# Chapter 10
# The Promotion of Science Values: Science Teachers' Perspectives and Practices

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**Abstract** Based on a qualitative case study, this chapter analyses science teachers' perspectives and practices with regard to the promotion of two curriculum-intended values—curiosity and rational thinking. Six science teachers representing a range of geographical locations, school types with different class sizes, lengths of teaching experience and educational qualifications, along with their associated science classes, each representing a case, participated in this study. Data were gathered through observing the teachers' science lessons, interviewing them as well as interviewing their students in focus groups. The cross-case analysis suggests that while both of the values were perceived to be important by the teachers, there were marked differences in their perceived importance and the corresponding teaching approaches. The discussion explores the meaning of these findings in terms of school science educational practice in Bangladesh.

**Keywords** Science teaching · Scientific literacy · Science values · Curiosity · Rational thinking

## Introduction

Like in many other developing countries (see, e.g. Nargund-Joshi, Rogers, & Akerson, 2011; Rampal, 1994), superstitious beliefs have been historically embedded in Bangladeshi society (Hossain, 2010). Hossain mentions some common superstitious beliefs held by Bangladeshi people, for example, wearing a *tabeej* (amulet) or ring for protection from evil spirits, getting pens blessed by a priest before exams and using a *tabeej* or voodoo doll to bring harm to enemies by using *kufri kalam* (incantation)—a common practice of black magic. As Bangladeshi, many students' worldviews are likely to have been shaped by such superstitious

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beliefs as they grow up. It is only natural therefore that from the very first Education Commission report published in the independent Bangladesh (Qudrat-e-Khuda et al., 1974) to the recent 2010 National Education Policy (Ministry of Education, 2010), it has been emphasised that learning science in schools would help students replace or marginalise their superstitious worldviews and assimilate within them the rational culture and spirit of science. In line with this, promoting science values has always been an important component in the intended school science curriculum (National Curriculum and Textbook Board [NCTB], 1995, 2012).

However, while the curriculum intends to promote science values, at implemented level science teaching and learning mostly still follow a content-dominated approach. This approach is manifested in two major but interrelated ways: (a) science textbooks, which are considered as a de facto curriculum, mainly focussing on academically oriented content (Sarkar, 2012a) and (b) school education, which is exam-driven where exams mostly demand memorisation and recall of the content from the textbooks (Holbrook, 2005; Tapan, 2010). In such a content-dominated education context, it is interesting and important to look at how science values are understood in science classes in Bangladesh. More specifically, in this chapter I discuss how science teachers perceive the notion of two curriculum-intended science values (e.g. curiosity and rational thinking) and how they translate their perspectives into actual classroom teaching. As teachers play a vital role in promoting science values (Corrigan, Dillon, & Gunstone, 2007), examining their perspectives and practices is perceived to be important in the teaching and learning experience. The following section presents a theoretical discussion on how values play roles in science curriculum and, in turn, in science teaching practices.

## Values and Science Curriculum: Theoretical Underpinnings

While traditionally science was perceived as a value-free discipline (Gunstone, Corrigan, & Dillon, 2007), 'values have always been explicitly and/or implicitly taught through the science curriculum because no curriculum is ever a value-free zone' (Hildebrand, 2007, p. 45). In recent times, there is an amplified awareness of the embeddedness of values in school science curricula in many countries including the United States, the United Kingdom and Australia (Corrigan et al., 2007). As Allchin (1999) argued, values intersect with science in three major ways:

> First, there are values, particularly epistemic values, which guide scientific research itself. Second, because the scientific enterprise is always embedded in some particular culture, values enter science through its individual practitioners, whether consciously or not. Finally, values emerge from science, both as a product and a process, and can be redistributed more broadly in the culture or society. (p. 1083)

In a similar vein, values embedded in a science curriculum are the result of choices made by each of the contributing domains (e.g. science, education, curriculum developers and the community) and thus are diversified. Because of such diversity, there is no consensus in the science education community regarding which values should be included in a given science curriculum (Hildebrand, 2007). Hodson and Reid (1988, p. 106), for instance, listed 17 values (e.g. intellectual curiosity, self-criticism, open-mindedness) to be incorporated in school science curricula for designing appropriate learning experiences for all students. While there is disagreement on which values should be included, a general agreement in the science education community suggests that values play an important role in the promotion of scientific literacy, which is worldwide considered as the primary purpose of school science curriculum (Organisation for Economic Co-operation and Development [OECD], 2006).

In Bangladesh, a common science curriculum caters for all students at the junior secondary level. Its aims are to build a strong foundation in science while still providing students with opportunities to use science in everyday life (NCTB, 2012)—an aim consistent with the notion of scientific literacy (Tytler, Osborne, Williams, Tytler, & Clark, 2008). However, no universally accepted consensus exists on *how* scientific literacy is understood (Roberts, 2007), and this may be due to the context dependency of scientific literacy. Experts in science education, however, agree that students must have some science knowledge to be scientifically literate (OECD, 2006; Osborne, 2007), and this knowledge must be understood and applied in contexts which individuals come across in everyday life (Bybee, Fensham, & Laurie, 2009). This notion suggests perceiving a scientifically literate person as an informed user and consumer of science knowledge who would be able to:

- Ask, find or determine answers to questions derived from curiosity about everyday experiences.
- Read with understanding articles about science in the popular press and to engage in social conversation about the validity of their conclusions.
- Pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately.
- Make informed decisions about the environment and their own health and well-being.

(Summarised from Goodrum, Hackling, & Rennie, 2001; National Research Council [NRC], 1996)

The importance of science knowledge in scientific literacy can further be discussed with respect to its intrinsic and instrumental justifications (Millar, 1996). Intrinsic justification refers to cultural aspects, that is, science knowledge can help people satisfy their curiosity about the natural world, which is also very important in learning (Howes, 2001; Murphy, 2009). On the other hand, instrumental justification refers to utilitarian aims, that is, science knowledge is necessary as a foundation for making informed practical decisions about everyday matters, participating in decision-making on science-related issues and working in science and technology-related jobs (Millar, 1996).

However, how people use (or fail to use) science knowledge in making and evaluating decisions and arguments is often guided by the values they espouse (Rennie, 2005, 2007). For example, the value of open-mindedness promotes an encouragement of curiosity and wonder in students, which in turn encourages them to ask questions and challenges them to support their own views with evidence and logic (Hare, 2009). Open-mindedness also prompts a person to explore and consider all available alternatives (Hare, 2009), and it is rational thinking which helps one choose among the alternatives (Tan, 1997) and help to build an argument and to reach an informed decision or a conclusion (Hare, 1979). Since scientific literacy is perceived as related to the making and evaluating of decisions and arguments, values therefore are an important facet of scientific literacy (Graber et al., 2001; Koballa, Kemp, & Evans, 1997; OECD, 2006).

As noted previously, while there is a range of values that can be included in the school science curriculum, this chapter focuses on two of them—curiosity and rational thinking. The reasons to focus on these two values are, firstly, the fact that both the current junior secondary science curriculum (NCTB, 2012) and its predecessor (NCTB, 1995) emphasised them and, secondly, an in-depth discussion on all other values would need more space that this volume does not allow. The following section presents how these two values have been problematised and understood in this research.

## *Curiosity*

Curiosity refers to 'wondering how things work; possessing an orientation to inquiry, to speculation, to chasing ideas and testing them against evidence' (Hildebrand, 2007, p. 53). It is the 'spark that ignites research' (Tan, 1997, p. 561) and leads people to ask questions and seek answers, which also lead to *new* questions to explore (Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003). This notion of curiosity may be manifested in science classrooms through encouraging students raising questions from their experiences and encouraging them to explore the questions or solve problems. Grandy and Duschl (2005) argued that even though the questions students generate at an early age may not necessarily be scientific, students should not be discouraged to ask 'unscientific' questions. Rather, teachers need to be empathic to students' questions but with intentions to help students learn ways to ask 'scientific' questions. Also, teachers may ask students questions to stimulate their thinking and to act as a role model of the enquiring individual, raising questions from experiences.

Wallace and Louden (2002) suggested that teachers ask 'what if'-type questions in order to help generate *new* 'what if'-type questions from the students themselves and to promote their curiosity. In order to encourage student thinking, Goodrum (2004) suggested teachers allowing sufficient 'wait time' for students and to listen carefully to students' responses. Wait time provides the opportunity for student reflection, while listening to students' responses helps teachers understand the thinking behind the responses, which eventually helps teachers ask follow-up questions to extend students' thinking.

### *Rational Thinking*

Rational thinking refers to being 'systematic and logical in thinking through ideas' (Hildebrand, 2007, p. 52). Rational thinking, therefore, emphasises 'argument, reasoning, logical analysis and explanations' (Corrigan & Gunstone, 2007, p. 145). Richetti and Tregoe (2001, pp. 7–8) described rational thinking as a process that entails an individual's 'ability to consider the relevant variables of a situation and to access, organise, and analyse relevant information (e.g., facts, opinions, judgments and data) to arrive at a sound conclusion'. At the macro level, rational thinking promotes an understanding of the rationality of science, which is why Matthews (1994) insisted rational thinking to be pertinent to science teaching. The importance of rational thinking, at the micro level, is that it helps people evaluate alternative ideas and reach an informed conclusion based on their evaluation (Padilla, Okey, & Dillashaw, 1983). This notion of rational thinking, as Siddique (2010) argued, can be manifested in science classrooms by encouraging students to be involved in arguments, debate and deductive reasoning.

## Research Design and Methods

This chapter presents Bangladeshi science teachers' perspectives of the promotion of curiosity and rational thinking in their science teaching practices. Data draw on from a multiple case study approach (Stake, 2006) while analysing six science classes as six cases. The rationale for considering multiple cases is that the individual cases would share both common and contrasting characteristics that would provide opportunities for an in-depth understanding of the research problem (Stake, 2006).

In the case selection process, demographic information of the participant teachers (e.g. school location, school type, teachers' teaching experiences and class size) were considered to ensure 'maximal variation', which helped provide a sound qualitative data set (Creswell & Plano Clark, 2007, p. 112). Considering these demographics, six teachers were selected as participants for the case studies. Selected teachers' demographic information presented in Table 10.1 show that they represent

**Table 10.1** Demographics of the participant teachers

| Criteria | Sabina[a] (F) | Alam (M) | Ashim (M) | Morshed (M) | Rashid (M) | Jasmine (F) |
|---|---|---|---|---|---|---|
| School location | Semiurban | Urban | Rural | Urban | Rural | Semiurban |
| School type | Co-ed | Co-ed | Boys' | Boys' | Girls' | Girls' |
| Class size | 53 | 50 | 100 | 65 | 85 | 70 |
| Teaching experiences | 12 years | 13 years | 10 years | 18 years | 16 years | 9 years |
| Educational qualifications | BSc | MSc | BSc | MSc | BA | MSc |

[a] All names are pseudonyms to protect the identity of the participants

a range of geographical locations (rural, semiurban and urban), school types (co-educational, boys' and girls') with different class sizes (from 50 to 100 students), lengths of teaching experience (from 9 to 18 years) as well as educational qualifications (science and non-science backgrounds). The six teachers and their associated science classes (including students) were considered as six cases. The research reported in this chapter is part of a PhD study (Sarkar, 2012b), which was approved by the Monash University Human Research Ethics Committee (CF09/1352 – 2009000712).

## *Data Sources*

A number of data sources, for example, interviews, lesson observations and focus group interviews, were used in this multiple case study research. Initially, a pre-lesson semi-structured interview (Patton, 2002) was conducted with each participant teacher to explore their perspectives on curriculum-intended science values. This pre-lesson interview, in addition, allowed to build familiarity with the study, to develop a sense of mutual trust and build rapport (Babbie, 2011) and to make practical arrangements for observing their lessons.

The researcher then observed a series of lessons (each lesson was for 30–35 min; three to four lessons for each participant teacher) as a passive observer (Mertens, 1998) to understand the ways in which they translated their perspectives into classroom teaching. In order to avoid any interruption to the usual school schedule, the teachers were not asked to teach any particular content/unit, although all the lessons on a particular unit taught by a particular teacher were observed. Considering that a unit may have different emphases at different times in the progress of the topic, observation of teaching the entire unit was thought to help understand a teacher's overall teaching approach. These observations provided rich examples of teachers' practices in science classrooms and acted as additional data sources to their espoused practices indicated in their pre-lesson interviews. In addition, observation of teachers' lessons helped me identify important aspects of their teaching, which became significant in further exploration during the post-lesson interviews by generating follow-up questions based on their teaching practices.

Observation data were recorded in two ways: note taking and audio recording. Jotted or sketchy notes were taken in order to keep abreast of what was happening in the class. In order to minimise the possibility of compromising the integrity of data, as soon as an observation was completed, elaborate notes were written in the form of brief reports with the help of the audio recording. If a classroom lecture quote seemed to be worthwhile to the researcher, he transformed the audio-recorded piece into words and put it in the report.

Each teacher was interviewed a second time (post-lesson interview) at the end of the last observation. This post-lesson interview provided teachers with opportunities to explain their classroom practices. Given that the teaching episodes would necessarily be varied from teacher to teacher, the post-lesson interviews were loosely guided by a list of questions that allowed to respond to a range of classroom episodes observed.

As students are an integral part of a class, their views about their class experiences are worthwhile in understanding how particular issues were raised and explored in science classes. Therefore six students from each of the selected teachers' science classes comprised each of the six focus groups. These focus groups provided insights into the range of views or experiences (Morgan & Krueger, 1993) that students had about the ways science was taught in their classes. In this research, focus group interviews were used as supporting and supplementary data sources to understand teachers' practices in science classes.

## *Data Analysis*

Digitally recorded individual interviews with teachers and focus group interviews with students were transcribed. The interview transcripts were sent back to the participant teachers to confirm the accuracy of the transcripts in order to enhance the credibility of data (Creswell, 2007). Along with the transcripts of interviews and focus group interviews, analysis of observation data was conducted from the written observation reports. Transcripts and observation reports were read several times to develop a deeper understanding of the data (Creswell, 2007). Data were then coded reflexively to identify emergent themes using a grounded theory approach to thematic analysis (Charmaz & Belgrave, 2012). Repetitions, local terms, metaphors and analogies and transitions in the transcripts were looked for while assigning codes to the data (Ryan & Bernard, 2003). Similar codes were iterated under the major codes which guided to identify emergent themes (Saldana, 2009). The software NVivo was used in managing coding; however, all coding was performed manually, with the written transcripts interpreted in context rather than as target words or phrases. This approach allowed for the perspectives and practices of the respondents to be identified without applying preconceptions. As this research sought respondents' perspectives and practices in the absence of a prior set of research findings from which a framework could have been constructed, it was reasonable not to impose a preconceived framework, which could potentially impose excessive and unnecessary rigidity to the study.

Based on the analysis procedure described above, detailed case reports for the participant teachers were then produced. These case reports were finally analysed applying a cross-case data analysis procedure (Stake, 2006) to understand the comparison of commonalities and differences in the themes that emerged across the cases. Following Stake, it was perceived that the common research questions (i.e. how science teachers perceive the notion of curiosity and rational thinking and how they translate their perspectives into classroom teaching practices) tied together all of the cases. Meaningful linkages and relationships were then constructed by analysing the degree of congruity or disparity across the cases. Concurring with Miles and Huberman (1994), it was perceived that a cross-case analysis helped achieve a deeper understanding of teacher's perspectives of the selected values, as well as the translation of their perspectives into classroom teaching.

## Results and Discussion

In presenting the cross-case analysis of the six case studies, it is necessary to offer a discussion on the results in order to provide exemplary elaborations of the themes that emerged. In this section the chapter presents the pattern of teachers' perspectives of the importance of each of the two values along with the teaching approaches they adopted to promote these values in their science classrooms.

### *Curiosity: Teachers' Perspectives and Practices*

#### Perceived Importance of Curiosity

From the cross-case analysis, it appeared that the teachers did perceive curiosity as an important element in learning science and generally for scientific literacy. The following are two comments from pre-lesson interviews with teachers, as examples:

> Curiosity brings questions and then it generates action to answer the questions. It is necessary to learn science. (Ashim)
>
> If I can foster students' curiosity, this will provide students with questions to explore. This [curiosity] will lead them to find answers to such questions. In order to answer such questions, they will explore various science books, magazines, newspapers. They will get science knowledge from these [resources]. This science knowledge can satisfy their curiosity and they can then use this [knowledge] in their everyday life as well. So, you see, curiosity is important for scientific literacy. (Sabina)

As evident in the comment above, Ashim made the case for curiosity in science learning as it prompted students to find the questions about the natural world and which could lead to finding ways to answer the questions. Sabina added that in answering questions, students would explore different resources (e.g. science books, magazines, newspapers) and extend their science knowledge, which would potentially be useful in their everyday life.

#### Teaching Approaches to Promote Curiosity

While all of the participant teachers perceived curiosity as important, their views on teaching approaches to promote this value varied. Based on the nature of teachers' attempts to promote curiosity, they were clustered in three categories: (a) teachers who articulate a teaching approach to promote curiosity but whose approach may actually be not helpful in promoting curiosity, (b) teachers who seem to fail in articulating a teaching approach to promote curiosity, and (c) teachers who articulate and practise a teaching approach that may promote curiosity. These categories were also found pertinent in regard to the value of rational thinking as will be discussed in the section following the next.

### Teachers Who Articulate a Teaching Approach but Whose Practice May Not Be Helpful to Promote Curiosity

Analysis of the cases reveals that while both Sabina and Alam attempted to promote curiosity in science teaching, in practice their attempts might not have helped promote students' curiosity. For example, in a bid to promote students' curiosity, Sabina considered asking students questions and encouraging them to ask questions as well. It seemed that she considered modelling the asking of questions as important in helping students to perceive this as a good thing to do. However, it was observed in her teaching of acids that she had asked students only verification-type questions, such as 'Have you heard about acid or alkali?', 'Do you know you take acids as food?' and 'What is the chemical name of edible soda?'

Such questions prompted students to answer the questions rather than encouraging them to identify and explore their experiences of acids in everyday life. Moreover, as observed, Sabina did not encourage students to ask questions *themselves*. Also, Sabina's classroom questioning did not include any 'what if'-type questions, which, as Wallace and Louden (2002) argued, could help students generate new 'what if'-type questions from themselves and help promote their curiosity. Therefore, it seemed that she had limited knowledge of the kinds of questioning that could promote students' curiosity.

While most of Sabina's students in the focus group interview could not articulate questions that they thought were generated from their curiosity, one of them was able to give voice to such a question. As can be seen in the comment below, curiosity led Sagar to seek the reason for the change in colour of litmus in acidic conditions:

> I saw that blue litmus turns into red if I put it in an acidic substance. I was wondering what the reason for this colour change is.

However, the failure of most students to generate questions as a result of their curiosity may render Sabina's views and teaching practice for promoting students' curiosity as questionable.

In a similar vein, while Alam perceived his students as 'very curious'—also observed in the focus group interview with students—his teaching approach could be seen as not helpful in promoting students' curiosity. Alam, in the pre-lesson interview, expressed the view that he could do so through providing 'thought provoking questions or statements at the beginning of a lesson and presenting stories on scientific discoveries that exemplify a scientist's curiosity'. As observed in his teaching of gravity, he presented the famous 'Newton and apple' story in the following way:

> When you throw something up, what happens? It falls to the ground, doesn't it? Do you know why this happens? Let me tell you a story. One day Newton was sitting under an apple tree and thinking about the motion of the planets. Suddenly, a ripe apple fell from the tree and hit him on the head. Many questions came to his mind at once. He started wondering, why did the apple fall towards the ground? Why did it not go upward? Why did it not stay still? Can you answer these questions? These questions led him to discover the famous laws of gravitational force.

While the veracity of this story is not beyond criticism (Patricia, 1999), this can be seen as an example of how an incident can cause people to wonder about the reason behind the incident. When presenting the story, he asked students questions; he did not, however, leave any wait time for students nor did he seem to be interested in listening to students' responses. As Goodrum (2004) argued, wait time can provide students with opportunities to articulate their thoughts and reflections, and listening to student responses helps teachers understand the thinking *behind* the responses, which eventually helps them ask follow-up questions to extend student thinking. Therefore, Alam's reluctance to be empathic towards students' responses and provide them with the appropriate 'wait time' may not have helped students extend their thinking and thus may not have been helpful in promoting their curiosity.

### Teachers Who Seem to Fail in Articulating a Teaching Approach to Promote Curiosity

Although Sabina and Alam's teaching approaches were questionable in regard to promoting students' curiosity, they were both at least able to articulate on their attempts. In contrast, Ashim and Rashid, in the pre-lesson interviews, could not specify how they taught to promote curiosity. As observed, their classroom teaching was found not to be helpful in promoting students' curiosity. For example, it was observed in Ashim's classroom teaching practice that he did not consider students' questions; in fact, on certain occasions, he even stopped students from asking questions. Here is a common example of classroom scenario as observed:

> Mishu: Sir, what will happen if I pour water...
> Ashim: Let me proceed, OK?

In the class lecture, Ashim described pouring water into sulphuric acid as dangerous but did not explain the reason why. In responding to this description, Mishu, a student, intended to ask what would happen if he poured water into sulphuric acid. Ashim did not allow Mishu's question to interrupt his procedure nor did he encourage his student to find the answer. In the post-lesson interview, I broached this issue with Ashim and asked for his explanation. He explained:

> Curiosity is good, I know. But it is also a fact that there have been some students who ask too many questions and create noise in the class. I can't tolerate that.

Classroom quietness, often in the form of pin-drop silence, is a traditionally expected norm in Bangladeshi classrooms as it is in neighbouring India (Rampal, 1994). It seemed that Ashim was concerned with maintaining classroom 'discipline' by preventing students from asking questions and keeping them quiet. Although Ashim discouraged students from asking questions, the focus group interview with his students elicited their curiosity about the natural world. Here are some examples of student questions that they were curious about:

> I wonder why spraying water extinguishes fire. I asked my cousin and he explained it to me. (Akil)
>
> Halley's Comet is seen from the Earth every 76 years. I wonder why it is seen every 76 years. I got a book in the [school] library and found the explanation. (Mizan)

As seen in the comments above, Akil and Mizan generated their own questions from their curiosity about the natural world yet sought answers in places outside their classrooms. I asked them why they did not ask these questions to their teacher. Both of them kept silent in response, possibly reflecting their discomfort in asking questions to their teacher. This in turn would seem to indicate that students had little scope or encouragement to ask questions in Ashim's science classes.

### Teachers Who Articulate and Practise a Teaching Approach That May Promote Curiosity

On the surface, the teaching approaches of Jasmine and Morshed could be seen as useful in promoting students' curiosity in science classes. However, there were marked differences in their teaching approaches as discussed below.

As observed in Jasmine's classroom lessons, she engaged students in observing different parts of the flowering plants available in their school surroundings. When the groups had completed their observations, they were then asked to have discussions on their observations and produce a brief report in which they were asked to include any questions they had from their observations. Each of the student groups was then asked to present their report. Jasmine acted as a moderator of this discussion, which was elaborated on further in the theoretical discussion on the life cycle of plants in general and then the life cycle of a chilli plant in particular. In the post-lesson interview, she elaborated on how this approach could promote students' curiosity:

> I asked them to discuss their observations about the plants they see around the school yard and then write a summary of the discussion. In the summary, they articulated what they had observed and what questions they found in their observations. I then led a discussion in order to address their questions.

Jasmine's approach to engaging students in observing different parts of plants around their surroundings helped them find questions from their observations. One such question from students, for example, was:

> A mango has just one seed in it, but a jackfruit has many seeds inside. Why? (Saba)

As observed in Jasmine's teaching practice, student Saba raised a question from her observation. Jasmine expressly appreciated Saba's question and went on to answer it. Such appreciation may encourage students to ask further questions to their teacher (Goodrum, 2004). In fact a reflection of the effectiveness of this teaching approach was also evident in the focus group interview with her students who provided examples of questions that they thought had generated from their curiosity about plants, and they appreciated Jasmine's encouragement in asking her such questions:

> Why are chillies hot? Maybe there is something in chillies. I asked Madam. She explained about capsaicin that makes chillies hot.... She liked the question. (Toma)

Similarly, Morshed was found to be empathic in addressing student's questions in his science class. He also acknowledged the limited time of a science class to address students' every curious question and, therefore, encouraged students to look at other available resources, for example, the school library, as observed in his lesson:

> But the thing is when you get an answer to one question, there would be another one, and then more coming. You can't get all answers in the classroom. But I keep trying to get it. You need to have a mind to look at other resources. … As I told you many times, go to the [school] library. Hundreds of books are there. They will help you open your eyes.

Morshed believed that science-related books available in the school library would help students find answers to some of their questions and, importantly, would lead to new questions to explore. In the focus group interview, his students also reported how they appreciated Morshed's encouragement to explore various resources seeking more in-depth responses to their questions:

> Sir encourages us to read science-related books and watch science-related programmes on TV. [By reading such books and watching such programmes] I come to know many things that I didn't know before. I like to know such new things. They are wonderful. (Moni)

The focus group interview with students also indicated that Morshed was actively responsive in helping students get answers to their questions:

> We learned that the valency of iron can be both 2 and 3. But the other elements that Sir discussed with us have only one valency. So I was wondering why iron has two different valencies. I asked Sir about this. He appreciated [my question] and explained it to me. (Atiq)

In the comment above, Atiq is curious to know the explanation for there being two valencies of iron, and his teacher appreciated his question and helped him in getting the explanation. Morshed's appreciation for student questions may further encourage students to raise and explore curious questions in science classes.

## *Rational Thinking: Teachers' Perspectives and Practices*

### Perceived Importance of Rational Thinking

From the cross-case analysis, it appeared that all the teachers within all of the cases perceived rational thinking as an important value of science education and scientific literacy. They believed that rational thinking could help students in making justifications and rejecting unjustified explanations. In particular, Sabina and Ashim extended the importance of rational thinking to challenge superstitions that were embedded in Bangladeshi society. For example, Sabina, in the pre-lesson interview, exemplified a superstition relating to acidity and explained how rational thinking could help students challenge superstitions:

> Last year, one of my students told me that she heard [from someone] that if one does not say Bismillah[1] before having meals, God produces acids [in the stomach] and the person will suffer from acidity pain. From learning about acids, they will know that we have acids in our stomach. When these [stomach and digestive tract] secrete more than the required amount of acids to digest food, we get pain from the acidity. They will use this knowledge in rationally analysing this superstition.

Sabina argued that science learning in school could help students form a scientific explanation of familiar everyday phenomena, such as the occurrence of acidity. Such an explanation can challenge these superstitions and promote rational thinking which would help students decide which explanation (scientific explanation or prevailing superstition) is more plausible to accept. The point here is that the causes of acidity may be explained in various superstitious ways (ignoring God being one of them), and these explanations may vary in different local contexts. However, the power of scientific explanations (e.g. explaining acidity scientifically) is that they are relatively universal and hence usable in different contexts. Sabina seems to have firmly espoused the belief that rational thinking would help students understand the power of scientific explanations in explaining natural everyday phenomena.

## Teaching Approaches to Promote Rational Thinking

The three categories of the teachers' teaching approaches to promote rational thinking are discussed below.

### Teachers Who Seem to Fail in Articulating a Teaching Approach to Promote Rational Thinking

While the cross-case analysis suggests that teachers had perceived the importance of rational thinking in science teaching, there is evidence that Ashim and Morshed could not specify *how* they considered rational thinking in their teaching practices. For example, Ashim, in the post-lesson interview, explained that rational thinking would be developed as a by-product of science education:

> There is no scope for any irrational thing in science; so, rational thinking will grow [automatically] with studying science.

[1] 'Bismillah' is an Arabic word, and the meaning is 'In the name of the Allah (God)'. As an Islamic convention, Bismillah is commonly uttered as a blessing before eating food and other actions.

This view could be seen as an indication of how little the value of rational thinking had explicitly framed his teaching. A corroboration of this lack of emphasis on developing rational thinking processes in his science class may also be seen in his students' focus group because none of the students were able to recognise how rational thinking was considered in the science class.

### Teachers Who Articulate a Teaching Approach but Whose Practice May Not Be Helpful to Promote Rational Thinking

The cross-case analysis shows that many of the teachers (Alam, Rashid and Jasmine) argued that engaging students in practical activities was useful in promoting rational thinking. However, observation of a series of lessons by Alam and Rashid did not provide any instance of engaging students in such activities. Focus group interviews with their students also suggested that they had no opportunities to be engaged in practical activities in science classes.

Jasmine, on the other hand, engaged students in an outdoor activity to teach about flowering plants and claimed that such an engagement would be useful in promoting rational thinking. However, she could not explain *how* this engagement could promote rational thinking. In addition, observation of her approach to engaging students in activities suggested her belief in the myth of a single universal 'scientific method' (see Abd-El-Khalick & Lederman, 2000; Lederman, 2004), which she had mentioned in the post-lesson interview: 'You have the systematic steps to follow when you are doing scientific activity and your rational thinking is developing'. As was observed in her class, she did not explicitly encourage students to design and conduct the activity in different ways. Such lack of explicit encouragement may suggest to students that there was only one single way to conduct an activity in science.

This message may further discourage students from devising and considering different ways to conduct science activities. If students were to offer suggestions about different ways to conduct the activities and to justify the plausibility of their suggestions, they would have used rational thinking in making their justifications. In this manner, students could have an opportunity to develop and use rational thinking in doing science activities. However, students were not given such opportunities as Jasmine attempted to engage them in science activities, and, therefore, it could be argued that she had failed to promote rational thinking. Rather it seems that her approach did not go beyond adopting 'cookbook' or 'recipe-like' science activities that engaged students in verifying the result of the activities rather than engaging in open inquiry, and this is still a common practice in Bangladesh (Siddique & Rahman, 2007).

### Teachers Who Articulate a Teaching Approach That May Promote Rational Thinking

Sabina's teaching approach could be seen as useful in promoting students' rational thinking in science classes. Sabina explained that she could promote rational thinking by encouraging students to emphasise justification in making arguments and communicating ideas and thoughts. As was observed, there were a number of instances in her classroom teaching that reflected her explicit encouragement of students to engage in this process of argument:

> Sabina: Now, can you describe what the taste of acid would be?
> (Some of the students raised their hands indicating they can answer. She invited one of them to explain.)
> Sabina: OK, Benu will tell us.
> Benu: It would be sour.
> Sabina: Sour? But why do you think so? What is your justification?
> Benu: We found from the litmus test that blue litmus turns red in contacting these foods [lemon, tamarind and vinegar]. Therefore, these [foods] contain acids. I know the taste of lemon, tamarind and vinegar; all of them are sour. So, the taste of acid would be sour.
> Sabina: Hmm … Good justification.

As can be seen in this classroom conversation, Sabina took an opportunity to promote emphasising justification in reaching to a conclusion. This notion of valuing justification was also reflected among her students. Comments from two students from the focus group interview are as follows:

> Madam (Sabina) always encourages us to talk rationally. When I go to say something, she will ask me to justify it. (Benu)
>
> There is a superstition that if you eat pineapple after taking milk, you may die from acidity. My grandmother always tells me this. Maybe people think that as both pineapple and milk are acidic, eating both of these foods together causes the stomach to be too acidic and causes acidity. But I learned that eating acidic foods does not cause the stomach to be more acidic. During the process of digestion, the stomach secretes hydrochloric acid, which is much more acidic than any kind of food. So, there is no point in believing in this superstition. (Abu)

Benu's comment above reflects the success of Sabina's encouragement of valuing rational thinking through emphasising justification in the communication of ideas. As an example of the use of rational thinking, Abu explained how science learning had helped him explain a superstitious belief regarding acidity. It seems from this comment that he was more convinced with the scientific explanation that he deduced from his science learning. This could be seen as an indication of the valuing of rational thinking as perceived by Corrigan and Gunstone (2007) who described emphasising justification and arguments as concepts of rational thinking; Sabina's practice thus may be viewed as promoting rational thinking. In addition, students' capacity to exemplify the use of rational thinking suggests that Sabina's teaching approach was helpful in promoting it.

## Concluding Remarks

This chapter analysed how science teachers in Bangladesh perceived curiosity and rational thinking and how they translated their perspectives into their classroom teaching practices. It is apparent from the cross-case analysis that both of these values were perceived as important for scientific literacy by these teachers. However, there were marked differences in their teaching approaches.

As can be seen, some participant teachers demonstrated teaching approaches which were arguably conducive to promoting the target values. This is encouraging in the existing teaching–learning contexts in Bangladesh, as has been highlighted in the context chapter (Chowdhury & Sarkar, this volume)—that in Bangladesh, school education is exam-driven because the success of teachers and schools is measured by students' results in the public exams. Since these public exams mostly demand memorisation and mechanical, noncritical recall of content from the textbooks, the power of exams reinforces teachers to encourage students in rote learning of content (Tapan, 2010). Teachers, therefore, often work on preparing students for the exams and feel reluctant to find ways to promote affective components (e.g. values) of the curriculum in science classes. While such contexts may not encourage teachers to think and develop strategies for promoting values (which are not assessed in exams), it is apparent that some of the participant teachers have indeed taught beyond the box in creative and productive ways.

This study has also revealed that some of the participant teachers found it difficult to find, develop and implement suitable teaching approaches to promote the target values. The teachers cannot be criticised for their limited capacity, since very little of their own academic and professional education in science have included attempts to understand the concepts of values in science education. Traditionally, as in many other contexts (Gunstone et al., 2007), school science education in Bangladesh has presented a content-dominated approach to science. Similarly, professional development programmes for science teachers have focussed primarily on promoting science content knowledge to teachers, possibly because specialised content knowledge is required to teach science at the school level, not to mention that many science teachers are from non-science backgrounds (Sarkar & Corrigan, 2014). Thus professional development practices may limit the scope for promoting the concepts of values and developing pedagogic knowledge for teachers so that they can develop the concepts of values and learn how to teach to promote them.

Since promoting values is a stated curricular aim of school science education in Bangladesh, it is reasonable to argue that these values should be taught explicitly in science studies at different educational levels and in different teacher education programmes designed for science teachers. Given this situation, I have felt the need for further research to understand how teacher education programmes in Bangladesh could help science teachers frame values in their science teaching practices.

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