Student Questioning in Student Talk: Understanding the Process and its Role in Doing Science

Gurinder Singh

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Guide: Karen Haydock

Co-guide: K K Mishra

Abstract

This study is aimed at understanding the nature and dynamics of middle school students' questioning process and its role in learning and doing science. For this we have looked at student discourse in classroom and out-of-classroom contexts. In classroom contexts, students were observed and recorded while being taught by their regular science teachers. In out-of-classroom contexts, students were observed and recorded while they worked in groups observing and investigating some physical stuff, with researchers acting as teachers. In the informal contexts, teachers' control was minimised by letting students work on their own with very little teacher intervention - researchers giving least instructions, and sometimes with no prior instructions. Here the purpose was to record students' spontaneous talk and questioning. Using conversation analysis methods, we transcribed and analysed teacher-student and student-student discourse to understand the process of questioning in the discourse. As we followed an emergent research design, our methods of recording, data collection, transcription and analysis evolved with the progress of our study.

We found that in comparison to classroom contexts, students talked and asked much more in the informal contexts. We also found that most of the student questioning in the informal contexts was authentic with students asking a large number of investigable questions. We found that in classroom discourse, dominated and driven by teacher or textbook questioning, students hardly had agency to meaningfully participate and engage in the discourse. In contrast we found that in the informal contexts students had agency in matters like turn-taking, allocation of turns, use of language, and exploring the stuff. In these contexts, student-student relations and their roles were dynamic and fluid, which kept changing and evolving during the discourse.

Furthermore, we found that student questioning in informal contexts evolved and progressed due to various kinds of conflicts and disagreements between students and between students and stuff, which classroom discourse generally suppressed. In the informal contexts students spontaneously engaged in various aspects of scientific inquiry to investigate their own questions. We discuss how and why the students engaged in a process in which questioning, observing, arguing, investigating and other aspects were integrated and interdependent. We also describe how doing science in these contexts could help students reflect about the nature of science. Furthermore, we describe how bringing certain elements of such a discourse in classrooms can

help giving student questioning a central role in doing science in classrooms.

Chapter 1 – Introduction

While interacting with children, especially younger children, we all have noticed amazing questions asked by the children with sometimes unending long chains of questions. Here is one example of my experience of talking to my 10 year old niece Savy, while showing her pictures of the moon taken by camera and she asking some interesting questions.

> Savy: ये telescope से planet के अंदर भी देख सकते हैं क्या ? उसके पेड़ वगैरा ? Mitti wagira? (Can the inside of the planet also be seen with a telescope? It's trees and all? Soil and all?)
> Savy: अगर suppose करो दूसरे planet पे लोग रहते हैं तो वो भी हमें देख रहे होंगे ? (Suppose if there are people living on another planet, so can they also see us?)
> Savy: जैसे वो छोटा सा तारा है तो हमारा planet भी उनको छोटा सा तारा दीखता होगा ? (Just like that tiny little star, so do they also see our planet like a tiny star?)

In another example, a 7 year old asks her grandmother:

> Shana: Why am I I?

And while children having a discussion about clothes with a teacher, a boy asks:

> Boy: कपडे पहनने का रिवाज़ इन्सानों में ही क्यों है, जानवरों में क्यों नहीं ? (Why do people have the custom of wearing clothes but animals don't?)

In Deepa Dhanraj's documentary film, Young Historians, while a group of children were asking their elders about the history of the village, and what the British Security forces did before Independence, we heard:

> Granpa: They could arrest people and put them in jail. People would be so scared they would pay their taxes.
> Boy: But Granpa, you said each village had 400-500 houses. What if 4 or 5 villages refused to pay taxes?

These questions show not just the curiosity and keen observations of children about their physical world but also their questioning of status quo and power structures within the social setup.

But in schools, do we really encourage or allow them to raise such questions? Or, do we keep telling them, making them memorise things, and feeding them with answers - answers for questions asked by adults? Do we listen to their questions, or think that they can be really critical and can ask challenging questions?

Asking questions is one of the primary ways of knowing about the world around us and one of primary reasons for communicating. Any kind of discourse, whether everyday or institutional, informal or formal, unstructured or structured, involves questioning. It's hard to have a discourse without having questions. However in the sphere of school, questioning seems to be less predominant, especially student questioning. If this is true, then why it is so? What does it reveal about the actual aims of education? These are some of the questions that motivate us to study student questioning.

1.1 Structure of the thesis

This thesis has been divided into eight chapters. Chapter 1 is the introduction, describing how and why we started looking into student questioning. This chapter sets the story of the journey of this study.

Chapter 2, critically reviews the literature around student questioning by looking at the kind of issues or questions that previous research has addressed and raises some important questions which previous research has not asked.

Chapter 3 describes our methods of collecting, transcribing and analysing student-student and student-teacher discourse and how our methods evolved during the course of our study. This chapter describes the schools and classrooms we used for our research. At the end of this chapter, we outline our research questions.

In Chapter 4 our observations of classroom teaching of three different science classroom have been reported. We have analysed the student and teacher questioning in these classes being taught by a regular science teacher.

Chapters 5, 6 and 7 report our analysis of data from the workshops that we conducted with students in informal settings. The purpose to conduct these workshops was to provide a context in which students would have spontaneous talk among themselves working in groups doing different activities or tasks.

Chapter 5 describes our identification and analysis of types and functions of students' questions in their spontaneous talk. Chapter 6 describes our analysis of the nature and dynamics of discourse among students in the informal settings and our understanding of the evolution and

progress of students' questioning process. Chapter 7 looks at the role of student questioning in doing science. We do so by looking at the interconnections of questioning with other aspects of scientific inquiry such as observing, arguing, comparing, analysing, hypothesising, investigating, answering etc. Though Chapters 5, 6 and 7 are based on the analysis of data from our workshops with students, but this analysis is not entirely independent of our observations about classroom discourse.

In the last chapter, Chapter 8, we summarise our conclusions and describe implications of our study for classroom teaching as well as for research in student questioning. Furthermore, we describe possible future directions of this work.

Chapter 2 - A critique of previous research on student questioning in student-student discourse: The need to ask new questions

In reviewing the literature on student questioning, we are primarily concerned with the literature on questioning among school students and its role in doing science.

2.1 Student talk and student questioning: some observational studies

Though there is widespread recognition of the importance of student questions in education in general and in science education in particular, classrooms generally lack student questioning and student talk, with domination of teacher questioning and teacher talk. Though we have not found many research reports on student questioning in India, what we have found supports our own observations that students generally do not talk and ask questions in classrooms and it is the teacher who does most of the talking and questioning (Kumar, 1989; Madhu, 2015; Sarangapani, 2003).

Even outside India the reports on questioning show a lack of student questioning as part of the classroom discourse (Almeida & de Souza, 2010; Barnes et al., 1971; Corey, 1940; Dillon, 1988b; Good, Slavings, Harel, & Emerson, 1987; Susskind, 1979). In his review of classroom observation studies on student questioning, Dillon (1988b) in his observations of 27 high school classrooms in 6 different schools, found that only 1 percent of all the students asked topic related information seeking questions and other 99 percent did not ask any topic related information

seeking questions. Furthermore, he reported that more than 62 percent of teacher talk was in the form of questions and only 6 percent of total students' talk was in the form of any kind of questions. The few student questions that are heard are usually asked by a very small number of students, with most students never heard asking a single question.

In a study of question asking among college undergraduates during communication courses, Pearson & West (1991) observed only 3.3 questions per hour asked by all the students together, which comes to 0.15 questions per hour per student in each class.

Although there are fewer recent classroom studies on student questioning, the situation regarding teacher and student questioning inside classroom does not seem to be very different from what it was 30 to 40 years back (Almeida & de Souza, 2010; Stains et al., 2018).

Irrespective of whether it is school, college or university, a typical classroom discourse involves an IRE pattern where teacher controls and dominates the entire discourse (Mehan, 1979). In such a pattern discourse gets initiated by the teacher asking a question to students (Initiation), students answering the teacher's question (Response) and the teacher evaluating or giving feedback on the student's response (Evaluation). Even if students do discussions and ask questions, it has to be according to certain rules and procedures which are very different from informal talk outside of the classroom: they are part of a large group in which they are supposed to raise hands and be called upon by the teacher before speaking, not speak out of turn, talk one at a time, stick to the topic, not sound stupid, etc. (Dillon 2004). All too often the teachers and/or the textbooks also give the expected answers, which the students are supposed to memorise. All this trains students at answering rather than asking questions and students in very early years of their schooling implicitly learn these rules of classroom talk (Dillon, 1988a).

Is this phenomenon, the lack of questioning and lack of talking among students, restricted only to classrooms and schools or is it universal, observed in out of school contexts as well? Do parents and other adults talk more and ask more and children only answer questions posed to them? There have been studies to understand children's talk and question asking behaviour in informal contexts. In a longitudinal study in the city of Bristol in UK, Gordon Wells (2009) studied pre-school students at their homes and at schools and found that in comparison to parents, teachers talked much more and asked more questions to the children. He concludes that,

at school, children are reduced for a much greater part of the time to the more passive role of respondent, trying to answer the teachers' many questions and carrying out their requests...

Wells claimed that this led to the reduction in the range and variety of children's talk that inside the class as compared to the talk at their homes. Though Wells' study described the relative differences in conversation patterns of parents and teachers, the study did not compare the question asking between children and parents in much detail.

One might wonder here, what would happen if teachers start talking and asking less? Although teacher's use of 'wait time' has been found to be effective in increasing students' questions (Rowe, 1986), a detailed study on teacher quietness or teacher asking and talking less to encourage student questioning is lacking. Also, more research is needed to find out how or whether the kind of questioning children do - or should do - in school differs from the kind they do outside of school or in more naturalistic situations - either with regard to topic or type of questioning.

2.2 Forms and functions of students' questions

In order to understand the forms and functions of students' questions, one needs to identify and separate questions from other types of utterances in the conversations. So one has to first understand 'what are questions', what it means to ask a question, and how the understanding is influenced by the researcher's philosophical and ideological perspectives.

2.2.1 Forms and types of student questions

Identifying questions and categorising questions are quite interwound, with both being part of the process of defining questions (Cifone, 2002). There have been some efforts by researchers to develop generic schemes or taxonomies of questions (Kearsley, 1976; Graesser, Person, & Huber, 1992).

Kearsley defined a question as an interrogative utterance aimed at seeking a response from the addressee, and thus excluded rhetorical questions, and questions to give commands and convey requests, from the category of 'true' questions. Researchers have adopted different criterion for identification and classification of questions. Graesser, Person and Huber (1992) also devised a

generic categorisation scheme, based on the functional aspects of questions. Their taxonomy included both interrogative and non-interrogative questions which call for a genuine inquiry. The taxonomy has 18 categories of questions including verification, comparison, definition, procedural, quantitative and request questions.

Apart from these, researchers have categorised questions using empirical data from their studies based on some kind of theoretical understanding or grounding about questions and questioning. Some of these researchers categorise students questions on the basis of cognitive level of questions, where certain questions like recall or factual questions are categorised as lower cognitive level questions and questions related to real life phenomenons, reflecting puzzlement and curiosity, asking for explanations and justifications or leading to investigation are categorised as higher cognitive level questions (King, 1994; Scardamalia & Bereiter, 1992; Chin & Kayalvizhi, 2002).

2.2.3 Student questioning: its importance and its functions

As reviewed by Edwards and Westgate (1994), research has shown many advantages of students talking in class. Education is a social process that requires much more than individual, isolated students listening, reflecting, and writing (Vygotsky, 1966). Students must be engaged in activities and real discussions in which they ask authentic questions.

Several authors have mentioned the need to reawaken the quality of asking questions, which children seem to abandon as they grow older (Falk & Margolin, 2005; Rothstein & Santana, 2011). Students' questions are thought to be crucial for science education and as a basis to design educational programs (Joshi, 2007). In their review of research on students' questions in science education, Chin and Osborne (2008) reported that students' questions are important for (1) students' knowledge construction, (2) encouraging participation of students in classroom discussions, (3) helping students to assess their own learning and (4) arousing epistemic curiosity. In addition, students' questions are also important because they help teachers in (1) formative assessment, (2) evaluating higher order thinking, (3) stimulating further inquiry and (4) fostering critical reflection on classroom practices.

In our view, an important advantage of student questioning could be that it accommodates the different interests of students which the teacher may not be aware of. In classrooms, which are

less child centred, teachers often expect specific responses to their questions (Roth, van Eijck, Reis, & Hsu, 2008), which obstructs students' own thinking as they try to guess expected answers.

Students questions, especially their spontaneous questions, can help teachers as well as researchers understand them better. As emphasised by Piaget (1923),*"There is no better introduction to child logic than the study of spontaneous questions."*

Questioning is necessary for both critical reasoning and scientific investigation: in order to observe, analyse and evaluate evidence, give justifications and explanations, as well as to make interconnections, postulate and test hypotheses and identify and clarify contradictions and doubts, and solve problems (Biddulph, Symington, & Osborne, 1986; Chin & Osborne, 2008). However, research in science education has looked at questioning in isolation from these different aspects of scientific inquiry. The thesis elaborates on this in detail.

2.2.3.1 Functions of student questioning

Seeking information and settling one's epistemic puzzlement are seen as the most important functions of questioning in conversations. But apart from these crucial functions, there are other important functions that questions perform.

In a review to understand the forms and functions of children's questions Cazden (1970) found that children ask questions for various reasons like, to test someone, to seek permissions, to seek attention, for confirmation, for repetition among other reasons.

Cifone (2002) in her study categorised students' questions according to various purposes of their questions and her categorisation is not generic and emerges from the purpose and the context of her study and the context of student discourse. Studies on similar lines would be more meaningful to understand the process of student questioning and its relationship to learning and doing of science.

Freed and Ehrlich (2010) found that one of the functions of questioning in institutional discourses was the allocation of turn-taking, with the questioner (for example a teacher) having the authority or right to initiate and allocate turns by asking questions. However, there has not

been much work to compare the functions and purposes of teachers' and students' questions inside the classrooms, and how it affects the distribution and dynamics of authority.

Since many of the studies on functions of children's question looked at questions of very young children and that too from informal settings, a comparison with regular classroom teaching situations is needed. In classrooms, students motivations and purposes of asking questions are probably very different from the out of classroom situations.

2.3 The need to understand the process of questioning and its role in doing science: Implications from philosophy of questioning and philosophy of science

Here in this section, we will look at questioning from the philosophical perspectives which we think are quite important and have been relatively ignored by the researchers.

Although, some researchers (Dillon, 2004; Kearsley, 1976; Van der Meij, 1994) have emphasised the need to understand the process of questioning and its role in learning specifically from the perspective of the learner, very few studies (Cifone, 2002) actually deal with such issues. Dillon (2004) argues that a question as a form or entity is the end product of a process, a process which starts with a percept (perception of something, a phenomenon or proposition) and ends with the expression of question (Dillon, 2004). Understanding the process would involve understanding the physical as well as psychological conditions under which questions arise and understanding the events of asking. This would help us in reflecting about the student-student discourse, student-teacher discourse, and the role of teacher and classroom conditions that can sustain student questioning. Van der Meij (1994) in his review on questioning research has suggested that there is a strong need to understand the process of questioning in order to give student questioning a bigger role in education.

Michel Meyer (1995), has proposed the theory of questioning called problematology, a unified theory to understand philosophy, science, and language. He argues that contemporary philosophy is based on the propositional model of reason where questioning has occupied a peripheral place and propositions or answers have become central. He says that this has happened even in science as well. Meyer argues that the very fact that the world is ever changing and the older experiences

or assumptions cease to be true and get questioned, questions rather than propositions are the basis of science, reason, thought and language.

We think Michel Meyer's theory could be very useful in understanding the process of questioning in everyday discourse as well as the discourse of science.

2.4 Issues/questions that student questioning research needs to address

As we have discussed, there is a need for more qualitative, descriptive studies to understand student questioning.

More research needs to be done to address the disturbing questions: Do schools teach children not to ask questions? And while at school, do young children actually learn that the school-school game is not to ask but answer? Does schooling lead to a permanent change in children's question asking behaviour? Does questioning decrease with age, regardless of what happens in the classroom? Are some cultures inherently 'non-questioning'?

The importance of student questioning is widely endorsed in educational philosophies and pedagogies. However, there is a lack of empirical studies to understand the functions and hence the reasons for student questioning in actual classrooms - and in student-student discourse. Also it would be interesting to compare the purposes of student questioning with that of teacher questioning to understand the dynamics of classroom discourse.

Student-student questioning is not well understood, and there is a lack of studies especially on their spontaneous questioning in more informal settings, at the level of middle-school and above. Students' spontaneous questioning, being oral, could be live and more dynamic and can be helpful in investigating students' understanding and meaning making in greater detail.

Also, if one of the main reasons for the lack of student talk is the dominance of teacher talk, more research is needed to understand the relation between teacher quietness and student questioning,

We wonder whether, an informal environment provides students an agency to ask authentic questions and to control and guide their discourse. Or in a naturalistic environment without an

adult, do children subject each other to censorship, ridicule, and manipulation - and not raise questions or engage in a dialogue? More research is needed on these questions,.

Research has focused on engaging students in open-ended explorations or activities, whereby students explore the ideas or questions/problems presented to them by the teachers. However, we think perhaps students should be engaged in activities or explorations stemming from their own ideas and questions. Such an approach will not just be open-ended but also what we call an 'open-beginninged' approach. The term open-beginning has been used by Dylan Wiliam (1998) and others (Greenes, 1997; Poddiakov, 2016) to define the openness of a problem/task in terms of its beginning state. According to them, if a problem is open for more than one interpretation by students or students have greater autonomy/freedom in interpreting a problem, it will be a more open-beginninged problem. Here we are using this term to define the autonomy given to the students to formulate their own questions and problems within a given context.

Furthermore, categorisation studies have focused a lot on lower vs higher cognitive questions although others have argued that such a differentiation is not very helpful in understanding questions, as meanings of questions are very much discourse and context dependent.

We see a disconnect between different research fields carrying out studies on questioning. In particular, science education research has failed to draw from studies in the philosophy of questioning in order to understand the dynamics of questions and answers in student-student discourse. For a meaningful understanding, questions have to be analysed with regard to their responses/answers and answers have to be analysed with regard to their questions. Also understanding questioning would require understanding social relations and the dynamics among interlocutors. The ideas proposed by Michel Meyer about questioning could be useful in understanding these dynamics of question-answer process. The relationship between student questioning and their argumentation needs to be explored. However, researchers have typically seen questions as an individual act rather than a group or collaborative act, and have ignored the argumentative properties of questioning.

Furthermore, questioning has been studied in isolation from different aspects of scientific inquiry and its role in doing science has not been well understood.

Chapter 3 - Investigating student interactions to understand student questioning: The emergent research design

In this study, our main objective is to understand student questioning. In understanding student questioning, our immediate objective was not to find out how we can train students at asking certain kinds of questions, but to understand the dynamics of the process of questioning. Our main aim was not to categorise or quantify different types of questions, but to find a few different examples of questioning and analyse them in depth to understand how and why they occur in order to understand the process of student questioning.

Our research design is an emergent one, as described by Lincoln & Guba (1985), such that our frameworks, research questions, methods of collecting data, methods of transcribing and analysing data evolved with the progress of our study. This progression was not a simple or linear one but one having interdependencies between different aspects of our research.

We started our study with some initial broader questions about student questions and methods of investigations, which evolved into more specific questions about students' questioning process with the progress of our study.

With progress of our study and the kind of questions we were looking into, we got more and more interested in students' spontaneous talk. With some readings around conversation analysis methods (Roth, 2005; Ten Have, 2007; Wooffitt, 2005), we refined our methods of transcription and analysis.

As we transcribed and analysed student interactions, we understood more about our ways of recording and collecting data. The initial analysis helped us in improving our recording methods, improving ways of listening and transcribing, what to focus upon, what kind of interactions to focus upon, refinement of our research questions etc. And this process was continuous.

3.1 Data reported in this study

We report two sets of data in this study, one set of data comes from our observation of teaching of regular science classrooms and the other set of data comes from our workshops with school students in which researchers acted as teachers.

We were not interested in conducting a survey in order to identify and/or find the frequencies of different kinds of questioning. Rather, we wanted to record lots of talk, both in classrooms and in more informal contexts, so that we would have a large database from which we could select particular episodes to analyse in great detail and depth in order to understand the questioning process. We looked through all the video and audio data, made summaries and discussed amongst us, and then selected the following parts of recordings for analysis for this thesis, as these were the most relevant parts for our research questions. As per ethical guidelines, we have used pseudo names in place of the original names of the schools, teachers and the students.

3.1.1 Classroom Observation data reported in the study

Class IX (54 students) of Shashtri Vidyalya, Mumbai being taught the topic of work and energy by their science teacher, Renubala. Most of the students, who had participated in Variegated tree sessions at HBCSE, two years previously, were present in this classroom.

Class VII (18 students) of Govt. Sen. Sec. School, Fatehpur, Ludhiana with teacher Sangeeta discussing questions from the chapter 'Story of Waste Water' in their science textbook.

Class IX (35 students) of Krishna High school, Mumbai being taught the topic of solid waste by their teacher Ashok.

3.1.2 Workshop data reported in the study

In all the workshops our main purpose was to record students' talk as they explored different physical stuff or performed some tasks or activities while working in groups. Workshops were 2 to 6 days long with 1-2 hours long sessions each day, with researchers acting as 'teacher' and the regular teacher usually not present. For Ludhiana schools, all our workshops were conducted in the school and within the school hours.

3.1.2.1 Exploring the variegated tree

This data is 48 minutes recording of students' observations and explorations of a tree. The plan was to first bring students near the variegated bhendi tree (*Talipariti tiliaceum*) in the garden of HBCSE and let them observe and talk, initially without telling them or instructing them in any way. These students, from Shashtri Vidaylya, Mumbai had just completed Class VII and were all 12-13 years old. After an open invitation to all the students of one section, six girls (Revati,

Tanya, Ishita, Kavita, Trupti, and Janvi) and 5 boys (Nimish, Keshav, Hemant, Binod, and Adil) obtained parental permission and attended the workshop. Throughout, students spoke mainly in Marathi, their mother tongue.

3.1.2.2 Making paper parachutes

This data is part of the day five of our 6 day workshop that we conducted with Class VIII students of Govt. Sen. Sec. School, Fatehpur, Ludhiana which mainly focused around activities related to free fall of various kinds of objects. On day five students were given the task of making paper parachutes using two A4 paper sheets. There were 20 students (19 boys and 1 girl) present. For this study we have transcribed and analysed the conversations of one group of boys (Gurpreet, Jaskaran and Hardeep) for the 24 minutes they sat together, discussed, planned, designed and made the parachute.

3.1.2.3 Observing ants

This data is part of day one of our 2 day workshop with class VIII students of Govt. Sen. Sec. School, Hazara, Ludhiana involving an activity of observing ants by feeding ants different food items. There were 26 students (12 girls and 14 boys) present. For this study, we have transcribed and analysed the session 2 of 33 minutes of recordings of the group of 6 girls' (Aisha, Kuldeep, Harmanpreet, Simranpreet, Sukhdeep and Gurpreet). This group of girls observed ants moving in and out of an ant hole near the bottom of the trunk of a tree while sitting and standing around the hole.

3.2 Methods of recording and collecting data

We recorded and observed teachers and students during classrooms and workshops by videotaping, audio taping, taking notes, collecting students' work and taking pictures and photographs. For our very first interaction done at HBCSE, we used two video recorders and one DSLR camera for video recording student interactions. Most of the time video recorders were used simultaneously, focussed on different students or on the same group, but from different angles. In subsequent work, in addition to the video cameras, we used at least two voice recorders, either placing a voice recorder on a nearby table or hung around the neck of a student who was in the group that was also being video recorded.

3.3 Our methods of analysis

We transcribed and analysed the data using Conversation Analysis methods in which we tried to analyse how meaning was constructed socially through the conversations, activity, gestures, and interactions between people as well as between people and the physical environment. We included ourselves as well as the students as subject/object of study, analysing the effects of power relations and differences between the students' and researchers' perceptions and understandings. We tried to understand and interpret students' meaning, reasoning, intentions, emotions, and signs of doing science, concentrating on the progression of the group conversation rather than analysing the utterances of individuals in isolation.

The transcription, translation, interpretation, categorisation, and analysis were all interdependent and evolving throughout the research, requiring continual referral back to the original data.

3.4 Our ideological and philosophical framework: Nature of education and nature of science

Our understanding and analysis of student-teacher interaction, student-student interactions and student-real world interactions is governed by frameworks, which we briefly outline below.

3.4.1 Nature of education and nature of schooling

Following Paulo Freire (1968) we see the value of (both natural and social) science education in its possible role to encourage students to work together in order to question the status quo and become more active participants in trying to create a better, more just and equitable world. Freire argues for critical education against the existing 'banking' model of education. From a critical education perspective knowledge is seen as process of 'problematisation' whereby one questions not just one's natural realities but also one's cultural and historical realities.

However, the current schooling seems to be training students to be good at listening and answering rather than arguing and questioning. Rather than having a pedagogy of questions, in schools we seem to have a pedagogy of answers. Freire and Faundez (1989) argue that such a pedagogy is anti-democratic and non-liberating as it restricts one's curiosity, creativity, and freedom of thought.

We agree with Freire that education is a political process and seeing it as neutral is a fallacy (Freire & Faundez, 1989). In this political process, knowledge of those who are in power gets legitimised. To understand the process of education one have to understand the existing power structures and the social, economical and political context.

3.4.2 Nature of reality and nature of science

Our understanding of the nature of reality is dialectical as described by Friedrich Engels (1886). As explained by Maurice Cornforth (2015) as well as Foster, Clark, and York (2010), this means that in physical reality, everything changes, and therefore things do not exist as things, but as things in the process of becoming something else. Thus we see the difficulties in thinking that a thing is identical with itself: because everything keeps changing and what is 'self' at one time no longer exists at another time.

Furthermore, for us 'nature' means nature/society: the inseparable unity of the human (social) and the non-human living and non-living environment, in their complex interactions, interdependencies, and movement. This is in accordance with Marx's (1844, p. 143) description of the dialectical relationship between society and nature. Thus, according to this understanding, the reality is the inseparable object/subject: we human beings are acting upon, studying, and doing science on a material world which is also acting upon us.

When we do (natural/social) science, understandings are probabilistic and can be challenged, questioned, investigated, requestioned, and reinvestigated. They keep changing as contradictory or new evidence is identified. New evidence keeps being found, partly because physical reality itself keeps changing. In doing science dialectically, we need to investigate how conflicts - inherent physical opposing forces - drive processes, rather than thinking that processes follow some basic, abstract 'laws' (see Singh, Shaikh, & Haydock, 2018).

Furthermore, in agreement with many other educationists and scientists, we see the scientific method as consisting of a network of various interdependent combinations, orders and numbers of different aspects or elements of a 'science toolbox' (Wivagg & Allchin, 2002). Within the variability, we see questioning and observing as two fundamental aspects of process of doing science. In relation to process of questioning, we see science as described by Meyer (1980b), whereby it is a process of dialectical interplay between questions and answers. This process, the

process of doing science, is necessarily subjective, influenced by emotions, and interdependent with social, political, and economic systems. These interdependencies are complex, conflicting, and require attention from science educationists.

3.6 Theoretical framework to analyse the process of questioning in students' spontaneous talk

Although, we found that previously developed frameworks, like those that are based on IRE analysis of discourse, were useful in analysing teacher-student discourse in classrooms, such methods could not be very useful to understand the student-student discourse especially in informal contexts. In comparison to classroom discourse between the teacher and the students, which is simple and somewhat structured, the everyday or the informal discourse is generally very complex and unstructured.

Furthermore, we are less interested in identifying and categorising questioning structures, and more interested in understanding the process of student questioning and how questioning evolves and progresses in student-student talks in informal contexts. And for such an analysis we see value in using Michel Meyer's theory of problematology (Meyer, 1995). As Meyer defines it, Problematology is a theory of questioning, a unified model to understand philosophy, science, and language. The theory of problematology is built upon questioning as a fundamental property which presents a new view of rationality in terms of questions and answers.

While explaining the question-answer relation, Meyer argues that a question can generate two kinds of responses or answers, apocritical and problematological answers. The apocritical answers lend solution and gives a closure or end to the problem. Whereas the problematological answers bring forth alternatives, newer questions and hence keep the inquiry open. Moreover, any answer, whether apocritical or problematological, could not be understood devoid of original questions. They lend meaning only in conjunction to the original question.

We will be using Meyer's theory of problematology and his ideas to explain the questioning process in the student-student discourse by analysing:

1. The question-answer relation in the process of questioning (Chapter 6)

2. The relationship of student questioning and argumentation (Chapter 6)

3. The role of students' question-answer process in their doing of science (Chapter 7).

3.7 Research Questions

Our research broadly focuses on understanding the process of student questioning. More specifically our questions are:

1. Understanding the questioning process inside science classroom contexts:

   a. What is the frequency and type of student questioning in actual classrooms and how is it similar or different to that of teacher questioning?

   b. What is the nature and dynamics of discourse in classroom during student and teacher questioning?

2. Understanding the student questioning process in informal contexts:

   a. What is the frequency and type of student questioning?

   b. How and why does student questioning arise, evolve and progress? What is the nature and dynamics of student-student and student-stuff interactions in the questioning process.

3. Understanding the role of the student questioning process in doing science in informal contexts

   a. How is student questioning related to student investigations of physical stuff?

   b. What is the interconnection between questioning and other aspects of scientific inquiry?

   c. How questioning and answering are related in the process of science?

Although we have presented these questions in a certain order and separately, but these cannot be understood in isolation from each other.

Chapter 4: Going into the classrooms: Observing student talk and questioning

In this chapter, we will look into the frequency and types of student as well as teacher questioning and the nature and dynamics of classroom discourse in order to understand the process of questioning inside science classrooms. We will do so by analysing our observations of three different science classrooms from three different schools (see **section 3.1.1**).

4.1 Teacher and student utterances

We define an utterance as any talk made by one speaker at a length about one topic which is more-or-less not interrupted by someone else. Based on our past experience we expected that the number of teacher utterances would be much greater than the number of student utterances. This was the case in teacher Sangeeta's classroom, but the number of teacher and student utterances were almost equal in case of teacher Renubala and Ashok's classrooms.

However, this does not mean students were talking as much as the teacher. Generally teacher utterances were much longer and sometimes 40-50 words long (or more than a minute), but a large number of students utterances were short: not more than 5 words. So it was clear that in all the classes we observed, teachers were, by far, doing most of the talking. Student utterances were very limited in time and type. Most of the times students were either giving the expected answers to the leading questions or agreeing with teacher's claims. They were not engaging much in argumentation with the teacher involving any kind of reasoning or justification.

Furthermore, most of the student talk that we observed in classrooms was directed to the teacher and rarely students directly addressed students.

4.2 Identifying and categorising students' questions

Our main goal is not to identify or name categories of students' questions as individual entities, nor are we interested in studying the frequency of different kinds of questions. Rather, we want to understand the process of student questioning. Therefore, we have to analyse questioning in context, it's development and evolution. However, in order to do this, we have to do some categorisation of questioning in relation to the process. Note that our categories are overlapping with blurred boundaries: one question may fit in a number of categories. Though we have used

some categories described in previous research, many of the categories and their definitions evolved as we analysed our data (Singh et al., 2018). Figure 4.1, showing the relationship between different kinds of student questions that we observed, includes most of the types of students' questions observed in both the classroom as well as the informal contexts. Each type will be defined and discussed in Chapters 4 and/or 5.

Figure 4.1 Types of questions

As we transcribed the tapes, we kept identifying the questions and the process of identification and categorisation was actually not separate, with most of the times identification and categorisation happening simultaneously. In our identification of the questioning, we had to understand the context in which a question emerged, who asked the question, whether it was addressed to a particular person, who responded and what was the response or sequence of responses following the question. This allows us to analyse the functions of the questioning and ***why*** the students and teachers are saying and doing what they are saying and doing.

4.2.1 Explicit and implicit questioning

In the languages we have used in our studies (Marathi, Hindi, Punjabi, and English), explicit questions (also called direct questions) may be identified by the use of WH signifiers (who, what, why, where, which, how), word order, or by the use of a typical inflection or rise in intonation on a particular word, all indicated by question marks when the questions are written.

However, as we transcribed the tapes, we realised that there are many questions, which do not appear very explicitly involving any kind of the above question markers or indicators. Such questions represented perplexity, doubt or confusion on the part of the speaker but were not stated explicitly by the speaker. For example, in Ashok's class at 09:01-9 Sajid asked an implicit question saying , **'वो तो काम आता है (That is used)'**. Though the sentence here does not have an explicit question marker, but it represented a doubt or conflict of Sajid about calling agriculture or garden waste as waste as that is actually useful. We have categorised it as an implicit investigable question. We indicate implicit questions without using a question mark in the end.

4.2.2 What kinds of questions did students ask in classrooms?

In the three classrooms that we report here, we found various kinds of students' questions, mostly asked by the students to the teacher, but in some cases (like student whispering to each other) asked by students to each other. We discuss some types like confiramtion, clarification, checking, investigable, basic questions of reality, etc. here.

Confirmation questions are the questions asked by someone to seek confirmation (seek agreement) of one's own response, procedure or task (Good et al., 1987). Generally a confirmation question is a statement with a ', na' or ', no' in its end, making it an explicit question. We call these questions as inauthentic questions because one already knows the answer to the question and is only trying to make others agree upon that answer. For example, in teacher Renubala's class, a student had given 'sound waves' as an example of a form of energy, to which the teacher asks, 'But where is displacement in sound energy?' Then the student replies that when we play songs and do dance then there is displacement. To which the teacher asks, 'But where is displacement?' To this, the student replies with a confirmation question that 'Dance is performed - there is displacement, na?

Clarification questions are asked by a person when that person heard something being said but could not hear it properly or could not understand what was said (Good et al., 1987)). Here is one example of a student in teacher Ashok's class at 23:08-7 asking a clarification question:

22:55-6 Ashok: *Ok* .. ***can you quickly copy the question what are the effects of solid waste?***
23:08-7 Student: **What are the effect of ?**
23:10-5 Ashok: ***What are the effects of solid waste?***

A checking question is generally a reply to a teacher's question, said in a doubting tone. The doubt is not an epistemic one but doubt about it being the answer the teacher expects. Here the student would seek an evaluation of his/her response from the teacher. Lemke (1990, p. 10) while discussing about students use of such a strategy in answering teacher's questions argues that it provides students with some kind of protection in case their answer is wrong. Here is one example, where Dalbir at 00:33-0 replying to the teacher Sangeeta's question about the relationship between cleanliness and diseases, implicitly questions his own answer.

00:31-0 Sangeeta: ***ਕੋਈ ਸੰਬੰਧ ਨੀ ਸਫਾਈ ਅਤੇ ਬਿਮਾਰੀ ਵਿੱਚ? (There is no relation between cleanliness and getting sick?)*** [asking rhetorically]

00:33-0 Dalbir: ਹੈਗਾ ਜੀ… **ਸਫਾਈ ਵਦੀਆ ਹੁੰਦੀ ਆ (**There is ... **Cleanliness is good)** [starts with a louder voice but towards end becomes very soft seemingly not sure whether this is the answer teacher is looking for]

00:36-2 Sangeeta (not satisfied with answer): ***ਸਫਾਈ ਵਦੀਆ ਹੁੰਦੀ ਆ ਫੇਰ? (If cleanliness is good then?)***

Investigable questions are relatively open-ended questions and may not have a fixed or pre-determined answer. Investigable questions have been defined by Christine Chin (2002) as those that 'allow students to generate and collect some original data, analyse and interpret their findings based on these data, and finally make a conclusion that addresses the investigative question posed, on the basis of available first-hand evidence.' Sajid's question '**वो तो काम आता है (That is used)'** described in section 4.2.1 is an example of an investigable question.

Basic questions of reality are somewhat similar to Piaget's definition of questions of reality and history (Piaget, 1923). These questions deal with some simple facts about reality which are relatively non-investigable and have certainty about answers. For example, a student asking about the voice recorder to Gurinder as Gurinder was placing it to record teacher Ashok's class, **"ये क्या है ? (What is it?)",** is an example of 'question of reality'.

Apart from these, students asked questions such as procedural questions, questions asking permission, questions making a request, factual question, and explanation questions.

4.2.3 Numbers of student questions

In all the three classes that we observed, the number of questions asked by the students is much less than the number of teacher questions. The rate of student questioning that we observed in these classes is not very different from what is reported by other researchers (see **section 2.1**).

It is important to note that a large percentage of students' questions, more than 50 percent among all the total questions asked by students together in three classes, are in the form of procedural or permission seeking questions. Altogether, there are very few explanation or investigable questions asked by the students. If we compare questions asked by students (per student) with questions asked by the teacher alone, then there is huge difference in these numbers. For example, teacher Renubala asked total 117 questions in the 23 minute class, whereas the total number of questions asked by all the 54 students in the same time are 13, making 0.2 questions asked per student in the entire class.

4.3 Students' agency to participate in the discourse

4.3.1 Teacher interrupting students vs students interrupting teacher

In our observations we found that students were often interrupted by the teacher as they spoke but the opposite, where a student interrupted a teacher was rare (except in whispers to other students). For students, generally they were nominated by the teacher for their turn or they have to seek permission (e.g. by raising hands) to take a turn to speak. But teachers did not require permission to take a turn to speak.

4.3.2 Whispering and illicit student talk

In the classes we observed, we found many instances of students whispering in low voices among each other. For example teacher Renubala in her class was talking about different forms of energy and was explaining energy as a form of work which involves some kind of displacement. So when one of the girls whispers that light is an example of energy, the other girl whispers her and asks where is the displacement in light. It is interesting to note that in this

whispering students raised questions to each other, which otherwise we did not notice in any of the classes as part of main classroom discourse.

We have not found any research reports that focus on student whispering or talking in classrooms. We wonder whether in this talking the students may be more apt to relate the topics to their own lives and experience, and ask important questions to each other and to themselves.

4.3.3 Disagreement with teacher and textbook as part of main classroom discourse

In the three classes that we report here, we observed very few instances where students explicitly disagreed with the teacher though teacher often disagreed with the students. Here we present an example of student disagreement. Teacher Renubala was asking students for examples of energy and insisting to give only those examples in which students could explain work done and displacement associated with the energy. So when one student gives solar energy as an example, the teacher disagrees and says there is no displacement in it. To this student responds that there is displacement as energy has reached from the sun to the solar panel. This is an example where a student tries to disagree with the teacher and move away from the boundaries set by the teacher or the textbook.

4.4 Understanding the structure of classroom discourse

In our observations of the three classrooms, the pattern of discourse among teacher and students that we observed was mostly different forms and combinations of teacher initiation (I), student response (R) and teacher evaluation/elaboration (E, or teacher feedback, F) with the most prevalent being the IRE triad (**see 2.1**). Here is an example of long sequence of teacher student talk from Sangeeta's class.

00:15-3 Sangeeta: ***ਹਾਂਜੀ . ਅਗਲਾ . question ਤੁਹਾਡਾ ਹੈਗਾ ਆ ... ਸਫਾਈ ਅਤੇ ਬਿਮਾਰੀਆਂ ਦੇ ਵਿਚ ਸੰਬੰਧ ਨੂੰ ਸਮਜਾਓ? (now . the next question is ... explain the relationship between cleanliness and getting sick?)*** [As she reads the question from the textbook] I

00:24-1 Sangeeta: ***ਫੇਰ ਮੈਨੂੰ ਇਹ ਦੱਸੋ ਸਫਾਈ ਤੇ ਬਿਮਾਰੀ ਦੇ ਵਿਚ ਆਪਸ ਚ ਕੋਈ ਸੰਬੰਧ ਹੈਗਾ ? (Then tell me whether there is some relationship between cleanliness and dieases?)*** I

00:27-7 Sangeeta (rhetorically, after she does not get any response): ***ਕੋਈ ਹੈ ਸੰਬੰਧ ਕੇ ਨਹੀ ? (Is there a relationship or not?)*** I

00:31-0 Sangeeta: ***ਕੋਈ ਸੰਬੰਧ ਨੀ ਸਫਾਈ ਤੇ ਬਿਮਾਰੀ ਵਿੱਚ? (There is not relationship between cleanliness and dieases?)*** [asking rhetorically] I

00:33-0 Dalbir (sitting on first bench on right most line): **ਹੈਗਾ ਜੀ .. ਸਫਾਈ ਵਦੀਆ ਹੁੰਦੀ ਆ …? (There is ... cleanliness is good)** [starts with a louder voice but towards end becomes very soft] R

00:36-2 Sangeeta: **ਸਫਾਈ ਵਦੀਆ ਹੁੰਦੀ ਆ ਫੇਰ? (Cleanliness is good then?)** I

00:37-9 Dalbir (answering teacher): ਜੀ ਇਸ ਕਰਕੇ ਸਾਨੂ ਸਫਾਈ ਰੱਖਣੀ ਚਾਹੀਦੀ- (So we should keep cleanliness-). R

00:39-3 Sangeeta: ***ਕਿਓਂ ਕਾਰਣ ਵੀ ਦੱਸੋ ?(Whhyy, tell reason also?)*** [stresses on 'why' by streching it while asking] I

00:41-2 Dalbir: ਜੀ ਸਾਨੂੰ ਬਿਮਾਰੀਆਂ ਨੀ ਲੱਗਦੀਆਂ ਜੀ (We do not get dieases) R

00:42-6 Sangeeta: ***ਕਿਓਂ ਨੀ ਲੱਗਦੀਆਂ ਬਿਮਾਰੀਆਂ?(Why we don't get dieases?)*** I

00:45-0 Dalbir: ਜੀ ਜਿਵੇਂ ਪਾਣੀ ਖੜਾ ਉਹਤੇ ਮੱਛਰ ਪੈਦਾ ਹੋਊ (Like there is stagnant water, mosquitos will breed there) R

00:48-7 Sangeeta (Dalbir has not stopped at this point but teacher gives her remarks as Dalbir continues speaking): ਹਾਂਜੀ (yes) E

00:49-0 Dalbir: ਜੀ ਉਹ ਕੱਟੂ ਤੇ ਡੇਂਗੂ ਹੋ ਜਾਉ (it will bite and then one will get dengue) R

00:51-0 Sangeeta: ਹਾਂਜੀ (yes) E

We notice that this sequence is more complex than IRE,IRE... It is rather, IIIRERIRIRERE.

Though here the discourse is not a simple IRE chain but the turns of asking, responding and evaluating remained fixed and in the control of the teacher. By keeping hold of the two key turns (asking and evaluating) of the three part sequence, the teacher controlled who, how and when someone will participate, and also the content and the length of the discourse. Furthermore the discourse was most of the times between the teacher and one student at a time. Students did not directly address each other.

Furthermore, it is interesting to note that student questioning at times disrupted the regular IRE discourse. For example Sajid's question in Ashok's class, '**वो तो काम आता है (That is used)'**, breaks and even inverts the regular discourse, by taking the turn of asking and thus implicitly passing the turn of responding to the teacher.

It may seem surprising that the IRE sequence is so ubiquitous and that teachers and students fall into their roles in IRE sequences so effortlessly, without even being fully conscious of those roles. The large prevalence of IRE discourse can be possibly explained by reflecting upon the nature of education and schooling which is centred around memorisation of expected answers without questioning the questions (see our framework in **Section 3.4.1)**. In such a pedagogy

teaching and learning functions to make students obedient and submissive, rather than being critical or to challenge authorities. Thus it ends up reinforcing the existing social structures.

4.5 Teacher questioning

Unlike students, teachers do not always ask questions because they are perplexed about what is being asked, but about what is being answered by the student. Due to these reasons, researchers have called teacher questions as 'exam' questions which are inauthentic. So teacher questioning is generally different from student questioning.

We found two particular types of questions which were specific to the teachers only. One of these is 'Complete the sentence questions'. In all the three classes that we observed, we found that at times the teacher would utter an incomplete sentence ending with rising intonation and students, generally in unison, would answer by completing the sentence. We call this as a 'complete the sentence' types of question. For example, in a discussion on waste decomposition in teacher Ashok's class, we heard Ashok at 13:57-7 asking, "***quickly. right. decompose* का मतलब क्या होता है *it will break into? (quickly, right, decompose means it will break into?)"***.

Such questions were clearly meant to reinforce the 'facts' and help students memorise 'teacher's answers' to questions that might later appear in examinations. This kind of questioning is similar to the 'incomplete turn constructional units' reported by Gene Lerner (1995).

Another kind of questioning, which was specific to teachers only, was teachers' rhetorical questioning. As discussed in Chapter 2, rhetorical questions are used to convey a strong disagreement or rejection of another person's view or argument, but not necessarily to seek a response. It is interesting to note that we did not find a single example of students asking a rhetorical question to the teachers. This could be because of the assertive nature of such questions and students' lower rank in terms of authority.

4.6 Summarising our classroom observations

We found that the situation in the classrooms we observed is similar to what is reported in previous studies by other researchers (reviewed in Chapter 2): a lack of student questioning and students talk and the dominance of teacher talk and teacher questioning. Students' utterances were very generally short compared to the teacher's utterances.

Even if students did ask questions, there were very few of those which showed disagreement with the teacher and the textbook or which led to further questioning or which engaged students critically.

Our study of classrooms also advances the understanding and categorisation of the nature of both student and teacher talk and questioning in the classroom. In our observations, we found teachers using rhetorical questioning to elicit 'expected' answers. Also, we have observed student whispering as one of the important means by which students take agency to participate in the classroom discourse. We observed a correspondence between student questioning and student disagreement with the teacher and the textbook.

Chapter 5: Students' spontaneous talk and questioning: identifying and categorising questions

We think that one of reasons that we did not notice much of student questioning inside classrooms was because there were hardly any opportunities for the students to talk with each other. Dillon (1983) argues that students engage in questioning and answering more readily with each other than with their teacher. Even if students had chances to talk inside the class, they did so by remaining within the frame of teacher or textbook.

Based on our prior experience, we thought of observing students in more informal contexts where students could have more opportunities for spontaneous talk and discussions. But we were not very sure how much of student talk and student questioning will occur in such contexts.

5.1 Did students talk?

In the three workshops (variegated tree exploration, ants observations and parachute making), as students worked and interacted in the groups, there were very few long pauses (more than 10 seconds) when students were not talking or not busy doing something. Most of the times students were interacting among each other with a continuous discourse happening amongst them. Often more than one student was talking at the same time.

For example to give an idea of how much talk did happen among students in these contexts, we found about 370 utterances all together by Gurpreet, Hardeep and Jaskaran in the parachute

making in 24 minutes of their interactions. If compared to the classroom situation, we observe much more talking happening in the informal explorations by students. In the other two contexts, the ants observations and variegated tree observation, the amount of student talk was even more than what we observed in the parachute making task.

5.2 Did the students ask questions spontaneously without teacher guidance?

In our workshops with students, we found much more student questioning as compared to the classroom contexts. **Table 5.1** describes briefly the number of questions asked by the students working in groups in each of the three informal contexts.

Table 5.1 Numbers of student questions found in informal contexts

	Parachute making	**Ants observation**	**Variegated tree observations**
Number of students	3	6	11
time for which recorded (min.)	24	33	48
Total questions asked in the entire time	66	97	162
Questions asked per student in the entire time	22	16.1	14.7
Question asked per student per hour	55	29	18.4
Question asked by all the students per hour	165	176.4	202.5

It is interesting to note that in the three contexts, the three groups we recorded, we observed all the students in the groups asking questions. However in our classroom observations we found only a few students in the entire class asking questions. The frequency of questions asked per student that we noticed in these contexts is almost 10 times as compared to what we noticed inside classrooms.

5.3 Types and functions of students' questions

In comparison to classroom contexts, identifying questions (as distinguished from non-questions) and categorising them was much more difficult in out of classroom contexts. In these contexts the discourse was generally very complex with use of language being more complicated and wide ranging (classroom language use was much more simple and limited). Language in informal contexts also involved greater use of expressions and gestures.

Some of the student questions that we notice in informal contexts are of different types and were not noticed in the classroom contexts. **Table 5.2** describes the different types of questions that we have found in the three informal contexts. The relationships between the different types of categorization of questions were given in **Figure 4.1** in Chapter 4.

Table 5.2 Types of student questions found in the informal contexts

Question type	**Parachute making (3 students recorded for 24 min.)**	**Ants observation (6 students recorded for 33 min)**	**Variegated tree observations (11 students recorded for 48 min.)**
Investigable	10	22	73
Basic question of reality	11	20	16
Procedural	19	27	23
Clarification	3	5	22
Explanation	3	3	0
Command	2	3	0
Request	4	4	0
Questions of language	0	0	7
Asking evaluation or judgement	1	0	0
Permission	0	3	0
Confirmation	3	3	10
Rhetorical	13	34	25
Not categorised	2	2	0
Total	**70**	**115**	**162**
Implicit	10	19	25

5.3.1 Implicit questioning

As described in the previous chapter (**section 4.3.1**) all the student questions that we noticed were either explicit or implicit. We here present one example of group implicit question from the ants observations by the girls, who had different kinds of food items, and wondered what to put and how to put them.

13:41 Simranpreet takes some honey in pinch of her fingers [By this time Simranpreet has already taken the sitting position and has stuff in her hand.]

13:43 Simranpreet is perhaps wondering where to put the honey

13:43 Harmanpreet to Simranpreet: ਯਾਰ ਉਰੇ ਲਾਦੇ ਮਾੜਾ ਜਿਹਾ (hey, stick it here little bit) [Harmanpreet asks Simranpreet to touch her finger just above the ants hole on the stem of the tree]

13:47 Kuldeep to Simranpreet: **ਉਰੇ ਲਾ … ਉਰੇ ਲਾਦੇ (stick here...stick here)**

13:50 Simranpreet touches her finger to the stem of the tree to stick some honey there

13:53 Aisha: **ਉਹ ਤਾਂ ਚੋ ਜੂ … ਨੀ ਚੰਗੀ ਤਰਾਂ (it can fall down...do it properly)**

13:54 Simranpreet listens to Aisha and again touches the stem with her finger soaked in honey, maybe to spread it properly

At 13:43 - 13:47 we see that Harmanpreet and Kuldeep tell Simranpreet where to put the honey. This indicates that there is an implicit question: "Where and how the honey should be put?" This question, which is also investigable, arises as there is a conflict: there are various possible places to put the honey, possible differences of opinion as to where it should be put, and reasons why it should be put in one or another place. This implicit investigable question probably arises only when the students are already in the act of putting the honey. If they were just thinking about what to do, the conflicts may not arise. But in the act of doing, more specificity is required, and a decision must be made, more or less explicitly. The act of doing may make the implicit more explicit.

5.3.2 Students' authentic and inauthentic questioning

As discussed in Chapter 2, sometimes questions are asked for purposes other than to seek answers. We have defined such questions as being inauthentic. Most of the student questions that we noticed both in classroom contexts as well as in informal contexts were authentic, such that students did not know the answer to the question.

In our observations of student-student talk in informal contexts, we found two kinds of questions being inauthentic, students' confirmation questions and rhetorical questions. For example in the variegated tree observations, Tanya's question at 02:44: **'हो ना मग show चं झाड आहे, हा मग**

त्याला नावं काहीतरी असेल, ना?' (Okay it's a 'show' tree, but it should have got some name, no?) is an example of a confirmation question.

It is interesting to note that in the classrooms that we observed we did not notice a single rhetorical question by the students but we noticed many rhetorical questions asked by teachers. In the student-student talk in the informal contexts students asked a large number of rhetorical questions to each other, but they never asked rhetorical questions to the teacher-researcher. This indicates that asking a rhetorical question may usually require that the one who is being addressed should not be in a position of too much authority over the asker.

Here is an example of student's rhetorical question. In the parachute making, Hardeep and Gurpreet were tying threads to the parachute one by one. At one point, Gurpreet takes all those threads and tied them together. To this Hardeep at 21:57-1 angrily objected and rhetorically asks why has he tied them. By this he meant that Gurpreet should not have tied the threads yet. To this Gurpreet replies by saying just be quiet. To this Hardeep again replies rhetorically at 22:03-6 by saying **"ਵਾਲਾ ਪਤਾ? (you know more?)".** By saying this he actually meant Gurpreet that you do not know better.

Both rhetorical and confirmation questions may have some implicit authenticity also. Rhetorical questions may be requests, inviting the hearer to agree or react (Henkemans, 2009, p. 16). Confirmation questions may be asked because the asker has some lingering doubt, or wants to check whether the hearer agrees. Though we have categorised the two kinds as inauthentic questions, but their boundaries for being inauthentic are not sharp.

Among the students' authentic questioning, we noticed investigable questions, basic questions of reality, permission question, procedural question, clarification questions, etc. In the informal contexts, we found many of the students' questions were investigable ones, which were very rare in our observations of classrooms (see **Section 5.3.1** for example of an investigable question). In the classrooms, students did not do any of the actual observations of the physical stuff and they hardly had any opportunities to talk with each other. We see these as the main reasons for the lack of investigable questions inside classrooms. It is interesting to note that investigable

questions, basic questions of reality, procedural questions and rhetorical questions together comprised a large percentage of all the students' questions in each of the three informal contexts.

5.4 Summary and discussion

In the three informal contexts we observed that students spontaneously got involved in talking and questioning without much of guidance by the teacher researchers. In these contexts, we noticed much more student-student talk and student questioning as compared to the classroom contexts. In the informal contexts students asked questions spontaneously even without being asked to ask.

In the informal contexts we noticed a large number of investigable questions asked by the students without much of teacher guidance. This is contrary to what other researchers (Chin, 2002) have reported that students need explicit training in framing or asking investigable questions. We will discuss the reasons for students asking investigable questions in informal contexts in later chapters.

Another important category of student questions that we noticed in our study is of implicit questions. Though we did notice a few of students' implicit questions inside classrooms, those questions were mostly questions of individual students rather than the group questions as we noticed in the informal contexts. In the informal contexts we observed students implicit questioning getting explicit as they interacted with each other and with the stuff. So we claim that an important role of student interactions with each other and with stuff is to make students' implicit questioning explicit. No previous studies have described about this kind of questioning.

Also in the informal contexts we observed students' frequent use of rhetorical questioning among themselves for making a point, showing disagreements, presenting a challenge, etc. Research has not yet explored students' rhetorical questioning both in the formal as well as informal contexts.

Chapter 6: Question-answer discourse: Nature and dynamics of the student questioning process

In the informal contexts, we observed much more of student-student talk and student questioning in comparison to classroom contexts. But why could this happen in informal contexts? Why students spontaneously got involved into talking and discussions and asked questions? To understand the reasons, in this chapter we will look into the the nature and dynamics of student-student discourse in informal contexts and try understanding the process of their questioning and answering.

6.1 Understanding the nature and dynamics of student-student discourse

In the three informal contexts, students worked in groups, interacting with each other and with the physical stuff without much of involvement of teacher-researchers. Teacher-researchers did not give any prior instructions on whether students should discuss in groups or talk with each other about their observations. However, students spontaneously got involved in talking and discussions. Even in the variegated tree observations where no prior groups were formed, students themselves formed their fluid groups and did talking. This freedom actually led them to assume and carry out important roles on their own. In comparison to classroom talk, the talk in informal contexts was much more dynamic and complex. Here we will try to understand those dynamics and complexities of their talk.

6.1.1 Understanding student agency in the discourse

In the informal contexts, students had agency in various matters of the discourse like in turn-taking and turn allocation, agency in exploring the stuff, agency in use of language, agency in co-constructing and changing the roles and power relations in a group etc.

As opposed to the classroom talking, where turn allocation and turn-taking was controlled by the teacher, in the informal contexts turn taking in student-student talk happened spontaneously. There was not necessarily any one person who controlled the talk, it was usually decided together by the participants. Nobody explicitly sought permission to seek the turn or change the turn.

In informal contexts, we did not notice any IRE pattern of talk as we had noticed in the classrooms. In the informal contexts, question and response sequences did happen but those were very dynamic and without much of explicit evaluation to the responses. In these contexts, the utterances were not all directed to a particular person as they were in the classrooms. Even if a statement or question was directed to a particular student, we observed instances where other students would reply.

In the three informal contexts, most of the student-student discourse happened as students explored some sort of physical stuff with agency to handle and explore the stuff. At the beginning of the variegated tree observations, some of the students like Nimish were hesitant to touch or manipulate the tree, whereas others like Adil, took the initiative to start observing and touching from the very beginning. With some students handling the tree, other started to follow them. By the end of the 48-minute session for exploring the tree, as a group, the students were quite involved in touching and manipulating the tree.

However, in the other two informal ocntexts, the parachute making and ants observation, students were much more active and felt agency to touch and manipulate the things from the very beginning. This could be because these workshops were done inside the school during the school hours.

Another factor that encouraged the students to talk and ask questions in the informal contexts was that they were allowed to speak in their own language. In these contexts the language used by the students to express themselves was very informal, involving much more range of usage of words, gestures, expressions, sounds, etc. However the language inside the classrooms seemed to be more formal and literary with restricted use of words and sounds. In the informal contexts students even took the freedom to use non-academic language such that they even coined their own words for naming the things. In the variegated tree observations, we noticed students created their own words for naming colours and naming the tree, without asking for recognition of these terminologies from authorities. For example, in the very beginning when one of the girls asked about the variegated tree, another girl replied by saying, 'mixed colour की झाड आहे (it's a mixed colour tree)'. Another girl, Revati, called the tree as 'show tree' and Trupti called it 'white पानांचं झाड (white leaves tree)'.

Also in the informal contexts, discourse among students was very complex with roles being very dynamic and fluid. For example in the parachute making activity, in the beginning Gurpreet was in control telling Hardeep and Jaskaran what to do and how to do it. Hardeep was very quiet and mostly acting mechanically whereas Jaskaran did get involved in argumentation about the design and making of the parachute from the beginning, though Gurpreet did not listen to him much. However, these roles changed with time with Hardeep getting more and more involved in argumentation with Gurpreet and confronting and disagreeing with him.

It is interesting that here students did have the agency to break or reverse their roles as well as roles of other students. But in the kind of classroom discourse that we observed this probably would not happen. As we have described, the classroom discourse was always between the teacher and one or more students, with the teacher being the one who initiated and guided the discourse. Thus the roles in classroom discourse were rigid and fixed.

6.1.2 Understanding student argumentation in their discourse

Argumentation is a dialogical and dialectical phenomenon involving critical engagement with opposing viewpoints through a social and collaborative process (Nielsen, 2013; Walton, 2005). Muller and Perret-Clermont (2009) says that argumentation occurs when there is a plurality or multiplicity of ideas.

Research on understanding students argumentation has generally focused on understanding, categorising, and evaluating the logic, structure (form), and products of argumentation rather than the process (Nielsen, 2013), the context, the function, and reasons for argumentation. Researchers studying student argumentation have largely ignored the role of student questioning in construction of their arguments and vice-versa. Michel Meyer and Marlene Cushman (1982), criticising propositional models to describe argumentation, argues for a question-answer model for describing argumentation.

In the student-student discourse in the informal contexts, we found that student questioning was very crucial for their participation in an argumentative discourse. Questioning led to conflicts and disagreements and conflicts and disagreements led to questioning. Also students used questions, especially rhetorical questions, for various kinds of arguments like showing disagreements, making a point, presenting a challenge, making claim and giving justification.

Students' use of rhetorical questions in student conversations especially in their argumentation has hardly been explored by the researchers.

Apart from making claims, giving justifications, etc. students also used questions to become cognizant of what they do not know, to get others to consider contradictions, and to become meaningfully involved in the discourse, which we see as important aspects for getting involved in argumentation.

Furthermore, student argumentation was not just governed by their questioning or some rational thoughts but also by their collective interactions, emotions, and social power relations. We noticed that, at times, conflicts arising from emotional and power relations dominated to an extent that it inhibited student questioning and their meaningful engagement in the discourse. We specifically found this in the girls' observations of the ants. Much of the argumentation was directly or indirectly about social relations and power dynamics within the group and between the group and outsiders: who should be where, who should or should not do or have done something, whether someone else agrees.

Kim and Roth (2018), who looked at argumentation as a social process, also describe how arguments get constructed in a group as a collaborative process. However, they do not dwell into issues of power relations and emotions within the group. We wonder whether efforts to individualise learning, and stifle (or deny the relevance of) social relations may inhibit discourse and the process of doing science.

Also, we found that observing and handling of physical stuff was important in students' construction and engagement in arguments. For example, in the variegated tree observations, students could not resolve their question about what kind of eggs they had found. It became problematised. A number of students were enthusiastic about doing various things to further investigate this question: keeping the eggs as pets and waiting to see what hatches; breaking an egg open; looking in a microscope (with or without dissecting). There were a range of variables the students considered when giving evidence for their claims as to what sort of animal did the eggs on the leaf: the size; the colour and shininess; the shape; and the number of eggs. Here we see that the students' argumentation was based more on their observations or experience than purely on logical reasoning.

However, interestingly, none of them suggested looking in a book or on internet, and none of them directly asked or suggested asking a teacher (maybe they assumed that if one of the present teachers knew, they would have offered the answer). Thus, having the stuff at hand during argumentation was very important. The point is that, as Eleanor Duckworth (2012) says, "In science, the stuff is the authority".

6.2 Understanding the process: How questioning arose, evolved and progressed?

6.2.1 Explaining the question-answer relation using Meyer's theory of problematology

In order to understand the question-answer relation we analyse one episode of the sequence of students' questions and responses from their observations of the variegated tree. This episode gets initiated by a question about flowers on the tree, verbalised by Trupti. The whole sequence of questions and responses, originating from Trupti's question, occurred in a very dynamic and complex way, with arguments proceeding at a more social, collaborative level than at a personal level. Both the questioning and the answering was collaborative.

For the whole of the episode, the discourse was centred around the two main questions - whether the tree (this particular tree) has flowers or whether the bud-like things are flowers. However there were other questions which emerged during the course of discussions among students like - whether all trees have flowers (implicit question), what could be an example of a flowerless tree, where are the flowers and whether the buds that look like flowers are small leaves. Using Meyer's (1995) ideas on the question-answer relationship, we analysed possible questions in the context of their replies and vice versa. Only when we looked at the discourse in the context of both, the so called questions and replies, we could make a meaningful understanding of the discourse.

Furthermore, it was not a simple q-a sequence in the sense that there was one question raised and answered and then another question and another answer. But rather one question, without being resolved, led to other questions. But how did these new questions emerge? They emerged from the problematological nature of the responses. This is shown for example, when in the reply to Revati saying 'Arre, no, no, all plants have flowers and then they turn into fruit', Ishita says, 'But

there are flowerless plants.' Independently neither of these statements appear to be problematological, but when the two are seen with respect to each other in this sequence, they become problematological giving rise to the question of whether all trees have flowers. Actually, it is difficult to say whether each of these statements in their isolation are answers or questions.

The problems/questions are not resolved or answered completely. They persist. So this nature of discourse cannot be understood in terms of 'problem solving' in which the problem becomes eliminated or closed but in terms of problematology in which problems are partially solved and partially persist explaining the rise of newer questions.

As the group/s did not come to a resolution on the question/s, questioning persisted. So this non-resolution or problematological answering gave rise to questioning. And answers were problematised with the questioning of answers (Meyer, 1995).

It may not have been important that the questions were resolved or not. It was less important that the students found out whether the tree had flowers or not than that they raised the questions and engaged in the process of observing and investigating, recognising conflicts.

6.2.2 How questioning initiated, evolved and progressed: Role of conflicts and disagreements

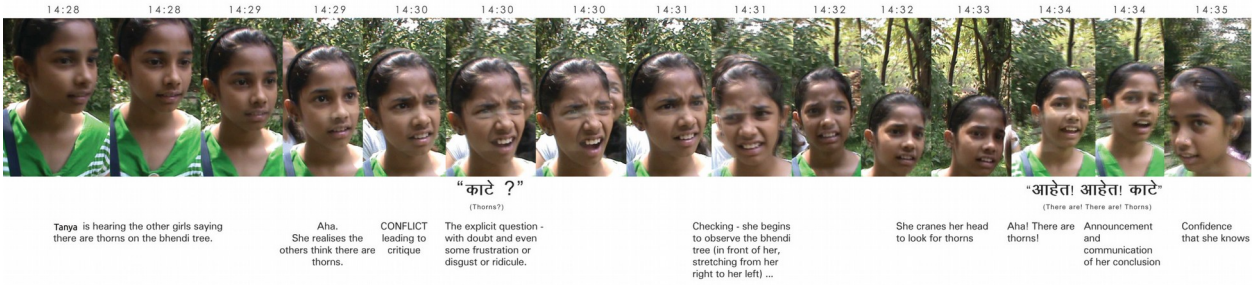
According to Meyer and Cushman (1982), to question something is to evoke alternatives. A question only arises when there are multiple views or opinions. Showing disagreement or conflict with some opinion is to evoke an alternate opinion.

In our observations of student-students talk in the informal contexts as well as classroom contexts, we found disagreements between student and student, between student and teacher, between students and physical stuff and between student himself/herself. These disagreements gave rise to questioning. It was not just that conflicts and disagreements led to questioning, questioning in turn also led to conflicts, disagreements or formation of alternate opinions and that's how the discourse and questioning sustained (Singh & Haydock, 2018). Since both of these processes may occur simultaneously and interdependently, it is a dialectical process.

Students not only showed conflicts and disagreements with others but also with themselves. Here is one example from variegated tree observations (**Figure 6.1**). This 10 second episode presented

through snapshots, shows the verbal and facial expressions of Tanya. It shows how a conflict arose from other students' observation and how it leads Tanya to question her own belief about the presence of thorns on the tree and then her observation of the tree, leading to a change in her earlier belief.

Figure 6.1 Tanya's 10 second investigation of thorns on the tree



This aspect of questioning, to challenge not just others but one's own beliefs as well, we believe is central to doing science and this is what we expect of the discourse in science classrooms to include. These and many other episodes present examples of different types and combinations of confusions, oppositions, and negotiations among students.

In our observations, students generally did not believe what they were told but instead called attention to counter-examples and showed disagreements with their peers and as well with their teachers. One of the reasons, for such disagreements, could be students' emotional attachment and ownership to the questions and the discourse.

6.2.3 The role of the nature of physical stuff: its role in questioning process

The outdoor environments, for example the variegated bhendi tree and the ants, were themselves dialectical. The tree was inherently contradictory: in addition to green leaves, it had leaves which were white and other colours even though green pigment is required for photosynthesis; it had root/thorns; it was a 'flowering tree' without flowers; etc. Even the colours were not what they appeared to be: they depended on the light and the environment, and even on social factors. We claim that this obvious contradictory and dialectical nature of the tree led the students to observe more closely, and observation led them to become more aware of the dialectical nature of the

tree. The dialectical nature of the stuff was the basis which gave rise to the students' dialectical conflicts which in turn gave rise to interactions, discussions, and questioning.

6.3 Summary and discussion

In student-student talk in the three informal contexts, we observed students taking agency in various aspects of discourse like turn-taking, initiating and terminating turns and topics, exploring the stuff, use of language, shaping roles and relations within a group etc. We see these as crucial roles to be performed by the students to participate more meaningfully in the classroom discourse. So the discourse in informal contexts was guided and shaped by the students themselves collaboratively. In comparison, classroom discourse was guided by mostly the teacher. Barnes and Todd (1977) argue that for a meaningful discourse in the classrooms students must be given authority for making important decisions in the talk. Van zee (2000) argues for the role of a teacher as as an organiser or context setter in such kind of discourse.

In the informal contexts students worked in small groups and had discussions with very little teacher guidance. Working in small groups probably help students form questions, because conflicts between different students' statements and observations are apt to arise because of students' perspectives and experiences. A student working individually may be more apt to think a question is resolved before it is even explicitly stated. Without realising that there is a conflict, an authentic question will not arise.

We see conflicts and disagreements with others as well as oneself as one of the important reasons for questioning to occur. This aspect of questioning, to challenge others as well as one's own beliefs, we see central to doing science and this is what expect the discourse in science classrooms to include.

Also, the question-answer process in the informal contexts we studied was very dynamic and comples. It progressed through sequences of questions and replies arising from interactions among students and students, and students and the physical stuff. Furthermore, at a number of occasions, we saw a shift in replies from being 'not questionable' to 'questionable'. Also the process of student questioning was not isolated from their observing, arguing, investigating, etc. We discuss these interrelationships in more detail in the next chapter.

We also noticed that student argumentation was closely tied with their questioning. Questioning arose because of the difference in opinions and conflicts. So the very reason that argumentation could emerge and sustain was questioning. Questioning was used by students to present different kinds of arguments like claim, justification, counterclaim, disagreement etc. However, in studies of student-student argumentation, the role of questioning has been completely ignored by researchers.

Our study provides evidence of the temporal nature of questions. We found that it is not easy to identify a moment in time when a question exists in a student's mind, or amongst a group of students. Implicit questions may gradually or suddenly become explicit, and may evolve over time, depending on the interactions between the students, and the interactions between the students and the real-world context - the stuff they are handling. Questions may appear and disappear - and even suddenly become replaced by transformed questions.

Chapter 7: Understanding the role of the student questioning process in doing science

As described previously (**Section 2.3** and **Section 3.4.2**), we see science more as a process than a body of knowledge, a process consisting of various elements or aspects of the 'science-toolbox', occurring in various orders and combinations. We also described how we see science as a questioning process, a process of dialectical interaction of questions and answers. Using this understanding of the nature of science we can make a meaningful analysis of the process of questioning - while also considering the nature and dynamics of students' question-answer process as described in Chapter 6.

7.1 Students' investigable questions and their investigations

In the three informal contexts of student interactions that we report in our study, we observed students asking many investigable questions (**Table 5.2**). The answers to these questions were relatively more contentious. They required or could lead to, some kind of investigation on part of students for answering such questions. We also noticed students performing investigations on their own to answer many of these questions.

We found that the sequences of dialogues initiated by students' investigable questions were interesting, in that they involved different kinds of confusions, conflicts, questions, agreements and disagreements among students. Many a times investigable questions did not get resolved completely and this at times led to long argumentative sequences of questions and responses.

For example from ants observations, girls had different kinds of conflicts: whether ants could eat large pieces of jaggery or they need to be fed very fine pieces, whether the ants will get afraid of their actions or movements or sounds near the ants' hole, whether this will prevent ants from coming out of the holes and eating jaggery, whether there are ants beneath the sand, whether ants will find the jaggery on their own or whether they need to be fed the jaggery pieces (like babies need to be fed). For all these so called investigable questions, girls tried doing different things like breaking jaggery into smaller pieces, scratching sand with stick, keeping quiet, not doing movements very close to ants hole, etc. Some of these questions were never resolved and persisted till the end.

Most of the students' investigations were spontaneous and immediately followed the question or occurred alongside the question. However at one of the instances we noticed a very interesting investigation carried out by a student who first carefully planned it with the help of his friend and then carried it out.

This episode is a part of the variegated tree observations by the students. In the very beginning, at around 02:26 minutes, Adil, standing along with another boy Keshav, went closer to the tree and touched a leaf which was mostly white with a little green and said, **'रंग तर गेला नाही ना? (Hasn't the colour gone?)'**.

Upon seeing Adil, another boy Nimish, standing slightly away from the tree said, **'हात नाही लावायच रे, कळत नाही काय? (Don't you know that you should not be touching it?)'**. With Nimish telling Adil to not touch the leaves, Adil moves back. Thereafter, Adil did not do or say anything about his question until after 5 Minutes, when he tried to investigate it.

Figure 7.1 Paint chipping off a wall compared to colour of the leaf

It could be that the variegated leaves might have reminded Adil of the way a wall looks when its paint starts chipping off (**Figure 7.1**), and by analogy, he hypothesized that the green colour was chipping off the leaves. He wanted to test this hypothesis by performing an investigation: scratching the leaf to see if the green colour comes off easily.

Adil did not give up on his original question. Five minutes later, when Nimish was some distance away, he planned to do an investigation by scratching a leaf to see if the green colour comes off easily. He took the help of his friend, Kaustubh, who watched the teacher (Karen) and told him when she looked at him while he was scratching the leaf. As Teajs was scratching the leaf, Karen turns over. Then they each pretended in their own way that they were not doing anything wrong: Keshav looked down and away, and Adil definitely looked straight at Karen, with an expression of contrived innocence (**Figure 7.2**).

For Adil the entire investigation seemed illegitimate: not being allowed by the teachers, although we never intended this and wanted the students to ask and investigate on their own.

Figure 7.2 Adil and Keshav pretending their innocence

In this episode, we see how the observation of dubious physical reality, made Adil confused and curious, led him to ask an investigable question and then take a 'risk' to investigate and answer his question. It explains an interesting aspect of asking questions and being curious, which is taking of 'risks'. Here in order to investigate his question Adil had to take the 'risk' of being 'caught' by the teacher. Just as in the classrooms, in everyday life also asking questions and being curious sometimes could be a risky affair especially when questioning involves challenging the status quo. So the way Adil pursues his question so fervently makes us wonder why students in classrooms become so passive, why they are not so curious.

7.2 Interconnection between questioning and other aspects of scientific inquiry

In our study of student questioning we observed questioning was not separate from other aspects like observing, hypothesising, arguing, comparing, analysing, investigating, etc. Each of these had a dynamic and dialectical relationship.

7.2.1 Student questioning and student observations

In the variegated tree observations, students had a question about the thorns on the tree. Only much after the workshop did we realise that this is a very interesting question, because we discovered that the variegated Talipariti tiliaceum is unusual (and different from the unvariegated variety) in that it has small aerial roots which appear in the monsoon monhs, some of which later turn into something that looks like thorns (**Figure 7.3**). So we ourselves wondered whether they are roots or thorns. Can one thing be both a root and a thorn? When does it stop being a root and

become a thorn? This is an example of an overlapping category: a root and/or thorn. This sort of classification is often ignored by school textbooks and teachers (Haydock & Patil, 2014).

Figure 7.3 Aerial roots on variegated tree

While answering the question about thorns, students got involved into seeing, touching, observing, hypothesizing, communicating, and questioning simultaneously, occuring in an interconnected manner. Observing led to questioning and questioning led to observing. This emphasizes our contention that science is a process, not a static thing. The answer in this case, the question about thorns, was still in substantial doubt, even if some students seem convinced one way or the other. It leads us to consider another teaching objective: for students to be ready to consider compelling evidence which contradicts even a strongly held belief in order to resolve contradictions. In other words, we hope that students are learning that in doing science, they must keep observing and referring to the "stuff" as the authority (Duckworth, 2006).

This also shows how both observing and questioning are very fundamental to the doing of science. So we can say that as students did observations they challenged/changed/modified their beliefs, which is the very act of questioning.

7.2.2 Role of language and student-student talk in doing science

Science is a social activity grounded in the actions, experiences, and interactions of human beings as part of a community who share certain values and beliefs. So science is a collaborative and collective act which cannot be reduced to individuals (Roth, 2007). Central to this collaborative act is the use of language.

In our observations of students in the informal contexts, we observed students engaging in various aspects of doing science, with student-student discourse being central (or crucial) for the

process. As described in Chapter 6, we noticed that students' agency in the use of language was one of the important reasons for their engagement in the discourse. Furthermore we also described how students took agency in steering the discourse. Since students had opportunities and agency in talking and communicating, conflicts inevitably led to questioning. So the act of letting students have a discourse in their own language in small groups while handling stuff was one of the main reasons for them getting engaged in different aspects of doing science.

7.2.3 Questioning and argumentation

Student questioning and argumentation were interdependent and in turn were related to other aspects like observing, interpreting, predicting, etc. in the doing of science. Observing and handling of stuff led to questioning and argumentation, and also questioning and argumentation led to observing and handling of the stuff. The interactions between students' questioning, their investigating of the stuff, and their argumentation were very complex and not linear. This is unlike the classroom contexts, where most of argumentation or reasoning was based on teacher or textbook's authority.

7.2.4 The importance of the stuff

In our observations we noticed that stuff or the physical material was very crucial for arguing, justifying, providing evidence, observing, investigating, etc. With students having agency in exploring the stuff they spontaneously observed and manipulated the stuff as they did questioning and argumentation among each other. Furthermore, as described in Chapter 3 (**Section 3.4.2**), we see reality as dialectical having inherent conflicts and contradictions and thus understanding and studying it involves conflicts and questioning.

Physical stuff played an important role for engaging students in different aspects of the scienrific inquiry. For example, in the ants observations, initially, students were given only jaggery to feed to the ants. The group of girls that we observed and report in our study, fed the jaggery to the ants, but it seemed that not many ants were coming over to the jaggery. At around 10 minutes girls seemed to be slightly bored and were asking Karen whether they can go.

But then they were given more types of food and suddenly girls seemed to be very excited, and again got interested in the ants. There was a lot of confusion and disagreement about which is

what, how to pour honey, where to pour honey, whether more ants would come on suagr, which stuff will make more ants come out, making the entire scene very interesting.

7.3 Science as a Question-Answer process of various interconnected aspects

In our observations of the student interactions in three informal contexts, we found students questioning, observing, arguing, justifying, giving evidence, hypothesising, predicting, classifying, comparing, investigating, etc., with all these aspects occuring in a complex interconnected way. We found that all these aspects of doing science were in turn interdependent upon student-student talk and their use of language. Student-student discourse was sustained because of conflicts between students and students and between students and the physical stuff. Because students had agency in bringing their varied ideas and experiences, conflicts and questioning was inevitable. Furthermore, in the informal contexts doing of science was more a collaborative and collective act.

We found that the observing and handling of the physical stuff was also crucial for doing of science. It was not just the presence of the stuff but students' agency in handling and exploring the stuff which was more important. Students' questions as well their replies were shaped by their continuous observations and interactions with the physical stuff. They did not resolve their questions purely on the basis of abstract reasoning. They were continuously referring back to the stuff for evidence, particularly when a justification for an argument became more controversial or the abstract reasoning did not work.

As compared to informal contexts, in classrooms that we observed, the students did not observe, investigate, or handle stuff - they only discussed it. Furthermore in classrooms, most of the discourse was between the teacher and students as compared to the discourse between students and students in the informal contexts. In classrooms we observed students getting involved into very few aspects of doing science, and that too in a very minimal and constrained manner. Students hardly got opportunities to ask questions, most of the times they only answered teacher's questions and answering only in particular ways as acceptable by the teacher.

Meyer (1980) sees the importance of questioning in professional science as well as in everyday learning. Using Meyer's theory of problematology, we have tried explaining the students'

questioning process and its role in doing science. Using the theory we could explain how newer problems or questions emerge from the problematological answers or replies, the answers which are partial in the sense that they refer both to previous problems that they have solved and refer to newer ones that they have given rise to. Such an understanding places focus on the importance of questioning in learning and doing science. Meyer (1980) argues that in science also, more attention has been given to the answers than to the questions. The act of asking, the process of asking, the nature of questions and the relevance of questions (in terms of whose questions and questions for whom) has not been given due regard. Meyer criticises such a positivist conception of science, where answers or results are seen as more important than questions and are seen in isolation to the process of questioning. The progress of science can only be understood by conceiving it as an integrated question-answer process.

As observed in classrooms, the purpose of questioning and answering was to resolve conflicts and disagreements. However we think, questioning is not just to resolve conflicts, but also to recognise and to create conflicts. Conflicts lead to further questioning and the need for further observing and investigating. We see questioning as being interdependent with observing and manipulating 'stuff' - things/processes in physical reality. Our goal as teachers is not just to increase scientific literacy by "making individuals critical consumers of scientific knowledge" (Millar & Osborne, 1998), but to promote scientific temper by encouraging people to collectively work together to become active questioners and practitioners of science throughout their lives - and to thus become more active participants in the process of intentionally creating a better, more just and more equitable world (Freire, 1968).

We want students to have dialogue in which they try to understand physical realities in relations to social realities and how the two realities are intertwined and not separate. That's how we interpret science.

Chapter 8: Outcomes, implications and future directions for research

In this study, we looked at the nature and dynamics of student talk and student questioning in the classroom as well as in the informal contexts to understand the process of their questioning. We also looked at teacher questioning to better understand the nature of classroom talk and

classroom questioning. Further, we analysed the role of student questioning in *doing* science and how it was related to various aspects of doing science.

As observed in our study, there are many important aspects of students' talk and student questioning in the informal contexts that are significant for the classroom contexts. Here, we briefly discuss these implications. Also, we discuss the implications for future research regarding student questioning and our own plans for extending this research.

8.1 Understanding the nature and dynamics of classroom talk and talk in informal contexts

In our investigation, we found students talking and asking much more in the informal contexts than in the classroom contexts. The talk in the informal contexts was mostly between students and students whereas in the classroom contexts it was mostly between the teacher and one student at a time (see **section 4.1** and **5.1**). We saw how student talk in the informal contexts was crucial for the process of questioning and investigating - and in *doing* science.

The nature and the dynamics of teacher-student and student-student talk in the two contexts were different. And only by understanding these dynamics, we understood the lack of student talk and questioning in the classroom contexts.

8.1.1 Authentic dialogical informal talk versus inauthentic monological classroom talk

In the informal contexts, student talk was mostly situated in genuine problems or questions occurring naturally and spontaneously. Here, the student talk was more meaningful, as they engaged with each other in questioning, answering and in arguments initiated by their own questions (see **section 6.1.2** and **7.2**). In classrooms, the talk was mostly between the teacher and one student and initiated/directed by the teacher's questions. This discourse did not involve any instances of observing, manipulating or investigating stuff with very few instances of student argumentation. In the informal contexts, student-student talk ensued and progressed on account of student questioning and argumentation while engaging in observing, manipulating and investigating the physical stuff. As students brought in their varied experiences and meanings, talk in these contexts was more dialectical in the sense that it emerged from opposing or

conflicting opinions among students, or conflicts between their beliefs and observations (see **section 6.2**).

Student utterances in informal contexts, where they addressed each other, were longer and more complex than student utterances in classrooms, where they addressed teachers. This is similar to what is reported by Dillon (1983) who points out that students more readily engage when they ask questions to each other, and give longer and complex responses than when they respond to teacher's questions.

In the informal contexts, students' did not simply believe what they were told, they often disagreed, challenged, questioned and gave counter-examples to present their opinions. Handling of physical stuff played an important role in this. Contrary to this, the classroom discourse was confirmatory and had very few argumentative instances of disagreements /challenges (see **section 4.3.3**) and it did not involve any instances of handling, observing or manipulating the stuff. Similar observations had been made by Sarangapani (2003 p. 214) who argues that in everyday sphere, contrary to classrooms, children do show disagreements and call upon evidence in case of conflicts.

8.1.2 Student agency and student autonomy in discourse

One of the important reasons that students felt more autonomy in the discourse in informal contexts was working with peers in small groups. Here, the discourse was collaboratively governed by students with its dynamics being very different from the classroom discourse.

In the informal contexts, students' participation in the talk was much more dialogic and democratic than the classroom talk. The decisions: who will talk, when someone will talk, what would be the topic, whether someone could disagree, whether a particular question or a response would be taken into consideration, etc. were all collaborative and spontaneous. These decisions were not explicit and emerged through dynamic student-student and student-stuff interactions. Meaning and validity of talk was situated in the context of the discourse rather than in the authority of textbooks or teachers (see **section 6.1.1**).

The classroom talk was also dynamic in the sense that it was not pre-scripted and was not a line by line or para by para recitation of the textbook but was spontaneous and developed with the

progress of the discourse. However, the classroom talk was governed by the teacher and the textbook. Important decisions regarding the turn-taking, topic of discourse, who would ask and answer, what would be considered as a question and as an answer, etc. were controlled by the teacher. Also, the structure of the classroom talk majorly followed IRE sequences (see **section 4.4**), where teacher questioning is structured around fixed or predetermined responses. This has been found to restrict student opportunities to participate in the discourse and demonstrate their argumentative abilities (Van Booven, 2015). However we did notice a few instances of student resistance by breaking these sequences through their questioning and getting involved in argumentation with the teacher.

In the informal discourse, we could not find the IRE pattern as observed in the classroom talk (see **section 6.1.1**). Working in groups in the informal groups, students had the agency not just in guiding the discourse but also in co-constructing and changing the norms of the discourse. The power relations and roles between students were dynamic which evolved/changed over time unlike being rigid teacher-student roles inside the classroom (see **section 6.1**).

Why did students have more agency in informal contexts? There are many factors that contributed to this. The students had agency because they had the stuff to observe and handle, and the informal environment conferred agency. The language in use was informal. Although the broad topic was decided by the teacher/researchers, to a great extent the specific contents for the talk and discussions were decided by the students. They were able to take agency because it was not taken away from them: they were hardly being admonished, punished or even evaluated.

This indicates that the students did not need to be 'taught' to take the agency to carry on discussions and arguments. They need opportunities. They need to be in a context where their agency is not being taken away. In such contexts, students are able to utilise their skills and competencies that exhibit their creative potential. Barnes and Todd (1977) argue that transmissive teaching practices undermine the creative potential of the children.

> *We do believe, however, that children are often underestimated, and that they possess skills and competencies which are rarely called upon in a conventional classroom (Barnes & Todd, 1977, p. ix)*

In the outside world, where children exhibit their natural competencies and thinking, calls for an investigation and understanding to bridge the gaps between everyday and school learning.

8.2 Understanding the student questioning process in informal contexts

Student questioning in the classroom and in informal contexts was different in many aspects. The differences were not just in terms of frequency or types of questions but also, and more importantly, in terms of the nature and dynamics of the questioning process in the two contexts.

8.2.1 Frequency, types and functions of questioning in classroom and informal contexts

Questioning in classrooms was dominated by the teacher, which mainly aimed at quizzing, evaluating and assessing students. In classrooms, questions have fixed and predetermined answers and students are supposed to memorise those answers. This is how they learn and acquire 'knowledge' (Sarangapani, 2003, p.169). However, the meaning and function of questioning that we observed in informal contexts was different; it was for various purposes and reasons like expressing requests, commands, anger, disagreements, surprise, disbelief, doubts, etc (see **section 5.3**).

Although in the informal contexts, more of the student questioning was authentic, there were questions like rhetorical and confirmation ones, which were relatively less authentic. It is interesting that inside classrooms, we did not observe a single rhetorical question by the students, though the teacher did ask a number of rhetorical questions. They were generally used for asserting opinions and showing disagreements. However, in the informal contexts students used rhetorical questioning to present challenges, show anger, express control or authority, etc. (see **section 6.1.2**). The absence of students' rhetorical questioning in classrooms indicates the lack of student agency and the hierarchical power relationship between the teacher and students in the discourse. However previous reaserch has not looked into these aspects of rhetorical questioning.

Another kind of questioning which previous research has not focused upon is students' implicit questioning. We observed this questioning in both the informal and classrooms contexts, though in classrooms it was comparatively rare. In the informal contexts, it occurred mostly as a group

questioning. That explains the rarity of these questions in the classroom context (see **section 5.3.1** and **4.2.1**).

Furthermore, in the informal contexts, we found students asking many more investigable questions than in classrooms. We found these questions as being more crucial for students' engagement in the discourse as well as in doing science. These questions led to longer, more complex argumentation (see **section 7.1**).

Questioning also played an important role in students' argumentation in both contexts. Not only students used questioning for presenting different kinds of arguments but importantly questioning and argumentation sustained each other on account of conflicts and disagreements. Our study is one of the few efforts to explore the role student questioning in their argumentation and the the role of social aspects in student argumentation.

8.2.2 How and why did student questioning occur and sustain in informal contexts?

One of the important reasons that students were able to ask more questions in informal contexts was that the discourse was mainly between students and guided and controlled by students themselves without much of the involvement of teacher/researcher. Students had agency in various matters of the discourse and this led to a more meaningful participation or engagement. In the informal context, students used language for expressing and understanding meanings in ways which were less constraining as compared to their use of language inside classrooms. The meaning-making was more collaborative and situated within the students' everyday experiences of the use of language. This is in line with Wells (2009), who argues that students' everyday experiences and language are valid and important in doing science.

But why did questioning arise at first and sustain in these contexts? In our analysis we found that students' questioning arose as a result of a number of different types of conflicts they faced: (a) conflicts between different observations; (b) conflicts between observations and beliefs; (c) conflicts between one's own beliefs; (d) conflicts between different students' beliefs; (e) conflicts between observing and not observing; and (f) conflicts between knowing and not knowing (see **section 6.2.2**).

Since there were differences of opinions, questioning arose and since those differences persisted, questioning and dialogue sustained. However, in classrooms where the discourse was mostly confirmatory, it often suppressed conflicts and disagreements. There were more procedural, clarification and confirmation kind of student questions in classrooms, and fewer questions voicing disagreements. Without the existence of multiple viewpoints or opinions, opinions or beliefs cannot be formed or changed. This is the process of learning. Children come to school from different backgrounds and cultures, with varied experiences and this could be source of their learning, their conflicts, and their questioning.

One of the things that led to conflicts and disagreements were handling and exploring the physical stuff. Since students' had agency in handling the stuff, they observed, manipulated and investigated it. Students were talking and arguing as they explored different things. Their asking was inteconnected with their observing, arguing and investigating.

So conflicts and disagreements gave rise to questioning and questioning, in turn, gave rise to conflicts and disagreements. Thus the discourse in informal contexts was comparatively more problematological in the sense that it was non-resolutory in nature. Meyer (1995) argues that language as well as discourse in general is problematological in nature. It is this problematological nature of answers or replies that explains the emergence of newer questions and hence the progress (see **section 6.2.1**).

One reason that students asked so many questions in the informal contexts could be that they were talking, not writing. Oral questioning is a dynamic process, which is more changeable, responsive, and 'living' than a relatively fixed, static piece of writing. Because talking is more spontaneous and immediate than writing, it may be more open to innovation and questioning. Vygotsky (1966) pointed out that, 'The motives for writing are more abstract, more intellectualized, further removed from immediate needs. …Writing also requires deliberate analytical action on the part of the child' (pp. 181–182).

8.3 Role of student questioning in doing science in informal contexts

The pedagogy of science that we observed in classrooms, was transmissive and focused around understanding the concepts or facts of science without engaging students in different aspects of science. In all the three classes, classroom teaching hardly provided any opportunities for the

students to do observations or investigations. Most of the classroom discourse and argumentation was driven by the teacher or textbook questions rather than the student questions, with predetermined answers (see **section 4.5**). So rather than questioning and answering emerging from students' own experiences, it was based on the authority of the teacher and the textbook that represented the so-called 'body of knowledge' of science.

This contrasts with what happened in the informal contexts: both questions and answers emerged through students' interactions with each other and the physical stuff. In these contexts, students engaged in different kinds of observations and investigations based on their own authentic questions. Analysing students' interactions in these contexts helped us in understanding how student got engaged in different aspects of doing science and how these aspects were interconnected with each other and with the process of student questioning (see **Section 7.2**).

8.3.1 Science as a questioning process of various interdependent aspects

In the informal contexts, students engaged in various aspects of doing science like observing, questioning, hypothesising, arguing, classifying, comparing, investigating, answering, etc. All these aspects were interconnected and interdependent with each other in complex ways, with questioning and observing being central in the process (see **Section 7.2**). Student questioning, as well as their answering, was dynamic that was evolving and progressing throughout. Students' arguments and their questions, especially rhetorical questions, were also guided by their emotions and power relations. Thus student engagement in different aspects of doing science was not just guided by their rational thoughts or decisions but also by their emotions and social relations (see **Section 6.1.2**). Questioning, observing, investigating, etc. were all done as part of a collaborative and collective process and were dependent upon student-student interactions.

One of the reasons that students got engaged in various aspects of doing science in informal contexts is that they were able to ask their own authentic questions arising out of various kinds of conflicts. And since students 'resolved' these questions themselves through their interactions and investigations with the physical stuff rather than relying on the authority of the teacher or the textbook, they inevitably engaged in different aspects. So both, the process of asking and answering was part of one process and intertwined in such complex ways that it was often

difficult to identify which was which. Moreover, since answering was partial or problematological, questioning sustained and progressed.

8.4 Implications and suggestions for classrooms, teachers and educators

Freire and Faundez (1989) have argued how the present education system is based on the pedagogy of answers, and hence anti-democratic. They argue for a pedagogy of questioning. We found that this pedagogy of answers is particularly prevalent in India, where schooling trains children at answering and not at raising questions, especially questions which are critical and challenge the status quo. As Padma Sarangapani writes: "... just one question from a student can threaten the status quo." (Sarangapani, 2002, p.12). It is not hard to see how fear is instilled and an unquestioning obedience to the teachers and textbook is enforced.

Though in our study we looked at particular classrooms, we could not understand the nature of student and teacher questioning inside these classrooms without reflecting upon the nature of education and schooling in general. So our analysis of classroom questioning or questioning in informal contexts required reflecting upon the role of larger existing social, economical and political structures (as discussed in our framework in **Section 3.4.1**). Thus the implications and suggestions which emerge from our study could be meaningful only when considered in relation to the possibility of systemic changes in education and in society.

8.4.1 Creating more equitable and democratic classrooms: Transforming student agency

1. In schools, we emphasise and value facts and answers. We like definitive answers. We like certainties. We admire those who provide answers. This over emphasis on answering undermines the importance of questioning.

However, questioning arises when we have perplexity, ambiguities, doubts, hesitations, dilemma, alternatives. So unless we give space for alternate student views and ideas, questioning would not arise, and we here see a close connection between questioning and democracy.

As we found in this study, conflicts and disagreements are the means by which questioning and discourse get sustained. So maybe we need to move away from the fact and concept based

confirmatory education towards a critical education based on the pedagogy of questions, with questions arising from students' experiences and their genuine problems (Freire, 1968).

2. We found that student whispering was an important means by which students engaged with each other in questioning and argumentation in classrooms. We think that such 'illicit' talking between students is important for their learning. Perhaps students sitting in the back of a class are already whispering illicit questions and raising challenges to what the teacher, textbook or other students are stating. So teachers can purposefully encourage such talk, maybe by taking unplanned pauses, as it would provide opportunities for students to talk amongst themselves.

3. In the informal contexts, we purposely tried to subvert the hierarchical power structure in which teachers control and guide students on what to do and how to do, but we were not sure how the students would react. However, they did show a collective agency. They gradually took control over the situation, as they realised that they could take quite a bit of freedom and that the teachers were not admonishing them.

We think this change or subversion of power was important for making students realise that their questions, observation, arguments, investigations, etc. are important and meaningful.

But how will this change come? For example, decreasing the reliance on the authority of textbooks and going beyond the textbook frame. Let students ask questions even if they are not directly related to a textbook topic. Teachers can purposefully try talking less and asking fewer questions and sometimes even being quiet. Teacher can try reducing their evaluation on students' responses and can rather ask for an evaluation from other students through discussions.

4. We found classroom discourse was governed by certain norms which restricted student talk and student questioning. For example, answering by students was supposed to be done in a particular way and little deviation in language, content or expression of their answers, was counted as 'wrong answers'. Also, there were norms like students cannot speak up in class, and interrupt—without raising their hands or being called upon. They cannot speak out of turn. They cannot disagree with the teacher and the textbook. They cannot speak and argue directly among each other in the classroom without teacher permission or teacher as mediator.

Unless we understand that the existing classroom norms are constraining and restricting students' participation, the situation won't change. So teachers need to reflect upon these unsaid norms and do conscious efforts to subvert such norms.

It's important that students start talking, and they should realise that their talk is important. We want that children should be given ample opportunities to talk and ask questions among themselves. They should realise that others (teachers, parent, and adults) are listening to them and valuing their questions.

8.4.2 Changing classroom practices of doing science

It is important that in schools we should be able to teach science in ways such that it should not project a distorted nature of science. There should be more opportunities for students to do science in classrooms where they get engaged in aspects like questioning, observing, arguing, investigating, etc. in small groups. The classrooms we observed hardly provided such oppotunities to students. We think unless students actually handle some physcial stuff and work to solve some of their own genuine problems, they cannot understand the nature of science.

8.4.3 Suggestions for Teacher Professional Development (TPD) programmes

1. It is important that there should be a discourse with teachers around their ideas of teacher and student questioning and how those ideas could be problematic. In my own experience of interacting with teachers, I have observed some teachers listing questions (when asked to list their questions after they observed some stuff and had discussions about that) for which they knew the answers. Also teachers sometimes think that science can provide answers to all questions and that answers of science are fixed and definitive or unique. Also teachers think that they should provide answers to all the students' questions, whereas there can always be some student questions which teachers cannot answer. Having a discourse around these and other issues with teachers could help make classrooms more conducive to student questioning.

2. Also there is need to have have discussions with teachers about how and why the process of teacher questioning (IRE process) occurs and how such a process might be constraining the student questioning.

3. Teachers can also be trained in some sort of action research whereby they listen to the recordings of their own classrooms or observe classrooms of other teachers to understand how much questioning students do in comparison to teacher questioning and whether and how teacher questioning influences student questioning.

8.5 Implications and suggestions for other researchers

Our study provides some insights and directions to previously researched aspects of student questioning. Our study also brings forth new aspects of student questioning. Further research in these older and newer aspects could lend important insights.

1. Implicit student questioning and the process of implicit questions becoming explicit.
2. Teacher and student rhetorical questioning and how it could help understanding the dynamics of student-student and student-teacher discourse, especially power dynamics.
3. The interrelation between student questioning and their argumentation.
4. Role of social factors like emotions, power relations, gender etc. in student questioning and argumentation.
5. The interrelation and interdependence between student questioning and various other aspects of doing science, like observing, various kinds of reasoning, hypothesizing, investigating, etc.
6. Role of physical stuff in the student questioning process.
7. Students' non-verbal questioning (gestures, facial expressions, etc.).

8.6 Limitations of the study

Though we wanted to observe and analyse students' spontaneous talk without any adults or the teacher, it was of course not possible to record or observe students without being present and therefore having some effect on the students. Their talk that we recorded was indeed informal but it may not have captured the kind of discourse students might be doing in their everyday talks without the presence of any adult around. We do think that it is important to understand student questioning in the absence of adults.

In classrooms it was not easy to find out what individual students were doing, whether they were listening to the teacher, what they were whispering, or whether they were engaged in some questioning with each other or with themselves. One of the reasons for this difficulty was that for

two of the classes (among three reported in this study) we only made audio recordings and thus could not see what students were doing. Also, we could only hear the voices of students who were talking loudly or sitting close to the recorder. Even in the class that we video recorded, we used only one video camera, which could only focus on a few of the students' actions.

Since we were interested in students' spontaneous questioning, in our reports we concentrated on their oral questioning. Though we have also collected students' written questions, and have done some analysis of them, we have not written about this work. Students' written questions could reveal more about the process of questioning, especially in relation to classroom contexts where more stress is given on written work.

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List of publications based on this PhD work

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Singh, G., Shaikh, R., & Haydock, K. (2018). Understanding student questioning. *Cultural Studies of Science Education*. https://doi.org/10.1007/s11422-018-9866-0

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