 |
| 18 | C | M | Gyan | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 |
| 19 | C | M | Mayur | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 |
| 20 | C | M | Nandan | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 |
| 21 | N | M | Harshal | | | | | | | | | | | | | | | | | | | | | | | | | | | | 9 |
| 22 | C | M | Shubh | | | | | | | | | | | | | | | | | | | | | | | | | | | | 9 |
| 23 | N | M | Nitesh | | | | | | | | | | | | | | | | | | | | | | | | | | | | 8 |
| 24 | C | M | Abhijeet | | | | | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| 25 | N | M | Akhil | | | | | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| 26 | N | M | Anil | | | | | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| 27 | N | M | Saurav | | | | | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| 28 | N | M | Harsh | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 29 | C | M | Nitin | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 30 | N | M | Deeksha | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 31 | N | M | Erwin | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 32 | C | M | Himanshu | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 33 | N | M | Imran | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 34 | N | M | Umesh | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 35 | C | M | Ronit | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| 36 | N | M | Aman | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 37 | N | M | Shaan | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 38 | N | M | Ambrish | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 39 | N | M | Gaurang | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 40 | N | M | Sanket | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **Average for boys** | **6.72** |
| | | | Total 40 | 38 | | | | | | | | | 19 | | | | | | 30 | | | | | | 18 | | | | | | **6.4** |

The difference in the number of aspects in which girls and boys indicated a change was not significant at p<.0.5

**Table L4:** Difference in outcomes for girls and boys: Comparison group

| No. | N/C | Gender | Student | Reports indicating engagement in learning science | | | | | | | | | Reports indicating confidence in learning science | | | | | | Reports indicating conceptions of science as processes | | | | | | Reports indicating a classroom culture of collaboration | | | | | | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | B1 | B2 | B3 | B4 | B5 | B6 | C1 | C2 | C3 | C4 | C5 | C6 | D1 | D2 | D3 | D4 | D5 | D6 | |
| 1 | C | F | Ajitha | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 2 | C | F | Amrita | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 3 | C | F | Antara | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 4 | C | F | Anu | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 5 | N | F | Anuja | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| 6 | N | F | Archana | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 7 | C | F | Arpita | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 8 | C | F | Ashwini | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 9 | N | F | Indira | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 10 | C | F | Komal | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 11 | N | F | Mugdha | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 9 |
| 12 | N | F | Naina | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 13 | C | F | Poorna | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 14 | N | F | Pragya | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 15 | C | F | Preeti | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 16 | N | F | Radha | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 17 | N | F | Sejal | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 18 | C | F | Vaishali | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Average for girls | 3.61 |
| 19 | N | M | Abhay | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 20 | N | M | Ajinkya | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 21 | N | M | Ansh | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| 22 | N | M | Anup | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 23 | N | M | Archit | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 24 | N | M | Arpit | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 25 | C | M | Arsh | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 26 | N | M | Ashutosh | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 27 | C | M | Ayush | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 28 | C | M | Dhamma | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 29 | N | M | Ethan | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 30 | N | M | Hardik | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 31 | N | M | Kinjal | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 32 | N | M | Nitin | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| 33 | N | M | Prabhat | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 34 | C | M | Pralhad | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 35 | N | M | Prashant | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 36 | N | M | Pravin | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 37 | N | M | Ravi | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 38 | N | M | Samar | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 39 | N | M | Tathagata | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 40 | C | M | Vardhaman | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 41 | N | M | Vinay | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 42 | C | M | Devesh | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Average for boys | 2.29 |
| | | | Total 41 | 30 | | | | | | | | | 14 | | | | | | 18 | | | | | | 3 | | | | | | 2.90 |

Girls in the comparison group show slightly more changes than boys; t(40)=2.09, p=.04

# M

## Data corroborated for various outcomes through multiple sources

The tables in this appendix correspond to Tables 5.25 and 5.26, in the sense that the cells in these tables contain details of the data for each of the color coded cell in Tables 5.25 and 5.26. Thus, qualitative data for each cell in those tables can be located here using the column number and student number or pseudonym.

**Table M1.** Reports on students' engagement with science learning: Inquiry group

| | | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **No.** | **Student** | **Change reported in response to questionnaire** | **Change reported in Interview** | **Aspect of engagement reported by parents** | **Reports from friends** | **Reports from teachers** | **Reports from observers** | **Wonderment question (W) or observation (O) by the student** | **Wonderment question (W) or observation (O) by parent** | **Students' reports from Winter Camp** |
| 1 | Suhail | Increase in Questioning | I became little observant, after class I recall what we did, if I have any questions...more after summer camp. I shared puzzling facts, interesting information with friends; It (science class) is funfilled, | | We try out experiments together, talk about science classes at school and at HBCSE | Quality of questions fantastic, thinks on his feet, visualises brilliantly | Asked brilliant questions, gave good answers | W | W | I was a bit observant about many things |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Kushal | | Zyada questions aate hain dimaag mein... Participation in science class a little more... kuch sikhaya toh discuss karte hain uske baad... plants ke baare mein seekhne mazaa aata hai | His awareness regarding science is increasing & wants know more deep about unknown scientific things | Participates more in class, discussion with friends (Gyat, Jayanti) | high level of participation, told me on occasion what specifically he did not understnd | Sincerely attempted to make sense of ideas, asked doubts to clarify if he did not understand something | | O | I started observing things more carefully |
| 3 | Asha | Yearning to learn more | | | Partipation more in science class | | | W, O | W | |
| 4 | Gyan | Increase in Questioning and Answering | Lots of questions come to my mind, also answer teacher's questions | | Discusses more (jayanti) | | | W, O | W | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | Jaya | | I like to search, find out more. You used to give questions to find out answer, I continue to do so. We (friends) interact more, talk about what we study, what teacher taught... pehle science boring I was not much interested... I like to know more about different parts of the body | her attitude has changed for observing & thinking | Talks more about science (Drishti) Answes more (Gyat) | | | | W, O | My interest in science increased |
| 6 | Mayur | Increase in interest | Started to take part in activities in the science class, answers and asks more, discussion and attention same as earlier... read sicence related books and try out experiments.. also like maths now | Along with his group of friends, keeps trying some experiments, to make things | | Asked very interesting questios, constantly working on some project or the other | Discussion in group with Sohel, tinkering with experiments at home, made interesting observations for ants HW | W | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 7 | Nandan | Increase in Questioning and Answering | Previously I was not confident about anything like I dont used to ask any question and wont answer what teacher used to ask.. but now I am much more confident... pay more attention in class | | | | | W, O | W, O | |
| 8 | Sherley | | | | | | Gathered around the teacher's desk in the break | W | W | |
| 9 | Harshal | Increase in interest, questioning and answering | Interest in science increased, ask questions | more attention towards science & other subjects | Asks more questions (Harshit) | | Participation and interest went up remarkably later on | | W | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | Shubh | Increase in Questioning and Answering | Question acche se answer karta hoon, marks in science have increased, pay more attention, I understand...study with interest | | Concentrates on learning in the class, volunteers to answer (Chandan), Answers in class, *pehle nahi karta tha...* (Gyat) | | | W, O | | |
| 11 | Srishti | Increase in interest | learn science with interest, find it easy (it is difficult but now it is easy) | Takes interest in science books and doing experiments herself | Answers more (Gyat) | | | | W | |
| 12 | Akshara | Increasse in Answering | *aata hai toh interest bhi badhta hai subject mein. Interest badhta hai toh theek se samajhmein bhi aata hai.* | | | Sustained engagement.. | Tried many activities at home, very engaged when in class, answered and asked questions many a times, took a stance when rest of the class was on the | | O | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | other side | | | |
| 13 | Nitesh | | | Yes, asks many questions | | later his engagement increased, participated | Participation and interst increased later | | W | |
| 14 | Abhijeet | Increase in interest | Increase in interest in science, Increased participation in science classes at school and in science projects, discussion with friends | | Answers more in class (Gyat) | | | | | I found scientific reasons behind our daily life |
| 15 | Akhil | Increase in interest | I found that I was more attentive in class, answering a bit more... | enjoys this practical science | | thought thru answers, tried expts, asked about it | Many a times, towards the end of camp, added to what others had to say, gave real good arguments | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 16 | Anil | Increase in interest | | yes, he is more interested in science subject | | | Later interest and participation both went up | | W | |
| 17 | Kulpreet | Increase in interest and Answering | I started enjoying school science classes, used to answer when teacher asked questions | | | | In the break, asked questions, tried out expereimtns | W, O | | |
| 18 | Sarah | | | she tries to find out more about things taught in class | | High level of intellectual engagemnt | | W | W | |
| 19 | Saurav | Increase in interest and questioning | | | | | Involved, especially during activities | | O | |
| 20 | Harsh | | In HBCSE classes, we enjoy it (science) | | | | | O | W, O | |
| 21 | Nitin | Increase in interest | | | | | | O | | I saw that I was thinking more about my doubts |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 22 | Arti | Increase in interest | Interest in science increased | more interested in doing scientific experiments | | | | | | |
| 23 | Deeksha | | | | | Quality of questions went up | lots of questions, involved, seeking clarification or based on observations | | O | |
| 24 | Erwin | Increase in Questioning | | | | | Quite involved in doing experiments/ activities with his group | | | |
| 25 | Himanshu | | difficult but interesting, ease in understanding... earlier was hard to understand | | | | | | O | |
| 26 | Imran | started thinking deeply in some observations and things, increase in answering | | | | | | | O | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 27 | Swara | Increase in interest | I have more fun here. | she reads science subject with more interest | | | Very detailed diary entries | | W | |
| 28 | Umesh | | | more attention to science than any other subject | | | | | | |
| 29 | Bhavna | Increasse in Answering | | Interest in science has increased | | | When she attempted to talk in front of the class, gave very good answers, also in writing in worksheets and diaries | | | |
| 30 | Jojo | | | | | lots of observations, questions, discussed during break | Asked questions during break, pursued a question and wsa desperate to know the answer | | | |
| 31 | Pranav | Increase in interest and answering | We have more fun here. | She has develop more interest in science now | | | | W | W, O | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 32 | Ronit | | | | | | | O | | |
| 33 | Aman | | | | | Engagement levels increased later | | | | |
| 34 | Shaan | Increase in interest | | | | Persisted in making the ‘cartesian diver’ work, interest/ attention increased later in camp | | | | |
| 35 | Ambrish | | | | | | | O | | |
| 36 | Gaurang | Increasse in Answering | | | | | | | | |
| 37 | Sanket | | | | | Did participate and enjoy the class | | | | |
| 38 | Vedika | | | | | | | | | |
| 39 | Veena | started interacting more in school science classes and with friends | | | | | | | | |
| 40 | Tarika | | | | | | | | | |

**Table M2.** Reports on students' engagement with science learning: Comparison group

| | | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **No.** | **Student** | **Change reported in response to questionnaire** | **Change reported in Interview** | **Aspect of engagement reported by parents** | **Reports from friends** | **Wonderment question or observation by student** | **Wondermen t question or observation reported by parent** | **Reports from teachers** | **Reports from observers** | **Students' reports from Winter camp** |
| 1 | Abhay | | | | | | | | | |
| 2 | Ajinkya | | | | | | | | | |
| 3 | Ajitha | | | | | | | tried to connect the facts to other events | Always interested and ready with an answer | With friends, I started discussing much more than compared to before |
| 4 | Amrita | | | | | | | | | |
| 5 | Ansh | | | | | | | Asks questions curious to know facts | Asked good questions | |
| 6 | Antara | | | | | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 7 | Anu | | ghar mein zyada baatein karti hoon science ke baare mein, participation in science class at school more – ask more questions | yes, child changes while discussions, demonstration & clarification of doubts about the science | | | | | | |
| 8 | Anuja | | | | | | W | Was trying to collect informati on after class also | took part in answering questions | |
| 9 | Anup | | | | | | | | | |
| 10 | Archana | | | | | | | | | |
| 11 | Archit | | | | | | | | | With friends I started discussing much more than compared to before |
| 12 | Arpit | Talking/ discussing more, Read more science related books, More | | More interested in science topics except Biology | | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | curious | | | | | | | | |
| 13 | Arpita | Increase in interest | ...pehle hard and boring lagta tha, abi theek hai, ask question in science class, pehle kuch poochti nai thi, parents ke saath discuss karti hoon, kuch samajhta nahi hai toh poochti hoon | yes, now she takes interest, discusses queries/problems or difficulties in class | | | | | | |
| 14 | Arsh | Increase in interest and answering | | | | | | | | |
| 15 | Ashutosh | Increase in interest and answering | | | | | W | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 16 | Ashwini | | | | has become more attentive in the classes... only in science classes... earlier she used to be quiet in the class and sit in the corner, now she answers (Vaishakhi) | | | | | |
| 17 | Ayush | | | Interested in science | | | | | | |
| 18 | Devesh | | | | | | | | | |
| 19 | Dhamma | | | | | | | | | |
| 20 | Ethan | | | | | | | | | |
| 21 | Indira | | | She began to like science more than earlier | | | W, O | Wants to clear all her confusio ns | Always interested, tried to give answeer | |
| 22 | Kartik | Increase in answering | | He was very enthusiastic & eager to learn more | | W | W, O | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 23 | Kinjal | | | | | W, O | | | Always active; volunteered many a times to answer | |
| 24 | Komal | | | | | | O | | | Now I mostly talk about stange things happening in nature such as how the first human being came to the earth and how the process continued |
| 25 | Mugdha | | Tried experiments at home, told teachers and friends about this in class; participation increased when topic same | | we discuss what we learned and sometimes I ask her to explain (Mandira) | | O | | Actively participates | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | Naina | | | | | | | | | | I like studying science and take interest in environment. I am also learning about various rare animals |
| 27 | Nitin | | | there is a definite rise in levels of enthusiasm exhibited | | W | | | | | |
| 28 | Poorna | | | | | | | | | | |
| 29 | Prabhat | | | | | | | | | | |
| 30 | Pragya | | | | | | | | | | |
| 31 | Pralhad | Increase in answering | | | | W, O | | | | | |
| 32 | Prashant | | | he started inquiring about Marine life | | | | | | | |
| 33 | Pravin | | Pays more attention when teacher shows or does an experiment | | | | O | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 34 | Preeti | | | yes, she is having lot of interest to learn about science | | | | | | | More anxious to learn, more questions come to my mind and |
| 35 | Radha | | | | | | | | | | |
| 36 | Ravi | | | yes, he attempted a few experiments in science at home,he demonstrate some physics concepts by things which were available at home | | | | | | Attentive, participatio n was good | |
| 37 | Samar | | | | | | | | | | |
| 38 | Sejal | | | yes, she take more interest in science subject | | | W | | | | |
| 39 | Tathagata | | little increase in answering | Science subject is more attractive | | | O | After class, he was asking questions related to the topic | Good participate d in class | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 40 | Vaishali | Increase in interest and answering | my concentration power is more now... only in science... And I find it now very interesting. | | | | | | | |
| 41 | Vardhaman | Increase in interest | | | | | | | | |
| 42 | Vinay | Increase in answering | | | | | | | usually interested, answered well | |

**Table M3.** Reports indicating confidence in learning science: Inquiry group

| | | B1 | B2 | B3 | B4 | B5 | B6 |
|---|---|---|---|---|---|---|---|
| No. | **Student** | **Change reported in response to questionnaire** | **Change reported in Interview** | **Reports from parents** | **Reports from friends** | **Reports from diaries** | **Reports from Winter camp** |
| 1 | Suhail | | | | | I also gave a good answers | |
| 2 | Kushal | | *pehle questions ka answer book mein doondhta tha, ab concept samajhta hoon aur khud ke mann se answer likhta hoon...* | | | | |
| 3 | Asha | More courage to answer/ ask a question | | | | Teacher asked us a difficult question...by this method it was easier to answeer | |
| 4 | Nandan | Earlier not confident, now I answer | Previously I was not confident about anything like I dont used to ask any question and wont answer what teacher used to ask.. but now I am much more confident... pay more attention in class | He has become more confident that earlier | | | I became more confident in school in asking questions |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5 | Gyan | learning science... easy lagta hai, connect kar sakte hain daily life se | | | | | |
| 6 | Jaya | | | | | | |
| 7 | Mayur | | My friends and relatives say that I will become a scientist | | | | |
| 8 | Sherley | | | | | | |
| 9 | Srishti | | learn science with interest, find it easy (it is difficult but now it is easy) | | | | |
| 10 | Harshal | | | | | | |
| 11 | Shubh | | Question acche se answer karta hoon, marks in science have increased, pay more attention, I understand... study with interest | | Answers in class, pehle nai karta tha (Earlier he would not answer in class) | | |
| 12 | Akshara | | I answer even if I am not sure, I will get feedback | | | | |
| 13 | Nitesh | Easier to understand what is taught in science classes | | | | | |
| 14 | Abhijeet | | | | | | |
| 15 | Akhil | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 16 | Anil | | | Her confidence has increased | | | |
| 17 | Saurav | Science easier to understand | | | | | |
| 18 | Sarah | | | | | | |
| 19 | Kulpreet | | | | | | |
| 20 | Harsh | | | | | | |
| 21 | Nitin | | | | | | |
| 22 | Arti | | | | | | |
| 23 | Erwin | | | | | Almost all my answers were correct | |
| 24 | Imran | I gave answers very nicely | | | | | |
| 25 | Umesh | | | | | | |
| 26 | Deeksha | | | | | | |
| 27 | Himanshu | | difficult but interesting, ease in understanding... earlier was hard to understand | | | | I can understand school science studies well |
| 28 | Swara | | | | | | |
| 29 | Bhavna | More courage to answer/ ask a question; I was able to answer many questions in school classes | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 30 | Jojo | | | | | | |
| 31 | Pranav | | | | | | |
| 32 | Ronit | | | | | I wrote a good poem | |
| 33 | Aman | | | | | | |
| 34 | Shaan | | | | | | |
| 35 | Ambrish | | | | | | |
| 36 | Vedika | | | | | | I am becoming good in science |
| 37 | Gaurang | | | | | | |
| 38 | Sanket | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 39 | Veena | | | | | | |
| 40 | Tarika | | | | | | |

**Table M4.** Reports indicating confidence in learning science: Comparison group

| | | B1 | B2 | B3 | B4 | B5 | B6 |
|---|---|---|---|---|---|---|---|
| **No.** | **Student** | **Change reported in response to questionnaire** | **Change reported in Interview** | **Reports from parents** | **Reports from friends** | **Winter camp** | **Reports from diaries** |
| 1 | Mugdha | | | | She used to first (sic) tell me science is very difficult, now she tells me it is easy, we discuss what we learned and sometimes I ask her to explain (Mandira) | | |
| 2 | Amrita | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3 | Indira | | feeling confident to speak related to science | | | | |
| 4 | Kartik | | | | | | |
| 5 | Komal | | | | | I started understanding the things in science taught in school more clearly and nicely | |
| 6 | Tathagata | | | | | | |
| 7 | Arpit | | | | | | |
| 8 | Arpita | | ask question in science class, pehle kuch poochti nai thi, darr lagta tha teacher se | | | | I am understanding more about science subject |
| 9 | Preeti | Feel more confident | little bit of confidence increased | | | I ask answers to my teachers | |
| 10 | Sejal | | | | | | |
| 11 | Ansh | | | | | | Now I am able to understand some things by experiments |
| 12 | Anuja | | | | | | |
| 13 | Nitin | Confidence has increased | | | | | |
| 14 | Ajinkya | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 15 | Ajitha | | | | | | |
| 16 | Anu | | Improved in studies, got knowledge, change in the way of talking, ghar mein zyada baatein karti hoon science ke baare mein, participation in science class at school more – ask more questions | | | | |
| 17 | Ashwini | | When topic same it was easier | | | When in school teacher asked some questions, I was able to answer them | |
| 18 | Ayush | | | More confident and brave | | Earlier I thought I would not be able to learn many hitngs but now my interest has grown | |
| 19 | Kinjal | | | | | | |
| 20 | Pralhad | | | | | | |
| 21 | Pravin | | | | | I can easily by heart my questions and answers | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 22 | Vaishali | | Yes... my concentration power is more now... only in science... And I find it now very interesting. I have become more faster... faster matlab pehle answer sochna padta tha.. abhi itna sochna nahi padta. | she talks more confidentally about science | | | |
| 23 | Archit | | | | | | |
| 24 | Arsh | | | | | | |
| 25 | Poorna | | Friends scholar bulate hain [Friends call me a 'scholar'] because I answer questions | | | If sombody asked about the topic I have learnt at HBCSE, I can explain and answer their queries | |
| 26 | Prashant | | | | | | |
| 27 | Vardhaman | | | | | | |
| 28 | Vinay | | | | | | |
| 29 | Abhay | | | | | | |
| 30 | Antara | Was very weak in science, abhi acche marks aate hain, answer in class, know more | | | | | |
| 31 | Anup | | | | | | |

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|---|---|---|---|---|---|---|---|
| 32 | Archana | | | | | | |
| 33 | Ashutosh | | | | | | |
| 34 | Devesh | | | | | I can study science without help | |
| 35 | Dhamma | | | | | | |
| 36 | Naina | | | | | | |
| 37 | Pragya | | | | | | |
| 38 | Radha | | | | | | |
| 39 | Ethan | | | | | | |
| 40 | Prabhat | | | | | | |
| 41 | Ravi | | | | | | |
| 42 | Samar | | | | | | |

**Table M5.** Reports indicating conceptions of science as processes: Inquiry group

| | | C1 | C2 | C3 | C4 | C5 | C6 |
|---|---|---|---|---|---|---|---|
| **No.** | **Student** | **What is Science?: Science as processes, related to daily life** | **Reported change in questionnaire/ interview** | **Change reported by parents** | **Asking a wonderment question or making an observation** | **Wonderment question or observation reported by parent** | **Reports from Winter camp** |
| 1 | Suhail | how things work, how plants grow, to explain something | Questioning | Tries to find out more about things and tries making things like a motor or a compass | W | W | I was a it observant about many things. I always pointed out some strange things to my friends and relatives |
| 2 | Kushal | Discussion about day to day life, surroundings | Change in the way of learning | Curious to know more | | O | I started observing things more carefully |
| 3 | Asha | | Yearning to learn more | | W, O | W | |
| 4 | Nandan | | Questioning | | W, O | W, O | |
| 5 | Gyan | find out how things work, about things happening around us | Questioning | | W, O | W | |
| 6 | Jaya | proofs, reason, cause and effect, thinking | Curious | | | W, O | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 7 | Mayur | doing experiements | Trying out experiments at home, Questioning | Keeps experimenting with things like a pencil cell | W | W | I started doing many experiemnts |
| 8 | Sherley | an opportunity to ask why? | Trying out experiments | | W | | |
| 9 | Srishti | trying to solve questions, finding out through experiements | | | | W | |
| 10 | Harshal | study about things like our body – what is inside, how does it work, keep studying to clear doubts, try out things so they get to know more | Questioning | | | W | |
| 11 | Shubh | experiments to understand what we find interesting | Questioning | | W, O | | |
| 12 | Akshara | | | | | O | |
| 13 | Nitesh | | | Aska many questions | | O | |
| 14 | Abhijeet | experiments to understand, to know more about, like what is inside a plant | | | | | I found scientific reasons behind our daily life |
| 15 | Akhil | | | | | | |
| 16 | Anil | study of nature, inventions & discovery | | | | W | |
| 17 | Saurav | (explaining) everything with a proof | Questioning | | | O | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 18 | Sarah | | | Tries to find out more about things taught in class | W | W | |
| 19 | Kulpreet | why things happen? How it started? | | | W,O | | |
| 20 | Harsh | | | | W, O | W, O | |
| 21 | Nitin | | | | O | W | I saw that I was thinking more about my doubts |
| 22 | Arti | | | | | | |
| 23 | Erwin | | Questioning | | | | |
| 24 | Imran | | Started to think deeply about some observations | | | O | |
| 25 | Umesh | we can know many things about daily life | | | | | |
| 26 | Deeksha | a thing that happens in day to day life | | | w | W, O | |
| 27 | Himanshu | | | | | O | |
| 28 | Swara | | | | | W | |
| 29 | Bhavna | | | | | | |
| 30 | Jojo | Trying out experiments | | | | | |
| 31 | Pranav | | | | | | |
| 32 | Ronit | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 33 | Aman | | | | | | |
| 34 | Shaan | | | | | | |
| 35 | Ambrish | | | | O | | |
| 36 | Vedika | | | | | | |
| 37 | Gaurang | | | | | | |
| 38 | Sanket | ... which gives answers but only when you ask | Curious | | O | | |
| 39 | Veena | something that deals with everyday life | | | | | |
| 40 | Tarika | | | | | | |

**Table M6.** Reports indicating conceptions of science as processes: Comparison group

| | | C1 | C2 | C3 | C4 | C5 | C6 |
|---|---|---|---|---|---|---|---|
| **No.** | **Student** | **What is Science?: Science as processes, related to daiy life** | **Reported change in questionnaire** | **Change reported by parents** | **Asking a wonderment question or making an observation** | **Wonderment question or observation reported by parent** | **Reports from Winter camp** |
| 1 | Mugdha | | Questioning, Tries experiment at home | Asks questions | | O | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | Amrita | | | | | W | |
| 3 | Indira | | | | | W, O | |
| 4 | Kartik | | | | W | W, O | |
| 5 | Komal | | | | | O | Now I mostly talk about stange things happening in nature such as how the first human being came to the earth and how the process continued |
| 6 | Tathagata | | | | | O | |
| 7 | Arpit | Science is our day to day observation in our surrounding and finding reason for it | Curious | | | | |
| 8 | Arpita | | | | | | |
| 9 | Preeti | | Questioning | | | | more questions come to my mind |
| 10 | Sejal | | | | | W | |
| 11 | Ansh | group of activities, experiments | | | | | |
| 12 | Anuja | | | | | W | |
| 13 | Nitin | | | | W | | |
| 14 | Ajinkya | | | | | | |
| 15 | Ajitha | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 16 | Anu | | | | | | |
| 17 | Ashwini | | | | | | |
| 18 | Ayush | | | | | | |
| 19 | Kinjal | | | | W, O | | |
| 20 | Pralhad | | | | W, O | | |
| 21 | Pravin | | | | | O | |
| 22 | Vaishali | | | | | | |
| 23 | Archit | | | | | | |
| 24 | Arsh | | | | | | |
| 25 | Poorna | | | | | | |
| 26 | Prashant | | | Inquiring more about marine life | | | |
| 27 | Vardhaman | | | | | | |
| 28 | Vinay | | | | | | |
| 29 | Abhay | Observation of nature around us | | | | | |
| 30 | Antara | | | | | | |
| 31 | Anup | | | | | | |
| 32 | Archana | | | | | | |
| 33 | Ashutosh | | | | | | |
| 34 | Devesh | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 35 | Dhamma | | | | | | |
| 36 | Naina | | | | | | I now wonder and have questions about the atmosphere. |
| 37 | Pragya | | | | | | |
| 38 | Radha | | | | | | |
| 39 | Ethan | | | | | | |
| 40 | Prabhat | | | | | | |
| 41 | Ravi | | | Attempted a few experiments at home | | | |
| 42 | Samar | | | | | | |

**Table M7.** Reports indicating a classroom culture of collaboration: Inquiry group

| | | D1 | D2 | D3 | D4 | D5 | D6 |
|---|---|---|---|---|---|---|---|
| **No.** | **Student** | **Change reported in response to questionnaire** | **Change reported in Interview** | **Mentions in diaries** | **Reports from parents** | **Reports from friends** | **Reports from Observers** |
| 1 | Suhail | | | We got the answer as... we discussed about the experiments and our doubts; we asked questions to her; Merlin and I completed making our toy | | | |
| 2 | Kushal | | | We all shared our views; we all shared what we saw in the previous classes | | | |
| 3 | Asha | | | Some told... | | | |
| 4 | Gyan | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5 | Jaya | | We (friends) interact more, talk about what we study, what teacher taught... | Some said weight, size... we all went deep in this topic; This whole day went in asking questions & giving/ finding answers. I was bored and also happy listening to these questions and their answers | Discusses with father | Talks more about science (Drishti) Answes more (Gyat) | |
| 6 | Mayur | | | | | | |
| 7 | Nandan | | | | | | |
| 8 | Sherley | | | | | | |
| 9 | Harshal | | | | | | |
| 10 | Shubh | | I shared puzzling facts, interesting information with friends | Mnay had written about fish and human and not the differences between them; all gave good answers but some didn't manage to do it | | | |
| 11 | Srishti | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 12 | Akshara | | | She gave us a question which confused many children and asked us to find it out ourselves by tomorrow; children brought their cubes of different sizes and other children brought their other homework where they...; many children answered to that question; many gave different answers | | | added to what others had to say |
| 13 | Nitesh | | | | | | |
| 14 | Abhijeet | | discussion with friends | | | | |
| 15 | Akhil | Talk more about science | | Today teacher saw the cubes we had amade, she appreciated our cubes; ...in the end all could answer. | | | |
| 16 | Anil | Dscuss about science | | | | | |
| 17 | Kulpreet | | | | he tries to make something or the other with electric things at home and alongwith classmates | Discusses more (Sohel) | Discussion in group with Sohel, tinkering with experiments at home, made interesting observations for ants HW |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 18 | Sarah | | | | | | |
| 19 | Saurav | | | | | | |
| 20 | Harsh | | | | | Discusses more (Jayanti | |
| 21 | Nitin | | | | | | |
| 22 | Arti | | | we were asked which container has more volume...we said both because... | | | |
| 23 | Deeksha | | | | | | |
| 24 | Erwin | | | | Asked question based on what was taught in class – if we put more pins on the cube thermacol it sinks,then if we remove one pin,it will sink or float? | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 25 | Himanshu | | | It was grest to present our views in the debate; ... we got varied answers; we asked doubts about what we had been taught; ... some told gold, so teacher asked them to explain why... | | | |
| 26 | Imran | | | | | | |
| 27 | Swara | | | | | | |
| 28 | Umesh | | *kuch sikhaya toh discuss karte hain uske baad* | | | discussion with friends (Gyat, Jayanti) | |
| 29 | Bhavna | | | | | | |
| 30 | Jojo | | | Those who had done it, told their answers to everybody; many asked questions about it | | | |
| 31 | Pranav | | | | | | |
| 32 | Ronit | | | | | | |
| 33 | Aman | | | Those who had done it, told their answers to everybody; many asked questions about it | | | |
| 34 | Shaan | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 35 | Ambrish | | | | | | |
| 36 | Gaurang | | | homework was to guess the animal but we all found it really difficult | | | |
| 37 | Sanket | | | | | | |
| 38 | Vedika | | | | | | |
| 39 | Veena | | | | | | |
| 40 | Tarika | | | | | | |

**Table M8.** Reports indicating a classroom culture of collaboration: Comparison group

| | | **D1** | **D2** | **D3** | **D4** | **D5** | **D6** |
|---|---|---|---|---|---|---|---|
| **No.** | **Student** | **Change reported in response to questionnaire** | **Change reported in Interview** | **Mentions in diaries** | **Reports from parents** | **Reports from friends** | **Reports from Observers** |
| 1 | Mugdha | | | | | | |
| 2 | Amrita | | | | | | |
| 3 | Indira | | | | | | |
| 4 | Kartik | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5 | Komal | Discuss more about science | While playing, I ask questions, friends say that it is time to play, not question | | | | |
| 6 | Tathagata | | | | | | |
| 7 | Arpit | Talk/ discuss more | | | | | |
| 8 | Arpita | | | | | | |
| 9 | Preeti | | | | | | |
| 10 | Sejal | | | | | | |
| 11 | Ansh | | | | | | |
| 12 | Anuja | | | | | | |
| 13 | Nitin | | | | | | |
| 14 | Ajinkya | | | | | | |
| 15 | Ajitha | | | | | | |
| 16 | Anu | | | | | | |
| 17 | Ashwini | | | | | | |
| 18 | Ayush | | | | | | |
| 19 | Kinjal | | | | | | |
| 20 | Pralhad | | | | | | |
| 21 | Pravin | | | | | | |
| 22 | Vaishali | | | | | | |
| 23 | Archit | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 24 | Arsh | | | | | | |
| 25 | Poorna | | | | | | |
| 26 | Prashant | | | | | | |
| 27 | Vardhaman | | | | | | |
| 28 | Vinay | | | | | | |
| 29 | Abhay | | | | | | |
| 30 | Antara | | | | | | |
| 31 | Anup | With friends I started discussing much more than compared to before | | | | | |
| 32 | Archana | | | | | | |
| 33 | Ashutosh | | | | | | |
| 34 | Devesh | | | | | | |
| 35 | Dhamma | | | | | | |
| 36 | Naina | | | | | | |
| 37 | Pragya | | | | | | |
| 38 | Radha | | | | | | |
| 39 | Ethan | | | | | | |
| 40 | Prabhat | | | | | | |
| 41 | Ravi | | | | | | |
| 42 | Samar | | | | | | |